

Larval development of the Cape Verdean damselfish *Chromis lubbocki*, with a note on Cape Verdean *Chromis cyanea* (Teleostei, Pomacentridae)

by

Hans-Christian JOHN (1) & Reinhold HANEL (2)

ABSTRACT. - A developmental series of *Chromis lubbocki* 3.5 to 16.0 mm length was obtained from the Cape Verde Archipelago, and waters south of it. Identification was based on the specific meristic and morphometric data for late flexion and postflexion larvae, and on a conforming pigment pattern in earlier stages. The development is described. Postflexion *C. lubbocki* are similar in morphometry and pigmentation to Mediterranean *C. chromis*, except that the paired fins are shorter, and the second anal spine is longer. Transforming *C. cyanea*, *C. limbata* and *C. multilineata* differ in pigmentation of the caudal fin from these two species.

RÉSUMÉ. - Développement larvaire de la Demoiselle du Cap-Vert, *Chromis lubbocki*, et note sur le cap-verdien *Chromis cyanea* (Teleostei, Pomacentridae).

Une série de développement larvaire de *Chromis lubbocki* d'une longueur allant de 3,5 à 16,0 mm a été obtenue à l'archipel du Cap-Vert ainsi que dans les eaux situées au sud de celui-ci. L'identification repose sur des données méristiques et morphométriques spécifiques de larves au stade de flexion tardive et en post-flexion ainsi que sur un patron de pigmentation caractéristique pour les stades les plus précoces. Le développement est décrit. *C. lubbocki* en stade postflexion est similaire au niveau morphométrique et pigmentaire au *Chromis chromis* méditerranéen à l'exception des nageoires paires qui sont plus courtes et d'une plus longue deuxième épine anale. Ces deux espèces diffèrent des *C. cyanea*, *C. limbata* et *C. multilineata* par la pigmentation de la nageoire caudale au stade de la transformation.

Key words. - Pomacentridae - *Chromis lubbocki* - ANE - Cape Verde Islands - Larval description.

The subtropical-tropical and reef-dwelling percoid family Pomacentridae (damselfishes) currently comprises worldwide 321 species (www.FishBase.org; Froese and Pauly, 2007) in 28 genera (Allen, 1991). Most damselfishes have demersal eggs and pelagic larvae (Breder and Rosen, 1966; Leis and Rennis, 1983) and a generally short duration of the planktonic phase of 2 to 5 weeks (Wellington and Victor, 1989; Kavanagh and Alford, 2003), which favours the development of endemic species at oceanic islands. *Chromis lubbocki* was described as a Cape Verdean endemic damselfish by Edwards (1986; for pomacentrid distributions see also Allen, 1991; Floeter *et al.*, 2008: their table S1), but its larvae remained hitherto undescribed.

Adult and postlarval Pomacentridae are generally deep-bodied fishes. Larvae show some superficial resemblance in body shape and pigmentation to several percoid families (Leis and Rennis, 1983), but can be distinguished from those by a vertebrae count of 25-27 (Watson, 1996), the presence of only two anal fin-spines, of which the second one is distinctly longer and solid, and a lower count in the second dorsal fin (Paris-Limouzi *et al.*, 2005). Flexion pomacentrid larvae undergo a considerable change in body proportion from

elongate (with a short, coiled gut, when they can most easily be mistaken for other percoids) to laterally compressed and humpbacked (Leis and Rennis, 1983). The genus *Chromis* comprises worldwide 85 species (www.FishBase.org, op. cit.). Keys for tropical East Atlantic adult pomacentrids were based on an oblique versus horizontal mouth, 12 to 14 dorsal spines, and moderately deep, or slender body (Blache *et al.*, 1970; Edwards, 1986; Reiner, 1996). Besides body-depth (for values see Allen, 1991), Blache *et al.* (1970), Wood (1977), Edwards (1986) and Reiner (1996) based their keys additionally on dentition of jaws, serrated versus smooth margin of the preopercle, gill-raker counts, number of scales, number of soft fin rays, number of gill rakers, and colour pattern.

Wood (1977) suggested to reintroduce *C. limbata* as species name for one of the East Atlantic *Chromis*. Arruda (1977) concluded at the same time on basis of hardly overlapping fin-ray meristics that Mediterranean and adjacent Eastern Atlantic *Chromis* represent different populations, with *C. chromis* in the Mediterranean (soft D- and A-ray modal values 10 each), and *C. limbata* (mode 11) in the East Atlantic. In the meantime also molecular evidence for these

(1) Leegerwall 13, 23570 Travemünde, GERMANY. [hans-christian.john@travedsl.de]

(2) Leibnitz-Institut für Meereswissenschaften, IFM-GEOMAR, Düsternbrooker Weg 20, 24105 Kiel, GERMANY. [rhanel@ifm-geomar.de]

two different species became available (Domingues *et al.*, 2005). Arruda (1979, this paper is difficult to obtain) extended his previous study on fin-ray meristics by data from other tropical East Atlantic populations, and Edwards (1986) revised the Northeast Atlantic *Chromis* to comprise 5 valid species. Besides the above mentioned characters, *C. lubbocki* was described to differ from the other eastern Atlantic *Chromis* (for these species, their meristics and nominal distributions see table II farther below) by proportionately shorter pectoral and pelvic fins, and a distinctly longer second anal spine (Edwards, 1986). However, in juvenile *C. lubbocki* the longest V-ray may reach the A-spines, too (Edwards, 1986). Adult *C. cyanea*, *C. limbata* and *C. multilineata*, but not *C. chromis* and *C. lubbocki*, have dark stripes on the distal margins of their caudal fins (Wood, 1977; Edwards, 1986; Allen, 1991).

Murphy *et al.* (2007) reviewed larval descriptions of Pomacentridae and estimated that early stages of only some 15% of all species worldwide have been described so far. From the six *Chromis*-species assumed by us to occur in the East Atlantic, larval descriptions exist for *C. chromis* (Fage, 1916; de Gaetani, 1932; Padoa 1956; Dekhnik, 1973); *C. cyanea* and *C. multilineata* (Paris-Limouzi *et al.*, 2005), and *C. limbata* (Ré and Gomes, 1982). This paper gives a first description of a developmental series of larval *Chromis lubbocki*, caught during 3 larval fish surveys in and near the Cape Verde Archipelago. Additionally two transforming *C. cyanea*, of which the occurrence there was thought to be questionable, were obtained.

MATERIAL AND METHODS

During the South Atlantic Expedition of FRV "Walther Herwig" 1970/71 the ship passed the Cape Verde Archipelago

twice, on the outbound leg (WH 36-1, November 1970, with 24 trawl- and neuston-net stations within the archipelago), and homewards (WH 36-3, April 1971, with only 4 ship stations, but 9 neuston-net tows between the islands). During both legs, neuston-sampling (500 μ m mesh-size) extended beyond the archipelago north- and southwards. During this cruise, 49 larvae at that time identified as "*Chromis chromis*" were caught (John, 1976/77). Twentyfive "*C. chromis*" in better condition had been entered into the fish larval collection of Zoologisches Museum Hamburg (ZMH) at that time, and under family number 475. The remaining 24 were stored as "surplus material WH-36" in ZMH, until we searched for earlier stages during preparation of this manuscript, with the result that 13 specimens could be reidentified, of which 4 small ones were used. The other larvae were dry, damaged, or misidentified preflexion *Cubiceps*-larvae. During RV "Poseidon" cruise Po 320/2 in April 2004, 11 IKMT-hauls (4 mm mesh-size) and 8 multinet-hauls (300 μ m mesh-size) were conducted within the archipelago yielding 5 specimens of *C. lubbocki* and 2 *C. cyanea*, which remained at the author's collection. A complete listing of the catch data is provided in table I. Length, meristic and some morphometric data for each collection specimen plus 4 of the above mentioned surplus material are given under results farther below.

Except for one *C. cyanea* (specimen K-170(g) preserved in ethanol), the fish larval catch was preserved on board in a buffered 4% formaldehyde-seawater solution. After sorting, all material from WH 36 remained in a 4% formaldehyde-freshwater solution at least until June 2005, after which the collection specimens were transferred into a Steedman-solution (Steedman, 1976). This material proved to be soft, deoxygenated and somewhat bleached during the current investigation, allowing somite-, respectively vertebrae counts over most of the length range without clearing, but retained nevertheless its basic pigmentation pattern. The material from

Table I. - Catch data of the material. [Données sur les prélèvements des spécimens.]

Cruise	Ship Station	Gear	Sample	N specimens	Date ddmmyy	Latitude ° 'N	Longitude ° 'W	Bottom depth m
WH36-1	33	NEU 31	47u	1	05.11.70	15 22	24 45	> 2000
WH36-3	486	NEU 258	397u	2	14.04.71	07 32	20 54	> 2000
WH36-3	494	NEU 267	414o	8	16.04.71	13 54	23 10	> 2000
WH36-3	494	NEU 267	415u	14	16.04.71	13 54	23 10	> 2000
WH36-3	494	NEU 268	417u	8	16.04.71	13 56	23 10	> 2000
WH36-3	494	NEU 269	418o	1	16.04.71	13 57	23 10	> 2000
WH36-3	494	NEU 269	419u	1	16.04.71	13 57	23 10	> 2000
WH36-3	494	NEU 270	421u	3	16.04.71	13 58	23 11	> 2000
Po320/2	83	IKMT	05/83	1	13.04.05	17 01	22 09	3295-3342
Po320/2	84	Multinet	05/84-N8	2	13.04.05	17 01	22 10	3315-3350
Po320/2	109	IKMT	11/109	1	15.04.05	17 14	22 00	603-1509
Po320/2	156	IKMT	156	1	20.04.05	14 42	24 52	2591-2927
Po320/2	170	IKMT	170	2	22.04.05	14 46	24 50	2921-3025

Po320/2 was transferred into Steedman-solution immediately after sorting in 2005/2006. It was less transparent, more rigid, but otherwise conforming in pigmentation, except for *C. cyanea*.

To identify the larvae we have compiled literature information on meristics, form of mouth, body depth, and distribution for all species of genera *Abudefduf*, *Chromis*, *Microspathodon*, *Stegastes* and *Similiparma* ever mentioned for the subtropical and tropical Northeast Atlantic, including records believed to be questionable, but excluding two other endemic species from São Tome and St. Helena. Sources for morphometry and meristics were Allen, 1991; Blache *et al.*, 1970; Wood, 1977; Edwards, 1986; Reiner, 1996; www.FishBase.org. We followed the synonymies by Allen (1991) and Edwards (1986) and believe therefore that the meristics of *C. chromis* listed in table II were smeared by the earlier systematic confusion of this species in the Fishbase-data set. The recentmost nominal distributions were taken from Floeter *et al.* (2008: table S1), and *C. chromis* does not occur in the tropical East Atlantic. *C. cyanea* was considered to be restricted to the West Atlantic by Allen (1991) and Floeter *et al.* (2008). We included it into our table II because of its original reference in Osorio (1909), followed by Lloris and Rucabado (1990), Reiner (1996), and the two specimens caught by us.

Besides the characteristic combination of 2 anal-fin spines with 12 to 14 dorsal-fin spines, principal character for generic assignment was the mouth morphology, being oblique in *Chromis* instead of terminal-horizontal as in other East Atlantic Pomacentridae (Blache *et al.*, 1970; Reiner, 1996). Species identification within the genus *Chromis* was based on (when developed) the counts of spines, respectively

soft rays of dorsal (D) and anal (A) fins, pectoral fin rays (P), and the ratio between body-length BL (notochord length NL at flexion, standard length SL at postflexion) versus maximum body depth (BDm). The respective values were extracted from Allen (1991) and listed in table II. BDm is comparable with body depth at the first dorsal spine, as used by Ré and Gomes (1982). This value is expressed below both in BL/BDm, as well as in percent of BL, because of different use in earlier literature. BL/BDm values below 2.0 are here classified as “deep-bodied”, 2.0-2.5 as “moderately deep”, and above 2.5 as “slender”. We measured also the distance snout-rear of anus (S-A) to describe the morphometric change during flexion. Some earlier literature contrastingly referred to preanal length, meaning the distance from snout to base of first anal spine. Measurements were taken to a precision of 0.1 mm, and in case morphometric data were not explicitly stated in literature quoted, comparative measurements were taken from the respective illustrations. Postflexion *Chromis*-larvae show a gap between the anus and the first A-spine (Kavanagh *et al.*, 2000). A-spines were consistently 2, ventral (V) spine was 1, when developed at all. Adult *C. lubbocki* is easily identifiable by its long second A-spine, exceeding the length of the following soft rays (Edwards, 1986). We have tried to describe the respective ontogenetic development whenever the condition of the soft-rayed part of the anal fin allowed. When during flexion fin-ray base numbers are stated, the total number of elements was counted, since spine-bases were not yet discernible from soft-ray ones. In larger larvae, the last D- and A-base generally carried twin-rays, expressed below by the number of respective bases plus “1/2”. VS stands for the number of somites, respectively vertebrae. In only a few specimens counts for P

Table II. - Compilation of morphometric and meristic data for pomacentrid species ever recorded from the Cape-Verde Archipelago, or adjacent areas. Meristic and morphometric data from Wood (1977) and Allen (1991). Nominal distributions are based on Allen (1991) and Floeter *et al.* (2008). Additional information on occurrence in, or near, the Cape Verde Archipelago is quoted individually. [Compilation des données morphométriques et méristiques de toutes les espèces de Pomacentridae de l'archipel du Cap-Vert et des zones proches. Les données méristiques et morphométriques sont de Wood (1977) et d'Allen (1991). Les distributions spécifiques sont fondées à partir de celles d'Allen (1971) et de Floeter *et al.* (2008). L'information supplémentaire sur la présence des espèces pour l'archipel du Cap-Vert et des alentours est ajoutée.]

Genus	Species	Mouth	D	A	P	GR	BL/BDm	Nominal distribution	Cape Verde Islands, or adjacent areas author(s)
<i>Abudefduf</i>	<i>hoefleri</i>	terminal	XIII14	II13	18-20	25-30	1.7-2.0	Cape Verde, Sao Tome	Edwards, 1986; Reiner, 1996
<i>Abudefduf</i>	<i>luridus</i>	terminal	XIII16-17	II13-14	20	13-16	2.0-2.1	Azores-Cape Verde	Edwards, 1986; Reiner, 1996
<i>Abudefduf</i>	<i>saxatilis</i>	terminal	XIII12-13	II10-13	16-20	23-31	1.6-2.0	Tropical E&W-Atlantic	Edwards, 1986; Reiner, 1996
<i>Abudefduf</i>	<i>taurus</i>	terminal	XIII11-13	II9-10	18-19	17-20	1.8-2.0	Tropical E&W-Atlantic	Edwards, 1986; Reiner, 1996
<i>Chromis</i>	<i>cadenati</i>	oblique	XIV10-11	II11-12	19-21	29-31	2.3-2.5	Tropical W-Africa	Edwards, 1986
<i>Chromis</i>	<i>chromis</i>	oblique	XIV9-11	II9-11	17-18	25-29	2.1-2.5	Mediterranean Sea	
<i>Chromis</i>	<i>cyanea</i>	oblique	XII12	II12	16-18	28-30	2.3-3.0	Bermuda & Caribbean	Osorio, 1909; Reiner, 1996
<i>Chromis</i>	<i>limbata</i>	oblique	XIV11-12	II10-12	18-20	25-31	1.9-2.2	Portugal-tropical E-Atlantic	Edwards, 1986
<i>Chromis</i>	<i>lubbocki</i>	oblique	XIV12	II11	19-21	30-33	2.0-2.5	Cape-Verde Islands	Edwards, 1986; Reiner, 1996
<i>Chromis</i>	<i>multilineata</i>	oblique	XIII12-13	II11-13	18-20	30-34	2.3-3.0	Tropical E&W-Atlantic	Edwards, 1986; Reiner, 1996
<i>Microspathodon</i>	<i>chrysurus</i>	terminal	XII14-15	II12-13	20-22	>15	1.7-2.0	tropical W-Atlantic	Blache <i>et al.</i> , 1970; Lloris & Rucabado, 1990
<i>Similiparma</i>	<i>hermani</i>	terminal	XIII17-18	II14	22-23	16-18	1.8-1.9	Cape-Verde Islands	Edwards, 1986; Reiner, 1996
<i>Stegastes</i>	<i>fuscus</i>	terminal	XII15-16	II13-14	19-20	18-22	1.9-2.2	W-Atlantic	Lloris and Rucabado, 1990
<i>Stegastes</i>	<i>imbricatus</i>	terminal	XII15-16	II13-14	20-21	16-19	1.9-2.1	Tropical E-Atlantic, Cape-Verde	Edwards, 1986
<i>Stegastes</i>	<i>leucostictus</i>	terminal	XIII13-16	II12-14	17-19	13-15	2.1-2.4	W-Atlantic	Reiner, 1996; Lloris & Rucabado, 1990

Table III. - Stage, meristics and body proportions of the investigated *Chromis*-larvae, arranged by ascending length. Prefix "S" (surplus material) in specimen label indicates a specimen not catalogued in the ZMH-collection. Prefix "K" (Kiel) indicates material remaining in possession of IFM-GEOMAR. Abbreviations: dam. = damaged, diff. = differentiating, AII/Asoft indicates whether the second A-spine was longer (>), shorter (<) or approximately equal to the following soft rays. For other abbreviations and measurements see 'materials and methods'. [Stades, données méristiques et proportions corporelles des larves étudiées de *Chromis* présentés par longueur croissante. Le préfixe "S" (matériel supplémentaire) dans l'étiquette du spécimen indique un spécimen non catalogué dans les collections ZMH. Le préfixe "K" (Kiel) indique que le matériel reste la propriété de IFM-GEOMAR. Signification des abréviations : dam. = abîmé, diff. = en différenciation, AII/Asoft indique que le second rayon épineux de la nageoire anale était plus long (>), plus court (<) ou approximativement égal aux rayons mous suivants. Pour les autres abréviations et mesures consulter la section "matériel et méthodes".]

Specimen Label	BL mm	Flexion	D-Spines	D-Rays	A-Rays	AII/Asoft	P-Rays	V-Rays	VS N	Op-ridge	Pop margin	BL/BD	BDm % BL	S-A % BL	Comment	Species
S-397u (b)	ca. 3.5	pre		bud	bud		base	absent	26	-		3.2	31.4		dam.	<i>C. lubbocki</i> ?
FI417u (h)	3.5	early	0	6 bases	8 bases		base	absent	>24	-	smooth	2.9	34.3	51.4	Fig. 1a	<i>C. lubbocki</i> ?
S-397u (a)	3.6	pre		none	none		base	absent	26	-		3.4	29.2	52.8	bleached	<i>C. lubbocki</i> ?
FI417u (a)	3.6	early		bud	bud		base	absent	>24	-	denticles	3.0	33.3	47.2	dam.	<i>C. lubbocki</i> ?
FI414o (a)	3.7	early	0	bud	bud		base	absent	26	-	smooth	2.8	35.1	51.4	dam.	<i>C. lubbocki</i> ?
FI417u (b)	3.7	early		bud	bud					-	denticles	2.8	35.1		contorted	<i>C. lubbocki</i> ?
S-47u	3.7	mid		bud	bud		base	absent	26	-	denticles	2.9	34.2	52.6	ruptured	<i>C. lubbocki</i> ?
S-418o	3.7	mid	bud	bud	bud			bud?	26	-		2.6	37.8	54.1	dam.	<i>C. lubbocki</i> ?
FI417u (f)	3.8	late		bud	bud		diff.	absent	26	-		2.4	42.1	55.3	dam.	<i>C. lubbocki</i> ?
FI417u (e)	4.0	mid	bud	bud	bud		base	absent	26	-	smooth	2.7	37.5	47.5		<i>C. lubbocki</i> ?
FI417u (g)	4.2	late	bud	9 bases	13 bases		diff.	absent	26	+	smooth	2.6	38.1	47.6	dam.	<i>C. lubbocki</i> ?
FI417u (d)	4.3	early	bud	11 bases	bud		diff.	absent	26	-	smooth	2.7	37.2	44.2		<i>C. lubbocki</i> ?
K-05/84-N8 (a)	6.3	post	13	12 1/2	11 1/2	>		5			spinules	2.2	46.0	63.5		<i>C. lubbocki</i>
K-05/84-N8 (b)	6.4	post	13	13 1/2	10 1/2	dam.	16?				spinules	2.3	43.8	64.1		<i>C. lubbocki</i>
FI414o (d)	7.4	late	14	12 1/2	11 1/2	>	≥7	present		+	spinules	2.5	40.5	63.5	Fig. 1b	<i>C. lubbocki</i>
FI415u (f)	ca. 7.5	post	14	12 bases	11 bases		base	4	26	-					dam.	<i>C. lubbocki</i>
FI417u (c)	7.9	post	14	12 1/2	10 1/2	dam. ?>	dam.	4	26	dam.	dam.	2.3	43.0	65.8	bleached	<i>C. lubbocki</i>
FI414o (e)	8.8	post	14	12	11 1/2	>		5	26		spinules				dam.	<i>C. lubbocki</i>
K-05/83 (f)	10.5	post	14	11 1/2	11 1/2	<	20	5			dam.	2.3	43.8	63.8		<i>C. lubbocki</i> ?
K-11/109 (f)	11.3	post	14	12 1/2	11 1/2	=	20				"spinules"	2.4	42.5	59.3		<i>C. lubbocki</i> ?
FI415u (h)	11.4	post	14	12 1/2	11 1/2	>			26	+	"spinules"	2.4	42.1	58.8		<i>C. lubbocki</i>
FI415u (j)	ca. 13	post	14	12 1/2	11 1/2	>	19	5	26	+	"spinules"			63.8	contorted	<i>C. lubbocki</i>
FI415u (g)	ca. 13	post	14	12	11 1/2	>	20	5		+	"spinules"			61.5	contorted	<i>C. lubbocki</i>
K-156 (a)	13.5	post	14	11	11	dam.	20	5			smooth	2.4	42.2	59.2		<i>C. lubbocki</i>
FI414o (f)	13.7	post	15	11 1/2	12 1/2	dam. ?>	22				serrate	2.1	46.7	61.3		<i>C. lubbocki</i>
FI414o (h)	14.0	post	14	12 1/2	11 1/2	dam. ?=	20	5			serrate	2.3	42.9	50.7	dam.	<i>C. lubbocki</i>
FI414o (g)	14.7	post	14	12 1/2	11 1/2	dam. ?=	19		26		serrate	2.3	43.5	59.2		<i>C. lubbocki</i>
FI415u (e)	14.7	post	14	12 1/2	11 1/2	dam. ?=	21	5		+	serrate	2.5	40.8	59.9		<i>C. lubbocki</i>
FI415u (d)	14.7	post	14	12 1/2	11 1/2		20	5		+		2.3	42.9	60.5		<i>C. lubbocki</i>
FI415u (c)	15.3	post	14	12 1/2	11 1/2	>	21	5		+	serrate	2.3	44.4	60.8	dam.	<i>C. lubbocki</i>
FI415u (b)	15.3	post	14	12 1/2	11 1/2	dam. ?=	20	5		+	serrate	2.3	43.8	61.4		<i>C. lubbocki</i>
FI414o (c)	15.4	post	14	12 1/2	11 1/2	dam.	21	5			serrate	2.2	46.1	64.9		<i>C. lubbocki</i>
FI415u (a)	15.7	post	14	12 1/2	11 1/2	>	21	5		+	serrate	2.4	42.0	61.8	Fig. 1c	<i>C. lubbocki</i>
FI414o (b)	16.0	post	14	12 1/2	11 1/2	dam. ?>		5	26		serrate	2.4	42.5	62.5		<i>C. lubbocki</i>
K-170 (g)	17.4	post	12	11	11 1/2	<	19	5		+	smooth	2.7	37.4	53.4		<i>C. cyanea</i> ?
K-170	18.2	post	12	11 1/2	12	<	18	5		+	serrate	2.8	35.7	52.7	Fig. 2	<i>C. cyanea</i>

and V could be made directly, otherwise we dissected these fins. We have furthermore traced the development of spination in the preopercle (Pop) and opercle (Op).

The combination of oblique mouth, fin-ray meristics and BDM ruled out any other genus than *Chromis* for the described material, and pointed to species *C. lubbocki* for at least 20 larger larvae. Larger larvae conform to the short paired fins and long second A-spine described for this species, too.

RESULTS

Description of larval *C. lubbocki*

Table III lists morphological and meristic observations for the 36 individual specimens of genus *Chromis*, arranged by ascending lengths. We caught only 2 preflexion larvae, but not any recently hatched ones. It can be seen that the full number of vertebrae (respectively somites) was differentiated during early flexion. The first fin-rays to develop were

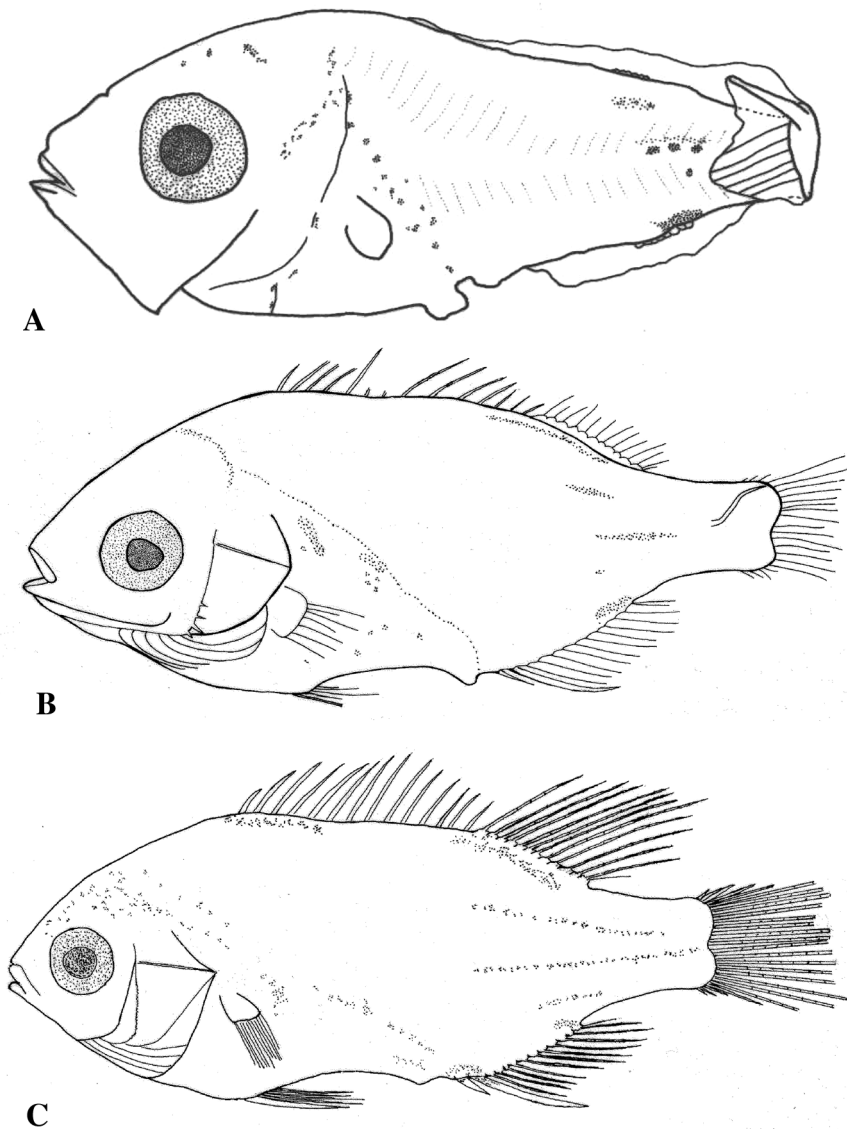


Figure 1. - Larvae of *Chromis lubbocki*. **A**: Early flexion, 3.5 mm NL (originally drawn from the right side). **B**: Late flexion, 7.4 mm SL. **C**: Transforming specimen, 15.7 mm SL. [Larves de *C. lubbocki*. **A** : Stade flexion précoce, LN = 3,5 mm (dessiné à partir du côté droit). **B** : Stade flexion tardive, LS = 7,4 mm. **C** : Spécimen en transformation, LS = 15,7 mm.]

some caudal rays projecting from a still nearly straight notochord tip downwards at early flexion (Fig. 1A). During this stage the larvae remained relatively slender, albeit deeper than described for preflexion *Chromis* spp. Flexion in *Chromis lubbocki* is associated with a temporary reduction in body length, an increase in body depth to > 40% SL, an increase in SA from ca. 50 to 60% SL at postflexion, and the development of fin-rays. Thus, during flexion a smaller body-length may in fact represent a more advanced stage. However, the anus always terminated distinctly anterior to the anal fin-base. Six branchiostegal rays became discernible. Some small larvae showed three to four small denticles each at the edge of the preopercle, the middle one was longest. In postflexion larvae up to 8 spinules were found there initially, seemingly remaining as 4 spinelike supports of the preopercular edge in deossified larger larvae, denoted as

“spinules” in table III. These supports did not protrude noticeably beyond the preopercles serrate margin at sizes larger 11 mm. Bases of D- and A rays developed already during early flexion, with the primordial fin-fold still persisting, and apparently commencing development from the middles of the soft-rayed fins. Spines, respectively soft-rays became discernible only at postflexion (6 mm SL and longer), when also the paired fins developed. Paired fins were complete at lengths of 8 mm, or more. Body shape and location of fins resembled that of adults, but the pectoral and pelvic fins were short, not reaching the anal fin, and the second anal spine became generally longer than the soft A-rays at postflexion (Fig. 1B, 1C).

C. lubbocki (and *C. cyanea*, specimens K-170; for catch locality see table I, for morphometric and meristic data see table III) developed a bony ridge across the operculum from

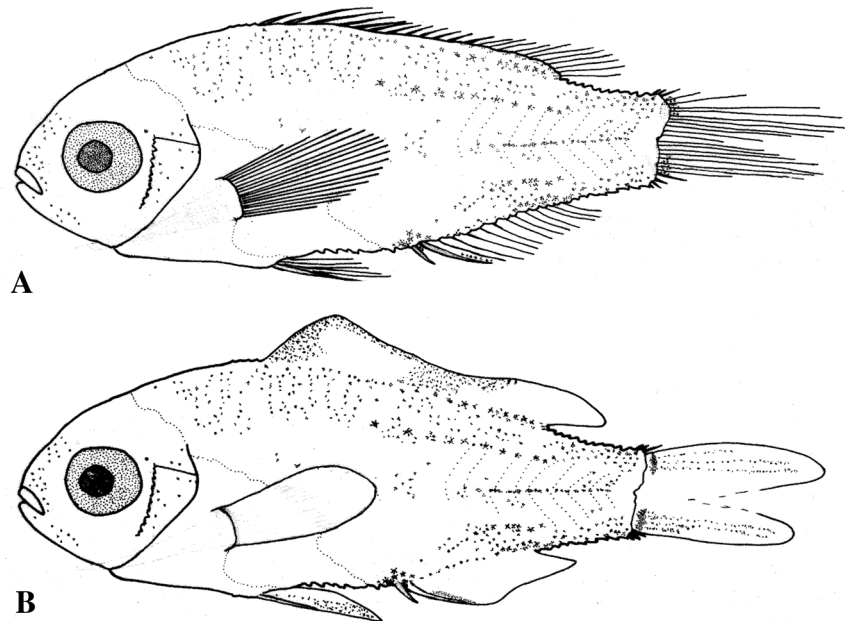


Figure 2. - Juvenile Cape Verdean *Chromis cyanea*, 18.2 mm SL. **A**: Specimen as viewed originally, flexed pectoral fin reconstructed from the right side. **B**: Reconstruction of juvenile fin pigment. [Juvénile du cap-verdien *C. cyanea*, LS = 18,2 mm. **A**: Spécimen tel qu'observé ; la nageoire pectorale, initialement recourbée, a été reconstruite à partir du côté droit. **B** : Reconstitution de la pigmentation des nageoires du juvénile.]

late flexion onwards (Tab. III; Fig. 1B, 1C). This opercular ridge terminated in a short spine, supporting the edge of the opercle, whilst in earlier stages the hind margin of the opercle was semicircular. In our larval specimens the ridge was generally horizontal, occasionally slanting slightly downwards as depicted in the illustrations. Whilst the exceptionally slender two *C. cyanea* developed large scales, all other larvae were still without scales.

Larvae identified as *C. lubbocki*, and also the smaller ones (not yet identifiable by fin-ray meristics), showed very consistent basic pigment patterns. Besides light pigmentation on head and digestive tract, conspicuous patterns were a lateral pigment line and longitudinal pigment patches at the (later) rear ends of the D- and A-fins. These 3 lines were persistent throughout the entire length range. In postflexion larvae, two more lines above and below the lateral one appeared. These 5 patterns were superficial and increased in length with development. Additionally, and also over the entire length range, an embedded pigment-line was found in the caudal peduncle above the notochord, respectively vertebral column. With developed unpaired fins, pigment was also found along the bases of the first D- and A-spines, but these fins otherwise remained unpigmented. In all *C. lubbocki* larvae the caudal fins (and its ray-bases) were unpigmented.

The transforming *C. cyanea*

The last two specimens listed in table III could be, on basis of meristics and slender body, either *C. multilineata*, or *C. cyanea*. Adults of both species have deeply forked caudal fins and dark bands along the distal C-lobes. Such pigment bands extended onto the dorsal and ventral margins of the

caudal peduncle in our specimens, as in *C. cyanea*, but are shorter in *C. multilineata*. Also because of the longer paired fins we consider this specimen to belong more likely to *C. cyanea* than to *C. multilineata*, where these fins do not reach beyond the anus. The hind margin of the preopercle was serrated. *C. cyanea* had a bony opercular ridge, and showed otherwise the above described basic pigment pattern of *C. lubbocki* as well, albeit much less prominent (Fig. 2). The pectoral fins were unpigmented, the ventral fin-spine was dark all over its length. The second anal spine showed dark pigment on its terminal half and hind side. Furthermore, dark pigment was found on the anterior part of the dorsal fin, and along the upper margins of both dorsal fins, as in the colouration of adult *C. cyanea*. A line of melanophores occurred along the lateral line from the mid of the first dorsal fin to about the end of the soft-rayed dorsal fin. The specimens conformed well with the existing description, except for a line of melanophores occurring along the myoseptum horizontale at the caudal peduncle.

Ecological note

Chromis lubbocki fry in this investigation was almost exclusively caught during the surveys in April, only one specimen had been caught in November. IKMT-samples yielded only 3 *C. lubbocki* and 2 *C. cyanea*. The multinet hauls resolved 8 strata each down to 250 m depth, but caught only two larval *C. lubbocki* in the uppermost 25 m. The neuston-net caught these larvae only during night- and twilight tows, and only 9 of the 38 larvae occurred in the uppermost 8 cm, the remainder in the stratum underneath (10-25 cm).

DISCUSSION

Flexion and transforming larvae of *C. lubbocki* resembled in morphometry and pigmentation closely those of *C. chromis* described from the Mediterranean Sea (Fage, 1916; de Gaetani, 1932; Padoa 1956), but can be discerned by their higher fin-ray counts, relatively shorter paired fins, and, when developed and not too damaged, easily by a second anal spine exceeding the length of the first anal soft-rays. Flexion larvae of most other *Chromis*-species seem similarly deep-bodied worldwide (see illustrations in Leis and Rennis, 1983; Kavanagh *et al.*, 2000; Suzuki *et al.*, 1985; Kingsford, 1985 for Indo-Pacific species; Paris-Limouzi *et al.*, 2005 for *C. cyanea*, *C. enchrysur* and *C. multilineata*). Ré and Gomes (1982) stated body depths of 39.3–45.2% of SL (postflexion *C. limbata*). An exemption makes Pacific *C. punctipinnis* with more slender flexion larvae (Watson, 1996: 27–30%).

A distinct gap between the anus and first anal spine remains in flexion (and postflexion) *C. chromis*, *C. cyanea*, *C. lubbocki*, *C. multilineata*, and, albeit smaller, in *C. enchrysur*. For the Northeast Atlantic this character allows an easy distinction from superficially similar nomeid larvae, for the Indo-Pacific it was classified to occur “in some species” (Kavanagh *et al.*, 2000). Although not apparent in some early descriptions of postflexion *Chromis* larvae (de Gaetani, 1932; Suzuki *et al.*, 1985; Kingsford, 1985), small denticles, temporarily spinules, or even distinct spines at the edge of the preoperculum seem fairly common in genus *Chromis* (Kavanagh *et al.*, 2000; Paris-Limouzi *et al.*, 2005; Watson, 1996). The above described opercular ridge is also generally visible in the just quoted illustrations, including de Gaetani (*op. cit.*).

The trunk-pigmentation illustrated for *C. lubbocki* consists mainly of five superficial lines of melanophores. It conforms with that of *C. chromis*, *C. multilineata*, and *C. punctipinnis* (only three lines were illustrated for *C. dispilus* and *C. notatus*), whilst flexion *C. cyanea* and *C. enchrysur* differ by a sparse dorsal pigmentation. The midlateral line of melanophores present in the three first mentioned species is said to be absent in *C. cyanea*, and to develop late in *C. enchrysur* (Paris-Limouzi *et al.*, *op. cit.*). However, our two transforming *C. cyanea* showed such a line along the caudal peduncle. Otherwise they conformed well with the existing description.

We did not catch any recently hatched *Chromis*-larvae. All earlier descriptions of preflexion *Chromis*-larvae show conformingly a very slender body with a short digestive tract and a ventral pigment line on the caudal peduncle (besides the above quoted descriptions see additionally Fujita 1957; Turner and Ebert, 1962; Dekhnik, 1973). The body becomes deeper shortly before flexion. Between these mentioned descriptions slight differences exist if or when dorsal pigment appears. Such differences also exist within a species,

as revealed comparing illustrations of early *C. chromis* larvae (de Gaetani, 1932; Dekhnik, 1973). We assume that early larvae of *C. lubbocki* resemble those of *C. chromis*, and do show dorsal pigment, because this pigment was prominent already in our smallest specimens.

Leis and Rennis (1983) and Kavanagh *et al.* (2000) stated that caudal fins of pomacentrid larvae generally remain unpigmented. This was the case in our larval *C. lubbocki* which has yellowish fins as adult. However, such, albeit slight, pigmentation appears on the upper and lower C-rays of *C. chromis* at lengths of and above 12 mm (see illustrations in de Gaetani, 1932). Ré and Gomes (1982: fig. 4) showed caudal pigment to be present, even much darker, in transforming Azorian *C. limbata*, and considered larval pigmentation to be of taxonomic value for genus *Chromis*. As mentioned above, caudal pigment occurs furthermore in juvenile *C. cyanea* and *C. multilineata* (Paris-Limouzi *et al.*, 2005; and our *C. cyanea*). In *C. limbata* the caudal pigment bands extend on the caudal peduncle until the end of the dorsal and anal fins, in *C. cyanea* much farther forwards. The latter two species differ, besides in body depth, length of paired fins, and meristics, also in pigmentation of the dorsal and anal fin. Kavanagh *et al.* (2000) claimed that larval pigmentation patterns should allow identification of several Indian Ocean species.

Flexion and transforming larvae were caught within the Cape Verde Archipelago itself, and in North Equatorial Current waters south and southwest of the Archipelago, above mostly oceanic depths (table I). For *C. cyanea* these data are the second record ever since Osorio (1909). Maximum lengths of the here investigated *Chromis* larvae clearly exceeded the settlement lengths described for *C. chromis* and *C. limbata* (Fage, 1916; Ré and Gomes, 1982), respectively for several congeners (Kavanagh and Alford, 2003). This can be explained by retarded settlement caused by larval drift beyond suitably shallow adult habitat (Wellington and Victor, 1989). The fate of larvae dispersed far into the open ocean remains unknown. The scarcity of preflexion larvae is probably due to the fact that we did not sample close to their shallow hatching depth. The seasonal catch data suggest that spawning of *C. lubbocki* is more intense in northern hemisphere spring than in autumn, because the number of neuston-net tows per season is inverse to the number of specimens caught by it (John, 1976/77). Flexion- and larger larvae apparently live in surface-near waters. Although multinet-samples resolved 8 strata down to 250 m depth, only two multinet-specimens were caught at all, and in the uppermost 25 m. In congruence with the sparse dorsal pigmentation untypical for neustonic organisms, the neuston-net caught these larvae only during night- and twilight tows, and mostly in the subsurface stratum (10–25 cm).

Acknowledgements. - Sorting the "Poseidon" samples was done by N. Fricke and O. Meyer-Klaeden (Kiel).

REFERENCES

- ALLEN G.R., 1991. - Riffbarsche der Welt. 271 p. Melle: Mergus. (German translation of Allen G.R., 1991. Damsel-fishes of the world. 271 p. Melle: Mergus.)
- ARRUDA L.M., 1977. - Morphological comparisons between the Mediterranean and northeast Atlantic populations of *Chromis chromis* L. (Pisces: Pomacentridae). *Arq. Mus. Bocage*, Ser. 2, 6(11): 207-217.
- ARRUDA L., 1979. - On the subspecific distinction between *limbatus* and *chromis* populations of *Chromis chromis*. In: Third European Ichthyological Congress, Warsaw, 12 p. (mimeo).
- BLACHE J., CADENAT J. & A. STAUCH, 1970. - Clés de Détermination des Poissons de Mer signalés dans l'Atlantique orientale. 479 p. Paris: ORSTOM, *Faune Tropicale* 18.
- BREDER C.M. & D.E. ROSEN, 1966. - Modes of Reproduction in Fishes. 941 p. New York: Natural History Press.
- DE GAETANI D., 1932. - Uova, larve e stadii giovanili die *Helias-tes chromis* Gthr. *Mem. R. Com. Talass. It.*, 193: 16 p.
- DEKHNİK T.V., 1973. - Ichthyoplankton of the Black Sea. 234 p. Kiev: Naukova Dumka (in Russian).
- DOMINGUES V.S., BUCCIARELLI G., ALMADA V.C. & G. BERNARDI, 2005. - Historical colonization and demography of the Mediterranean damselfish, *Chromis chromis*. *Molec. Ecol.*, 14: 4051-4063.
- EDWARDS A.J., 1986. - A new damselfish *Chromis lubbocki* (Teleostei, Pomacentridae) from the Cape Verde Archipelago, with notes on Eastern Atlantic pomacentrids. *Zool. Meded. (Leiden)*, 60(12): 181-207.
- FAGE L., 1916. - Shore Fishes: Macrorhamphosidae, Ammodytidae, Atherinidae, Serranidae, Cheilodipteridae, Cepolidae, Sparidae, Mullidae, Pomacentridae, Labridae, Caproidae, Gobiidae, Scorpaenidae, Triglidae, Cyclopteridae, Trachinidae, Uranoscopidae, Callionymidae, Blenniidae, Ophidiidae. *Rep. Dan. Oceanogr. Exped. Medit.* 1908-1910, 2(A3): 1-154.
- FLOETER S.R., ROCHA L.A., ROBERTSON D.R., JOYEUX J.C., SMITH-VANIZ W.F., WIRTZ P., EDWARDS A.J., BARREIROS J.P., FERREIRA C.E.L., GASPARINI J.L., BRITO A., FALCÓN J.M., BOWEN B.W. & G. BERNARDI, 2008. - Atlantic reef fish biogeography and evolution. *J. Biogeogr.*, 35(1): 22-47.
- FROESE R. & D. PAULY. (eds), 2007. - FishBase. World Wide Web electronic publication. www.fishbase.org, version (01/2007).
- FUJITA S., 1957. - On the development and prelarval stage of a damselfish, *Chromis notatus* (Temminck et Schlegel). *Jpn. J. Ichthyol.*, 6: 87-90.
- JOHN H.-C., 1976/77. - Die Häufigkeit des Ichthyoplanktons an der Oberfläche des mittleren und südlichen Atlantischen Ozeans. *Meeresforsch.*, 25(1-2): 23-36.
- KINGSFORD M.J., 1985. - The demersal eggs and planktonic larvae of *Chromis dispilus* (Teleostei, Pomacentridae) in north-eastern New Zealand waters. *New Zealand J. Mar. Freshw. Res.*, 19(4): 429-438.
- KAVANAGH K.D., LEIS J.M. & D.S. RENNIS, 2000. - 83. Pomacentridae. In: The Larvae of Indo-Pacific Coastal Fishes: An Identification Guide to Marine Fish Larvae (Leis, J.M. & B.M. Carson-Ewart, eds), pp. 526-535. Leiden: Brill.
- KAVANAGH K.D. & R.A. ALFORD, 2003. - Sensory and skeletal development and growth in relation to the duration of the embryonic and larval stages in damselfishes (Pomacentridae). *Biol. J. Linn. Soc.*, 80: 187-206.
- LEIS J.M. & D.S. RENNIS, 1983. - The Larvae of Indo-Pacific Coral-Reef Fishes. 269 p. Honolulu: Univ. of Hawaii Press.
- LLORIS D. & J. RUCABADO, 1990. - Pomacentridae. In: CLOFETA, Check-list of the Fishes of the Eastern Tropical Atlantic II (Quéro J.-C., Hureau J.-C., Karrer C., Post A. & L. Saldanha, eds), pp. 842-850. Paris: UNESCO.
- MURPHY B.F., LEIS J.M. & K.D. KAVANAGH, 2007. - Larval development of the Ambon damselfish *Pomacentrus ambonensis*, with a summary of pomacentrid development. *J. Fish. Biol.*, 71: 569-584.
- OSORIO B., 1909. - Peixes colhidos nas vishinhancas do Archipelago de Cabo Verde. *Mems Mus. Bocage*, 2: 51-77.
- PADOA E., 1956. - Sottordine: Chromides. In: Fauna e flora del Golfo di Napoli 38(3). Uova, larve e stadi giovanili di Teleostei (Lo Bianco S., ed.), pp. 573-576. Naples: Stazione Zoologica.
- PARIS-LIMOUZI C.B., SPONAUGLE S., COWEN R.K. & T. ROTUNNO, 2005. - Pomacentridae: Damsel-fishes. In: Early Stages of Atlantic Fishes: An Identification Guide for the Western Central Atlantic (Richards W.J., ed.), Vol. 2, pp. 1787-1818. Boca Raton: Taylor and Francis.
- RÉ P. & J. GOMES, 1982. - The eggs, newly hatched larvae and juveniles of the Azorian *Chromis* (Pisces: Pomacentridae). *Bolm Soc. Port. Ciênc. Nat.*, 21: 9-18.
- REINER F., 1996. - Catalogo dos Peixes do Archipelago de Cabo Verde. 339 p. Publ. Avulsas do IPIMAR. Lisboa: IPIMAR.
- STEEDMAN H.F., 1976. - Zooplankton fixation and preservation. 350 p. Paris: UNESCO. Monogr. Oceanogr. Methodol., 4.
- SUZUKI K., HIOKI S., & M. KURITA, 1985. - Life history of the damselfish *Chromis notatus* in Suruga Bay. *J. School Mar. Sci. Technol., Tokai Univ.*, 21: 115-127.
- TURNER C.H. & E.E. EBERT, 1962. - The nesting of *Chromis punctipinnis* (Cooper) and a description of their eggs and larvae. *Calif. Fish Game*, 48(4): 243-248.
- WATSON W., 1996. - Pomacentridae: Damsel-fishes. In: The Early Stages of Fishes in the California Current Region. (Moser, H.G., ed.), pp. 1054-1063. CALCOFI Atlas No. 33.
- WELLINGTON G.M. & B.C. VICTOR, 1989. - Planktonic larval duration of one hundred species of Pacific and Atlantic damselfishes. *Mar. Biol.*, 101: 557-567.
- WOOD E.M., 1977. - A review of damselfishes (Pisces: Pomacentridae) of the genus *Chromis* from the central and eastern Atlantic and Mediterranean. *J. Fish Biol.*, 10(4): 331-345.

Reçu le 23 avril 2007.

Accepté pour publication le 22 mai 2008.