

# Description and ecology of larvae of *Glossogobius callidus* and *Redigobius dewaali* (Gobiidae) from temperate South African estuaries

Nadine A. Strydom<sup>1\*</sup> & Francisco J. Neira<sup>2</sup>

<sup>1</sup>South African Institute for Aquatic Biodiversity, Private Bag 1015, Grahamstown, 6140 South Africa  
<sup>2</sup>Marine Research Laboratories, Tasmanian Aquaculture and Fisheries Institute (TAFI), University of Tasmania, Nubeena Crescent, Taroona, Tasmania 7053, Australia

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This paper describes the morphology and ecology of the larvae and early juveniles of two common gobiids in warm temperate South African estuaries. The early developmental stages of *Glossogobius callidus* and *Redigobius dewaali* were collected during plankton surveys in seven permanently open and five intermittently open estuaries along southeastern South Africa. Larval *G. callidus* have a characteristic ventral row of pigment that extends from the cleithral symphysis along the ventral midline of the tail to the end of the caudal peduncle; notochord flexion takes place at the yolk-sac stage, between 3 and 4 mm BL. Larval *R. dewaali* are characterized by having two very large stellate melanophores on the ventral surface of the trunk and tail, and internal pigment between the snout and hindgut; notochord flexion takes place between 4 and 6 mm. Body lengths at settlement for *G. callidus* and *R. dewaali* are 13 mm and 16 mm, respectively. *G. callidus* and *R. dewaali* dominate the larval gobiid catch in warm temperate estuaries. Estuary type and freshwater input played a defining role in the occurrence of larvae of these, often sympatric, species in temperate estuaries. Larval *G. callidus* occurred in both permanently open and intermittently open estuaries, and were most abundant in mesohaline regions over the spring/summer period. By contrast, larval *R. dewaali* occurred exclusively in permanently open estuaries and were more prevalent in the fresh and oligohaline regions in autumn. Larvae of both species were more prevalent in freshwater-rich estuaries. Densities of *G. callidus* and *R. dewaali* peaked at 101 and 3829 larvae per 100 m<sup>3</sup> respectively. The usefulness of using the early stages of these gobiids as indicators of estuarine health based on their specific and often prolific estuarine occurrence is discussed.

**Key words:** Gobiidae, larval stages, estuaries, freshwater abstraction, indicator species.

## INTRODUCTION

Two common, endemic, often sympatric, gobies of South African temperate estuaries are the river goby, *Glossogobius callidus* (Smith), and the checked goby, *Redigobius dewaali* (Weber). The river goby is abundant in coastal rivers and estuaries, and breeds mainly during spring (October–November) in southeast coast estuaries (Whitfield 1998). The checked goby, the only known *Redigobius* species occurring in southern Africa, occurs in clear, vegetated littoral habitats of floodplain pans, lakes and estuaries, and is believed to breed during spring and summer (September–February) (Skelton 2001). Similar to the situation with bays and estuaries in temperate Australia (e.g. Neira *et al.* 1992; Neira & Potter 1994; Neira & Sporcic

2002), larval gobiids often constitute the most abundant fish taxa in plankton surveys in both temperate and subtropical estuaries in South Africa (e.g. Harris & Cyrus 2000; Strydom *et al.* 2003), and therefore constitute an important component of planktonic estuarine fauna. Aside from larvae belonging to the genus *Caffrogobius*, larvae of *G. callidus* and *R. dewaali* were found to dominate the gobiid catch in warm temperate estuaries (Strydom *et al.* 2003).

While gobiid larvae are particularly well described for several species elsewhere (e.g. Ruple 1984; Dotsu *et al.* 1988; Neira *et al.* 1998; Leis & Carson-Ewart 2000), no published information exists for gobiid species occurring in South African estuaries, except for an unpublished report on the larvae of the Knysna sand goby, *Psammogobius knysnaensis*, by Melville-Smith (1979). In this paper, we provide

\*Author for correspondence. E-mail n.stydom@ru.ac.za

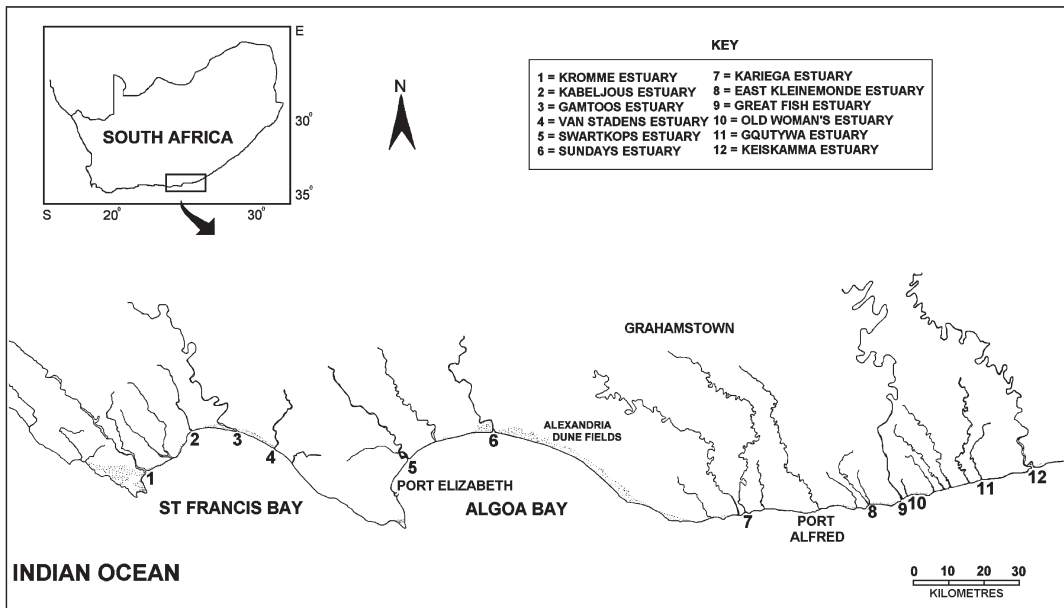


Fig. 1. Geographical position of the study area showing location of warm temperate estuaries surveyed in South Africa (Strydom *et al.* 2003)

a detailed description of the larval stages of *G. callidus* and *R. dewaali*, and present ecological information on the larvae of these two species obtained from 12 estuaries in the region.

## MATERIALS & METHODS

### Study area

Larval and juvenile gobiids were collected during a survey of 12 estuaries along the Eastern Cape coast of South Africa. Estuaries were selected to represent common estuary types and varying degrees of anthropogenic influence in the region. Eastwards, large permanently open estuaries included the Kromme, Gamtoos, Swartkops, Sundays, Kariega, Great Fish and Keiskamma; intermittently open estuaries comprised the Kabeljous, Van Stadens, East Kleinemonde, Old Woman's and Gqutywa (Fig. 1). The region is warm temperate, with a bimodal rainfall that peaks generally in winter and spring (Lubke & de Moor 1998). Permanently open estuaries are subjected to a semi-diurnal tidal pattern, with a tidal range of approximately 1.6 m (microtidal). Physical characteristics defining these systems are given in Strydom *et al.* (2003).

### Field sampling and laboratory analyses

Details of plankton sampling and gear used are

provided in Strydom *et al.* (2003). Sampling was conducted at night during each season between July 1998 and July 1999. Two sub-surface (upper 0.8 m) samples (= replicates) were collected per site in each estuary using two WP2 plankton nets, each measuring 570 mm in mouth diameter and 2.5 m in net length with a mesh size of 0.2 mm. The nets were fitted with Kahlsico 005 WA 130 flowmeters and were towed obliquely at speeds of 1–2 knots for 3 minutes. Samples were fixed on site with 5% buffered formalin. Average water volume filtered during each tow was 16.3 m<sup>3</sup> (S.E. ± 0.5).

Temperature (°C) and salinity (PSU—practical salinity units) data were obtained at 0.5 m intervals between the surface and bottom of each site using a Valeport Conductivity-Temperature-Depth (CTD) unit. Water transparency data (depth, cm) were obtained at all sites with a Secchi disc, and all measurements converted into an extinction coefficient ( $k$ ) using the formula  $k = 1.7/D$  (Secchi depth) (Dawes 1981).

Samples were processed in the laboratory and all larval and early juvenile gobiids removed. Gobiids were identified using body shape and other morphological features, and assembled in a developmental series from juveniles to preflexion larvae using fin-ray counts and pigment (Neira *et al.* 1998). Species identifications were based on Smith & Heemstra (1995). All terminology

pertaining to larval fishes follows Neira *et al.* (1998). Lengths provided correspond to body length (BL, mm), i.e. notochord length (snout tip to notochord tip) in preflexion and flexion larvae, and standard length (snout tip to posterior hypural margin) in postflexion larvae and juveniles. Lengths and other body measurements were made to the nearest 0.1 mm using an eyepiece micrometer for larvae <10 mm and Vernier callipers for larger individuals. Larval fish density was expressed as number of larvae per 100 m<sup>3</sup>.

A total of 30 specimens of *G. callidus* (3.50–13.75 mm), and 45 specimens of *R. dewaali* (2.24–21.13 mm BL) were used to describe pigmentation, morphometrics and meristics. Specimens were removed for drawing and the remainder were cleared and stained (Potthoff 1984) in order to count fin elements and vertebrae. Representatives of the different developmental stages described (*G. callidus* = SAIAB 74295; *R. dewaali* = SAIAB 74296) were deposited into the fish collection at the South African Institute for Aquatic Biodiversity.

#### Data analyses

For statistical purposes, sites in each estuary were grouped into zones based on salinity ranges in the water column at each site. The salinity zones (i.e. fresh, oligohaline, mesohaline, polyhaline, euhaline and hypersaline), as well as their corresponding salinity ranges, are defined in Strydom *et al.* (2003). The 'fresh' zone was added to this classification, and the salinity range of the hypersaline zone was adjusted to suit warm temperate estuaries and take into account the average salinity of seawater ( $\geq 35.2$ ) in this region of South Africa (Schumann 1998).

Non-parametric tests were used for all analyses, as parametric test assumptions (normality and homogeneity of variance) were not met (post transformation). The Kruskal-Wallis ANOVA by ranks test was used to assess differences in gobiid densities between estuaries, seasons and salinity zones. In all analyses, actual replicate values of gobiid densities per site were used, i.e. no data were averaged prior to statistical tests. Multiple linear stepwise regression (MLR) was used to determine whether gobiid densities were significantly associated with environmental variables. The following regression statistics are reported:  $adjR^2$  = adjusted coefficient of determination (goodness of fit);  $R$  = correlation coefficient;  $F$  =  $F$ -statistic.

## RESULTS

### Larval descriptions

#### *Glossogobius callidus*

Larvae are elongate (body depth, BD 17–20%), and have a moderate to large head (head length, HL 21–34%) and a long gut (pre-anal length, PAL 50–54%) (Fig. 2; Table 1). There are 26 myomeres (10 + 16) and 26 vertebrae. Notochord flexion starts at approximately 3 mm and is complete by 4 mm. Larvae are lightly pigmented. There is a melanophore at the lower jaw angle in flexion and postflexion larvae, and no pigment on the snout or head until the early juvenile stage ( $\geq 10$  mm). A row of melanophores extends ventrally from the isthmus to the pelvic-fin base, and another diagonally from the eye through to the mouth in early juveniles. The entire head is sprinkled with many small melanophores from 12 mm.

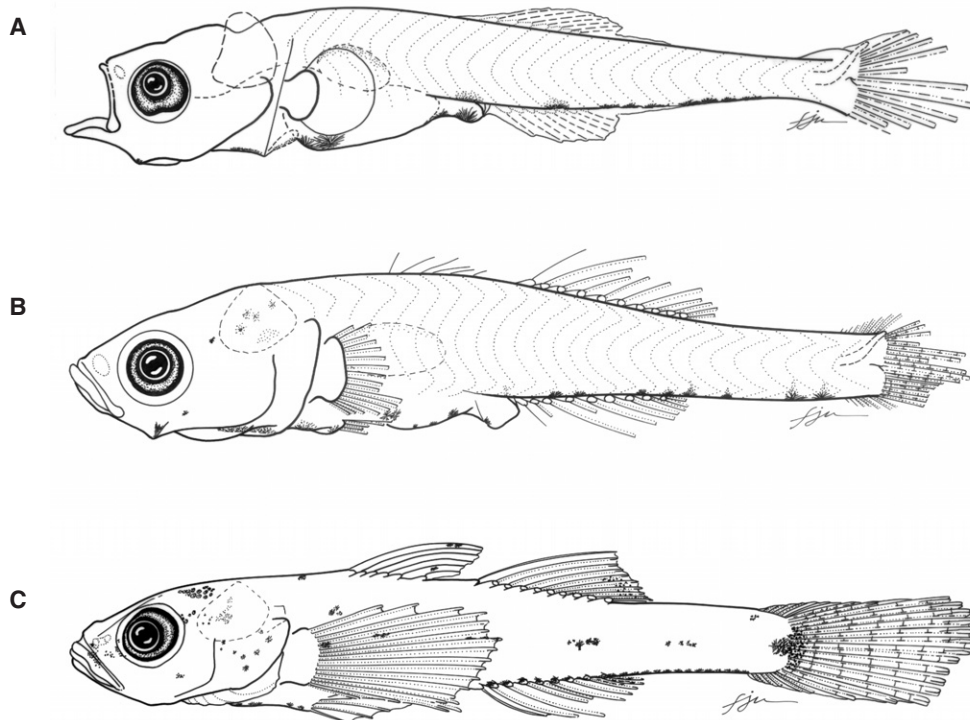
Internal pigment in the trunk region is present dorsally over the gas bladder in flexion and postflexion larvae. A single row of melanophores ventrally along the isthmus splits to form a double row along the foregut, joining again at the anus. One melanophore is situated at the anus and another directly above the posterior end of the hindgut. Isolated internal melanophores appear on the nape and along the vertebral column by 6 mm. Melanophores appear along the lateral midline at about 7 mm.

A single row of irregularly spaced melanophores is present along the ventral midline of the tail, together with a row of small melanophores on either side of the anal fin in flexion and postflexion larvae. No pigment is visible at the notochord tip. The melanophore cluster forming the characteristic dark spot over the caudal peduncle of this species is visible from 11 mm.

Small villiform teeth appear in the upper jaw by 6 mm becoming numerous in both jaws by 7 mm and becoming curved by 12 mm. Spines and rays of all fins are formed by 6.0 mm (Fig. 2B) and scales are present on the trunk at 12 mm.

#### *Redigobius dewaali*

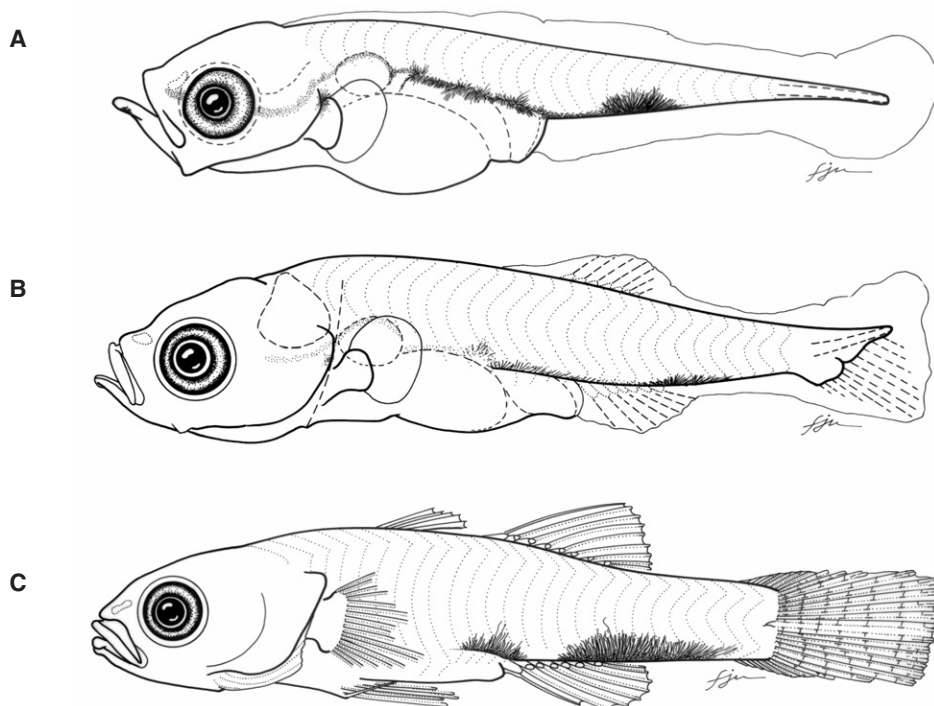
Larvae have a moderate body (BD 22–24%), a small to moderate head (HL 19–28%) and a long (PAL 52–58%) gut (Fig. 3; Table 1). There are 26–27 myomeres (10–12 + 14–16) and 26 vertebrae. Notochord flexion starts at approximately 4 mm and is complete by 6 mm. Larvae are moderately pigmented. Yolk-sac larvae have internal pigment



**Fig. 2.** Larval stages of *Glossogobius callidus* from warm temperate estuaries of South Africa. **A**, 3.96 mm BL flexion larva; note developing pelvic fin and remnants of yolk sac; **B**, 6.00 mm BL early postflexion larva; **C**, 13.37 mm BL early juvenile; forming scales and head pores have been omitted. Drawn by F.J. Neira.

**Table 1.** Length range, mean body length and body proportions of larval and juvenile *Glossogobius callidus* and *Redigobius dewaali* collected in warm temperate estuaries of South Africa. Body length = BL, head length = HL, eye diameter = ED, body depth = BD, pre-anal length = PAL. Values for HL, ED, BD and PAL are given as percentages of body length (% BL). Standard deviation ( $\pm$ ) is shown in brackets.

	Flexion (n = 7)	Postflexion (n = 10)	Early juvenile (n = 10)	Juvenile (n = 3)	
<b><i>Glossogobius callidus</i></b>					
BL range (mm)	3.5–4.0	4.2–6.9	9.6–13.3	13.4 <	
BL (mm)	3.9 (0.2)	5.3 (1.1)	11.3 (1.2)	13.5 (0.2)	
HL (% BL)	21.9 (1.8)	27.0 (3.1)	32.2 (1.3)	33.3 (1.3)	
ED (% BL)	6.5 (0.6)	6.9 (0.5)	7.8 (0.3)	9.5 (0.1)	
BD (% BL)	16.9 (0.8)	17.6 (1.3)	19.2 (1.0)	19.5 (0.6)	
PAL (% BL)	50.3 (1.0)	52.3 (2.5)	53.0 (0.8)	53.7 (0.6)	
	Preflexion (n = 15)	Flexion (n = 10)	Postflexion (n = 10)	Early juvenile (n = 2)	Juvenile (n = 2)
<b><i>Redigobius dewaali</i></b>					
BL range (mm)	2.2–3.5	4.0–5.4	5.6–11.8	12.4–14.8	16.8 <
BL (mm)	2.6 (0.4)	4.8 (0.5)	8.7 (2.0)	13.6 (1.7)	18.9 (3.1)
HL (% BL)	22.2 (2.5)	26.6 (3.1)	30.3 (1.3)	27.9 (3.7)	28.8 (1.4)
ED (% BL)	9.8 (1.0)	8.2 (0.4)	8.4 (0.5)	9.2 (0.2)	8.3 (0.9)
BD (% BL)	20.7 (2.1)	20.4 (0.8)	21.9 (1.0)	23.9 (1.0)	24.2 (1.6)
PAL (% BL)	52.9 (2.1)	60.5 (3.2)	59.7 (2.4)	57.3 (3.2)	58.0 (2.5)



**Fig. 3.** Larval stages of *Redigobius dewaali* from warm temperate estuaries of South Africa. **A**, 2.62 mm BL preflexion larva; note prominent yolk sac; **B**, 3.78 mm BL flexion larva; **C**, 7.72 mm BL postflexion larva. Drawn by F.J. Neira.

that extends from the tip of the snout, along the roof of the mouth, past the eye and extending across the operculum to the pectoral-fin base. An external melanophore is present at the tip of the lower jaw. A few isolated melanophores form over the head and operculum from 10 mm. The entire head of the early juvenile fish has many small melanophores.

Internal pigment in the trunk region extends from the dorsal region of the pectoral-fin base, dorsally along the gas bladder, to the anterior part of the hindgut. This distribution of internal pigment from the hindgut to the eye forms a stripe, which is present throughout larval development, but becomes less prominent with growth. One very large stellate melanophore is present ventrally on the trunk above the hindgut, becoming internal between 5 and 8 mm. A stellate melanophore is present on the fore- and hindgut in preflexion larvae. The large stellate melanophore anterior to the gas bladder becomes more prominent in flexion larvae. An external melanophore occurs dorsally at the pectoral-fin base. A set of paired melanophores occurs along the first dorsal-fin base by 10 mm, with a dense concentration of melanophores becoming visible on the anterior

dorsal-fin rays from 11.5 mm. This batch of melanophores forms a pigment spot characteristic of the species. Dorsal and lateral pigmentation becomes more prominent and extends ventrally with growth. In early juveniles, these melanophores become denser along the mid-lateral line forming five spots. Pigmentation develops along the pectoral-fin rays from 14 mm.

The tail in yolk-sac larvae possesses two very large melanophores (appearing often as a single, fused melanophore) situated midway along the ventral midline, often extending dorsally over the lateral surface of the body. These melanophores are visible throughout larval development although after 10 mm, they are significantly reduced in size. Internal melanophores are visible anterior to the last vertebra at 10 mm, extending anteriorly across the vertebrae with growth. Four melanophores occur along the ventral midline of the tail in early juveniles, between the base of the caudal peduncle and the anal fin. The anal fin is also pigmented, with melanophores present between rays 2–3 and 5–6.

Isolated teeth are visible in the lower jaw at 5 mm becoming numerous in both jaws at 8 mm. Spines and rays of all fins are formed by 8 mm. By 19 mm,

**Table 2.** Salinity (PSU), temperature (°C) and water transparency (*k*) measurements recorded in selected warm temperate estuaries of South Africa (June 1998–March 1999 survey) after Strydom *et al.* (2003).

Estuary {length sampled (km), no. of stations sampled}	Physico-chemical variables	Mean	Median	Range
<b>Permanently open estuaries</b>				
Kariega {17, 9}	Salinity	32.75	34.18	25.45–35.74
	Temperature	19.45	20.28	9.01–27.92
	Water transparency	0.02	0.02	0.01–0.03
Great Fish {14, 6}	Salinity	14.03	9.69	0.00–35.26
	Temperature	20.33	20.13	15.09–26.43
	Water transparency	0.34	0.09	0.01–1.70
Keiskamma {20, 9}	Salinity	12.67	10.19	0.00–34.70
	Temperature	20.94	20.76	15.71–26.38
	Water transparency	0.36	0.07	0.02–1.70
Sundays {19, 9}	Salinity	14.80	14.43	1.94–33.31
	Temperature	20.40	18.82	12.60–28.49
	Water transparency	0.04	0.03	0.01–0.09
Swartkops {15, 7}	Salinity	28.75	29.60	19.10–35.39
	Temperature	20.08	18.11	14.89–26.52
	Water transparency	0.01	0.01	0.01–0.03
Gamtoos {18, 8}	Salinity	22.83	26.31	0.60–34.68
	Temperature	19.52	19.37	11.13–25.77
	Water transparency	0.02	0.02	0.01–0.03
Kromme {14, 7}	Salinity	34.62	34.93	32.32–36.68
	Temperature	18.70	17.14	13.00–25.29
	Water transparency	0.02	0.02	0.01–0.03
<b>Intermittently open estuaries</b>				
East Kleinemonde {2.5, 5}	Salinity	16.93	14.60	10.69–23.71
	Temperature	21.06	23.14	13.28–26.02
	Water transparency	0.02	0.02	0.01–0.03
Old Woman's {0.8, 2}	Salinity	30.72	31.65	16.91–36.28
	Temperature	20.29	21.55	13.27–27.20
	Water transparency	0.01	0.01	0.01–0.02
Gqutywa {2.0, 3}	Salinity	39.82	39.87	35.66–43.19
	Temperature	21.92	22.79	15.11–28.01
	Water transparency	0.03	0.03	0.02–0.04
Van Stadens {1.5, 3}	Salinity	13.02	13.27	2.69–18.94
	Temperature	20.10	20.60	11.99–28.64
	Water transparency	0.01	0.01	0.01–0.02
Kabeljous {1.7, 3}	Salinity	32.76	34.33	19.79–40.57
	Temperature	20.16	20.07	14.33–26.43
	Water transparency	0.02	0.02	0.01–0.04

the fish bears scales, a full fin ray complement and pigmentation characteristic of the juvenile and adult fish (Fig. 4).

## Ecology

### *Environmental variability*

Salinity and water transparency varied significantly between and within permanently open ( $P < 0.01$ ;  $n = 128$ ) and intermittently open ( $P <$

$0.01$ ;  $n = 440$ ) estuaries, while temperatures did not (Table 2). Hypersaline/marine-dominated estuaries included the Kariega, Kromme, Kabeljous and Gqutywa, whereas freshwater-rich estuaries included the Keiskamma, Great Fish, Sundays, Van Stadens and Gamtoos. Estuaries displaying very high turbidities were the Keiskamma and Great Fish, whereas those with very low turbidities included the Kariega, Swartkops and Van Stadens.



**Fig. 4.** Early juvenile *Redigobius dewaali*, 11.9 mm BL (**top**) and early juvenile *Glossogobius callidus*, 13.2 mm BL (**bottom**) from warm temperate estuaries of South Africa.

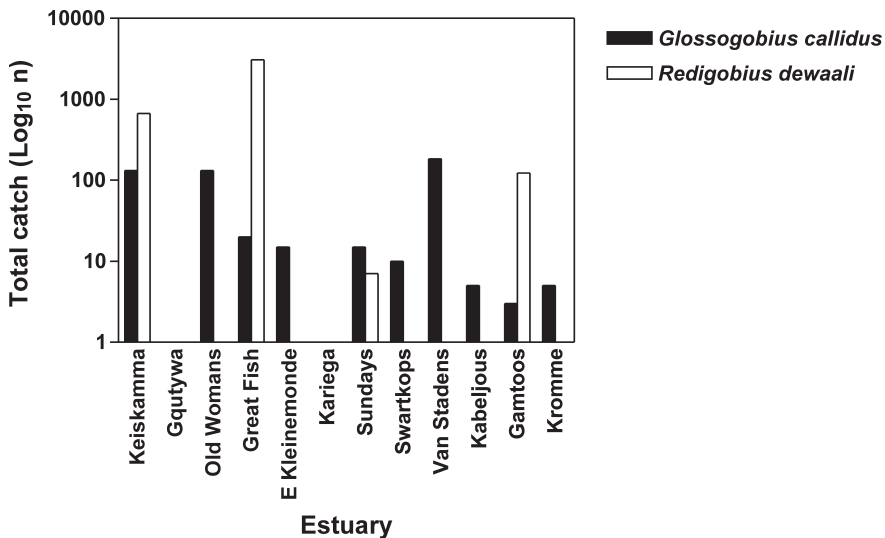
*Species occurrence*

Larval *G. callidus*, including flexion (yolksac) larvae through to early juveniles (2.2–22.9 mm), were caught in permanently open ( $n = 186$ ) and intermittently open ( $n = 336$ ) estuaries, while preflexion through to postflexion larvae of *R. dewaali* (2.0–18.7 mm) occurred only in permanently open estuaries ( $n = 3\ 872$ ) (Fig. 5).

*Temporal, spatial and environmental trends in gobiid density*

Densities of larvae and early juveniles of both

species varied significantly between seasons ( $P < 0.01$ ;  $n = 4$ ). *G. callidus* were most abundant during spring and summer, whereas early stages of *R. dewaali* were more abundant in autumn (Table 3; Fig. 6). Larvae also displayed a significant difference in distribution between salinity zones ( $P < 0.01$ ;  $n = 6$ ). *G. callidus* were more abundant in mesohaline regions while *R. dewaali* were abundant in both oligohaline and freshwater regions (Table 3; Fig. 7). Larval densities were highly variable and were dependent on estuary type, season and salinity zone. Maximum densities



**Fig. 5.** Total catch of *Glossogobius callidus* and *Redigobius dewaali* in selected warm temperate estuaries of South Africa (June 1998 – March 1999 survey).

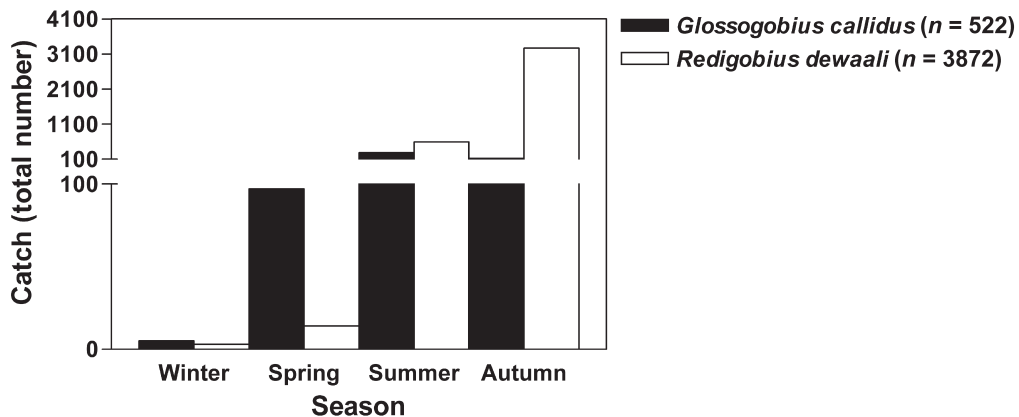
**Table 3.** Mean, median and range of densities (no./100 m<sup>3</sup>) recorded for larval *Glossogobius callidus* and *Redigobius dewaali* collected in four seasons in different salinity zones in Eastern Cape estuaries, South Africa. (–) indicates no specimens were recorded in the estuary.

	<i>Glossogobius callidus</i>			<i>Redigobius dewaali</i>		
	Mean	Median	Range	Mean	Median	Range
<b>Estuary</b>						
<b>Permanently open</b>						
Kromme (tributary)	0.6	0	0–8.6	0.1	0	0–7.2
Gamtoos	0.4	0	0–17.6	8.2	0	0–128.6
Swartkops	1.17	0	0–48.2	–	–	–
Sundays	0.9	0	0–36.3	0.6	0	0–17.7
Kariega	0.1	0	0–5.5	–	–	–
Great Fish	2.1	0	0–33.6	307.6	3.0	0–3826.3
Keiskamma	7.8	0	0–101.8	35.9	0	0–438.7
<b>Intermittently open</b>						
Kabeljous	1.0	0	0–9.6	–	–	–
Van Stadens	39.8	2.8	0–299.0	–	–	–
East Kleinemonde	2.3	0	0–38.5	–	–	–
Old Woman's	46.9	0	0–252.5	–	–	–
Gqutywa	–	–	–	–	–	–
<b>Salinity zone</b>						
Fresh	11.0	0	0–101.8	72.7	35.8	0–438.7
Oligohaline	5.7	0	0–44.7	300.6	0	0–3826.3
Mesohaline	14.4	0	0–299.0	9.1	0	0–221.6
Polyhaline	0.9	0	0–48.2	3.5	0	0–123.7
Euhaline	2.3	0	0–252.5	0.4	0	0–36.1
Hypersaline	0.1	0	0–4.9	–	–	–
<b>Season</b>						
Summer	10.9	0	0–252.5	16.9	0	0–221.6
Autumn	4.1	0	0–101.8	109.1	0	0–3826.3
Winter	0.1	0	0–17.2	0.1	0	0–3.2
Spring	3.8	0	0–299.0	0.5	0	0–21.6

recorded for *G. callidus* and *R. dewaali* were 299 and 3826 larvae per 100 m<sup>3</sup>, respectively (Table 3).

Multiple linear regression analyses indicated that salinity in permanently open estuaries had a significant negative relationship with densities of

*G. callidus* ( $P < 0.001$ ,  $\text{adj}R^2 = 0.10$ ,  $R = 0.33$ ,  $F = 17.69$ ) and *R. dewaali* ( $P < 0.01$ ,  $\text{adj}R^2 = 0.06$ ,  $R = 0.25$ ,  $F = 9.45$ ). However, temperature in open estuaries had a significant positive relationship with densities of *G. callidus* ( $P < 0.001$ ) and *R.*

**Fig. 6.** Total seasonal catch of *Glossogobius callidus* and *Redigobius dewaali* in selected warm temperate estuaries of South Africa (June 1998 – March 1999 survey).



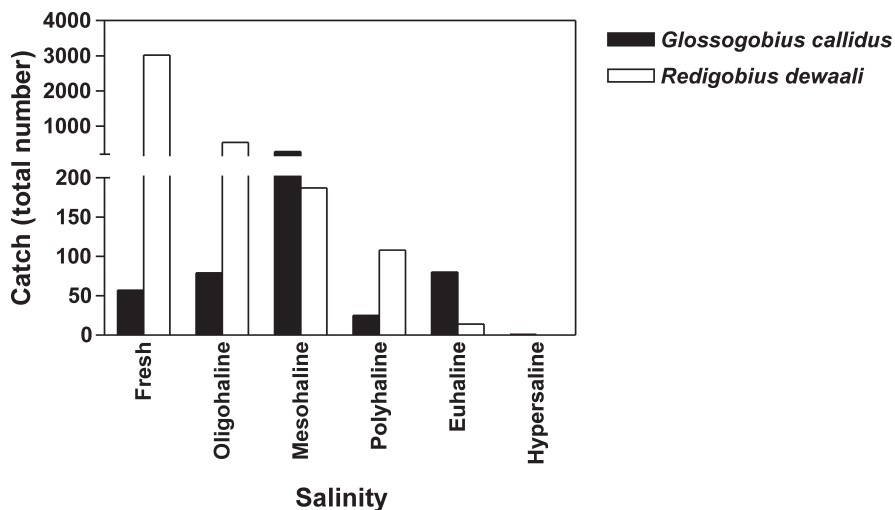


Fig. 7. Total catch of *Glossogobius callidus* and *Redigobius dewaali* in salinity zones characterizing selected warm temperate estuaries of South Africa (June 1998–March 1999 survey).

*dewaali* ( $P < 0.05$ ). Densities of *G. callidus* in intermittently open estuaries also showed a positive relationship with temperature ( $P < 0.001$ ,  $\text{adj}R^2 = 0.04$ ,  $R = 0.25$ ,  $F = 2.72$ ). No *R. dewaali* were recorded in intermittently open estuaries.

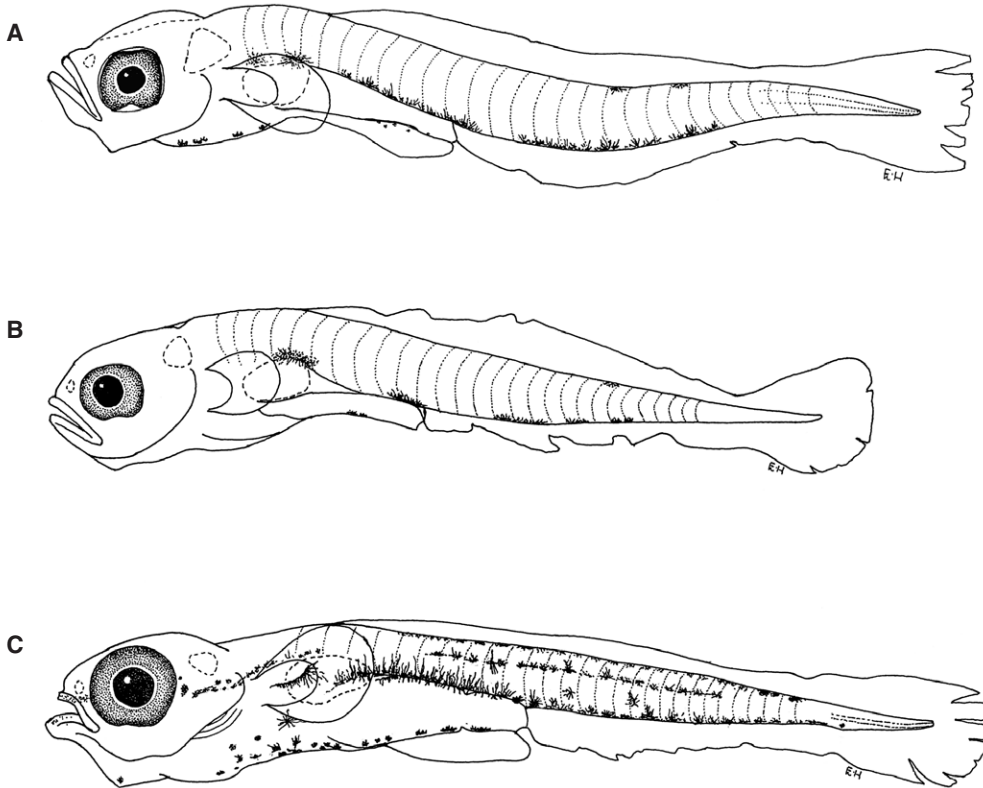
## DISCUSSION

Larvae of *G. callidus* and *R. dewaali* can be easily distinguished from other common gobiids found in the region. Diagnostic features of larval *G. callidus* include the pigment along the ventral surface of the trunk and tail and the slender shape of the body, whereas *R. dewaali* can be identified by the two very large stellate melanophores on the ventral surface of the trunk and tail, and the internal pigment stripe extending between the snout and foregut. Other gobiids commonly occurring in these systems have not been described but *Caffrogobius* species, likely to be confused with *Glossogobius* larvae, generally possess a single row of pigment along the ventral surface between the trunk and tail. This row is continuous in *Caffrogobius gilchristi* but in *C. nudiceps*, ventral pigmentation consists of 3–4 melanophores clustered midway along the tail region. *Caffrogobius* larvae also typically possess one or two melanophores on the dorsal surface of the tail, anterior to the caudal peduncle (Fig. 8). *Redigobius* larvae are characteristic and cannot be confused with other genera. Similarly, the larvae of the other common gobiid in temperate estuaries, *Psammogobius knysnaensis*, are easily distinguished by three characteristic rows of melanophores extending along the dorsal, lateral

and ventral surface of the trunk and tail (unpublished description, Melville-Smith 1979) as illustrated in Fig. 8.

Larval *G. callidus* are more developed at birth than larval *R. dewaali*, a feature that may enhance their survival and position maintenance within the estuary. This is suggested by the occurrence of some flexion in *G. callidus* larvae still in possession of a yolk-sac, indicating that the onset of notochord flexion may occur during late stages of embryogenesis. In addition, no preflexion stages of this estuary-resident species were recorded in any estuaries despite the prolific occurrence of larvae in some systems.

Larval *G. callidus* were caught in all permanently open and intermittently open estuaries sampled, with highest densities recorded in intermittently open systems. Larval *R. dewaali*, on the other hand, were only found in permanently open estuaries. While the distribution of larvae of these endemic gobiids appears to overlap in estuaries where they are sympatric, variations in peak larval densities suggests a staggered spatial and temporal breeding pattern by adults of these species occurring in the same estuaries. The strong positive relationship between larval density and temperature observed for these species reflects the seasonality observed in larval occurrence and hence adult spawning. The larvae of both species contribute greatly to the larval gobiid catch in temperate estuaries, and are also noteworthy species in the estuarine larval fish assemblages of warm temperate South Africa. Larval *G. callidus* and *R. dewaali* comprised 1.2 and



**Fig. 8.** Gobiid larvae commonly encountered in warm temperate estuaries of South Africa. **A** = *Caffrogobius gilchristi*, 3.05 mm BL (SAIAB 76370); **B** = *Caffrogobius nudiceps*, 2.90 mm BL (SAIAB 76372); **C** = *Psammogobius knysnaensis*, 3.0 mm BL (SAIAB 76371). Drawn by E. Heemstra.

8.9% of the total larval catch in these systems, respectively (Strydom *et al.* 2003). Densities of larvae of these endemic gobiids were highest in freshwater rich estuaries, such as the Keiskamma, Great Fish, Sundays and Gamtoos systems, and low salinity zones within these estuaries. This was evidenced by the negative regression relationship between larval density and salinity. Larvae of these species were absent in the hypersaline Gqutywa, Kariega and Kromme systems, although *G. callidus* larvae were caught in a large freshwater-rich tributary of the Kromme Estuary. Naturally hypersaline estuaries are rare and usually hypersalinity in South African estuaries is a symptom of anthropogenic changes to the river e.g. dams, resulting in low or absent river flow to the estuary. Adult *R. dewaali* have been recorded in the upper reaches of the Kariega and Gqutywa estuaries under hypersaline conditions (Ter Morshuizen & Whitfield 1994; Vorwerk *et al.* 2001), but the absence of freshwater pulses to trigger spawning events (Strydom & Whitfield

2000) may reduce the frequency of spawning in these systems. If these gobiids do not breed or have limited breeding in freshwater-deprived habitats, this could eventually lead to the exclusion of these species from anthropogenically-altered estuaries. Compounding this is the low productivity of phyto- and zooplankton in freshwater-deprived estuaries (Grange *et al.* 2000), which could have negative feeding implications for the planktonic larvae of this species in the upper reaches of these estuaries.

The larvae of these two common gobiids were not specifically recorded in other warm temperate larval fish surveys (excluding Strydom *et al.* 2003) conducted in the Great Fish (Whitfield 1994), Kariega (Whitfield 1994), Sundays (Harrison & Whitfield 1990; Whitfield 1994), Swartkops (Melville-Smith & Baird 1980; Beckley 1985), Van Stadens (Dundas 1994), Kabeljous (Dundas 1994), Kromme (Melville-Smith 1981), Seekoei (Dundas 1994) and Swartvlei (Whitfield 1989a,b) systems. In most of these studies, researchers combined

unidentified Gobiidae together (e.g. Whitfield 1989a; Harrison & Whitfield 1990; Dundas 1994), largely due to the difficulty of separating gobiid larvae out between species as a result of the lack of gobiid descriptions in the literature. In addition, many authors spent relatively short periods in their careers working on larval fishes, which is not conducive to building of large larval fish collections that would enable serial identification of larvae from younger and older specimens. This has resulted in the loss of valuable ecological information on the Gobiidae component of larval fish assemblages in estuaries of the warm temperate, Eastern Cape. Fortunately, the same trend does not exist for the subtropical estuaries of the KwaZulu-Natal region. Harris & Cyrus (2000) surveyed larval fishes in three estuaries and made good headway in identifying Gobiidae, unfortunately descriptive information on larvae was not published in this work.

Compounding the lack of records of other gobiid species in past warm temperate studies, researchers often confined larval fish surveys to the lower reaches of estuaries and for short periods of time, resulting in the under-representation of other gobiid larvae. Comprehensive baseline larval fish surveys extending across the entire length of the estuary and multi-estuary sampling are the only means of achieving accurate holistic views of larval fish assemblages utilizing these systems.

The larvae of the two gobiid species described in this paper could be used as indicator organisms, particularly when assessing estuarine health or ecosystem change in anthropogenically altered estuaries over long periods of time. This is derived from their specific and often prolific occurrence in 'healthy' estuaries receiving an adequate supply of freshwater along the temperate coast of South Africa, which will give an indication of fish breeding in the system and the success thereof. Larval fishes are ideally suited to be used as indicators of estuarine health and/or ecosystem change (e.g. Neira & Sporlic 2002), as their occurrence, composition, stages of development and muscle condition gives an indication of suitability of nursery habitat, adult breeding, degree of encroachment by non-estuarine species and food availability within the water column. In addition, the ubiquity of the larval stage among marine and estuarine fishes offers the unique opportunity to use a single type of collecting device, usually a plankton net, to sample many kinds of fishes at once. Sampling fish larvae as opposed to repro-

ductively active adults in any ecosystem is genetically inexpensive.

However, the biggest challenge when using larval fishes in applied studies in South African estuaries is acquiring a descriptive base for the larvae of these species. Descriptive information on the larvae of fishes occurring in both estuaries and marine waters is severely lacking.

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