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Aspects of the fishery, maturation and net selectivity of the wedge sole (*Dicologoglossa cuneata*) off south-western Iberia: implications for fishery management

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*The wedge sole (*Dicologoglossa cuneata*, Moreau 1881) is a commercially important species for the artisanal fleet operating off the south-western Iberian Peninsula. During 2004 and 2005 a study was undertaken aiming to provide a scientific basis for management. Data collection included information on aspects of the fishery, spawning season, size at first maturity, tangle and gill-net selectivity. Seven nominal mesh sizes were used (40, 45 and 50 mm tangle nets and 40, 50, 60 and 70 mm gill-nets). Spawning lasts from December to June, with peaks in March and May. Length at first maturity for females was estimated at 18.5 cm. Catch rates decreased sharply with increasing mesh size, with tangle nets providing the highest yields. The log-normal selectivity model provided the best fit for specimens that were wedged. The higher catch-per-unit-effort of the smaller mesh sizes and the modal length of the fitted selectivity curve being below the size-at-maturity for wedge sole, suggests that the 50 mm nominal mesh size tangle net is the most appropriate for ensuring the fishery sustainability. Nevertheless, the minimum legal size should increase to at least 18 cm and a time–area closure should be implemented off the Guadiana River mouth.*

Keywords: *Dicologoglossa cuneata*, fishery, maturity, selectivity, tangle and gill nets, south-western Iberia

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INTRODUCTION

Dicologoglossa cuneata (Moreau 1881), commonly known as the wedge sole, is a benthic species belonging to the Soleidae family, whose geographical distribution extends from the eastern Atlantic (Bay of Biscay southward) and the Mediterranean, along the west coast of Africa to South Africa. Its bathymetric range extends from the shallow subtidal down to about 400 m, but is most common on sandy or sandy–muddy bottoms in warm waters with temperature above 9°C, at depths from 10–50 m (Whitehead *et al.*, 1986).

On the southern Atlantic coast of the Iberian Peninsula (Algarve coast and Gulf of Cadiz) the *D. cuneata* fishery is of particular importance, namely for the artisanal fleet, due to its high consumption in Andalucia. The wedge sole is one of the most important demersal fisheries in the Gulf of Cadiz, but the annual production decreased from 3014 t to 763 t, between 1985 and 2000 (source: Junta de Andalucía). Off the Algarve coast its average annual production was in the order of 27 t between 1995 and 2005, but showing a decreasing trend from 2001 forwards (source: DGPA—General Fisheries and Aquaculture Directorate). In contrast to the decreasing trend of the annual landings since at least 1985, the mean price has consistently increased since 1998, with the wedge sole becoming one of the most important sources of income for the local artisanal fleet. On the Portuguese southern coast prices can reach up to 15€/kg at auction (9.50€/kg on average; source DGPA). Off the Spanish coast it is mostly targeted by trawlers, while off southern Portugal it is targeted by both tangle and gill-nets. The catch of *D. cuneata* in the Algarve region occurs mostly to the east of the Cape of Santa Maria, on sandy bottom grounds, where it represents up to 13% of the gill-net catches. The tangle nets fishery is particularly important in the vicinity of the Guadiana River mouth, especially during spring and summer. *Dicologoglossa cuneata* accounts for between 70% and 95% of the total tangle net catch, depending on the mesh size and season (unpublished data by IPIMAR—National Fisheries and Marine Research Laboratory). However, the latter fishery is illegal, as it makes use of mesh sizes smaller (between 40 and 50 mm) than the national legal one (60 mm). Consequently, there has been a persistent request from the fisher communities to revise (down) the current regulation on set nets mesh size, based on the argument that the latter mesh provides very low catches. Currently, the fishery is mostly managed based on the use of technical measures concerning minimum mesh sizes, net lengths (that vary with vessel size) and minimum landing size (15 cm of total length).

Because of the selective nature of set nets, mesh size can be controlled to restrict the size of fish captured, and either selection or retention curves can be used to calculate an optimal mesh size. Furthermore, managers would like to predict what effect any proposed change in mesh regulations might have on the size composition of the catch and yield. For

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these reasons, gill-net selectivity has often been estimated using a variety of methods for different fish species (see reviews by Hamley, 1975; Millar & Fryer, 1999). In recent years, new maximum likelihood based methods have been developed (Hovgård, 1996; Millar & Holst, 1997).

Various aspects of the distribution (Lagardère, 1982; Jiménez *et al.*, 1998; Cabral, 2000; Prista *et al.*, 2003), feeding ecology (Lagardère, 1975; Belghyti *et al.*, 1993; Cabral *et al.*, 2002), reproduction and growth (Marinaro *et al.*, 1979; Lagardère, 1980; Lagardère & Aboussouan, 1981; Dinis, 1986; Belghyti, 1990; Jiménez *et al.*, 1998; Jiménez & Piñeiro, 2001; García-Isarch *et al.*, 2006) and fisheries (Jiménez *et al.*, 1998) of the wedge sole have been studied in different areas. However, to our best knowledge minor attention has been given to the selectivity of set fishing gears for this species, as a single study was conducted for gill-nets off the Portuguese western coast (Fonseca *et al.*, 2005).

This paper reports the results of a study aiming to evaluate the possibility of including the tangle net in a forthcoming revision of the current management regulation for the wedge sole artisanal fishery in southern Portuguese waters (south-west of the Iberian Peninsula). Here we report aspects of the: (i) fishery; (ii) spawning season and size at first maturity; (iii) tangle and gill-net selectivity curves; (iv) catch; and (v) provide guidance for management regulation.

MATERIALS AND METHODS

Fishing trials

In early 2004 commercial fishermen were interviewed in order to obtain details on the design and operation of the set nets (gill-nets and tangle nets) used in the fishery off the Algarve coast and a net of average specifications was then constructed. The main differences found between the two nets concerned the mesh size, the height and the non-existence of floats on the tangle nets. Such differences are a result of the depth of the fishing ground, with tangle nets of smaller mesh sizes being used in shallower waters. All specifications correspond to the commercial practice. Inner mesh size was measured between opposite knots when fully stretched, taking a sample of 25 randomly chosen meshes per net, using a steel ruler and light manual force to stretch the mesh. All nets were made of a polyamide monofilament light green twine, with a diameter of 0.25 mm and 0.30 mm for the tangle nets and gill-nets, respectively. The tangle nets were on average 53 m long and 1.25 m high, while the gill-nets were smaller in length (45 m) but greater in height (2.6 m). The hanging ratios of these nets were 0.55 and 0.50 on the head rope and 0.57 and 0.54 on the lead rope, for the tangle nets and gill- nets, respectively. In the case of the gill-nets floatation was given by 32 PVC floats (24 gf) in each panel.

For the fishing trials two experimental fleets were constructed, consisting of 10 randomly distributed panels of each mesh size: 40, 45 and 50 mm for the tangle nets and 40, 50, 60, and 70 mm for the gill-nets, respectively. A total of 82 fishing trials were carried out in spring and summer 2004, off the south-eastern coast of the Algarve (on the Monte Gordo Bay), at depths ranging from 5 to 15 m (Figure 1, to the north of zone A):

Tangle nets: 41 (20 in spring and 21 in summer) fishing trials were made onboard commercial vessels. The adopted soak time was that used by the commercial fishermen, setting the nets in the late afternoon and retrieving them the following morning immediately after the sunrise (about 10 to 12 hours of fishing).

Gill-nets: 41 (20 in spring and 21 in summer) fishing trials were carried out on board the RVs 'Tellina' and 'Diplodus'. The adopted soak time was that used by the commercial fishermen, setting the nets 3 to 4 hours before the sunrise and pulling them 1 to 2 hours after sunrise (4 to 6 hours of fishing).

Three other fleets consisting of 15 panels of 50 mm gill-nets were also constructed, aiming to compare spatial differences in terms of catch size–frequency distributions and mean sizes. These were simultaneously fished in 3 zones: (A) eastern; (B) central; and (C) western (Figure 1). Fishing

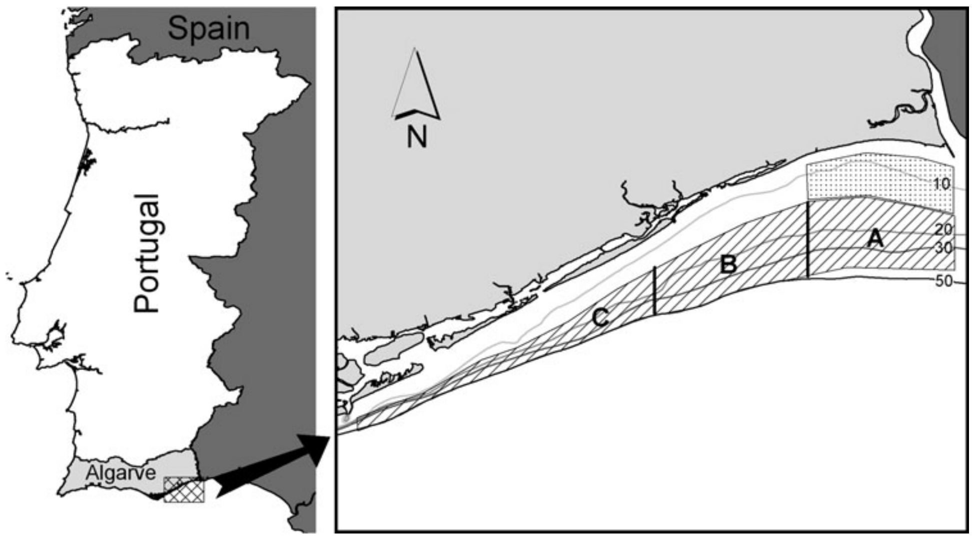

Fig. 1. Areas sampled for *Dicologoglossa cuneata* by tangle nets (dotted) and gill-nets (dashed) off the southern coast of the Algarve (Portugal). A, B and C are sub-areas.

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operations were conducted during spring 2005, at depths ranging from 15 to 40 m. The fishing trials were carried out on board commercial vessels, and the fishing regime adopted was that described above for the gill-nets. A total of 45 net sets were made (15 in each zone).

All specimens caught were sorted by gear and mesh size. The total length (TL) was measured to the nearest lower millimetre. A macroscopic seven stage scale of gonad maturation (for details see Laevastu, 1971) was used and all individuals assigned to stages from 4 to 7 were considered mature.

Estimation of gill-net selectivity

The gill-net selectivity was estimated by means of the GILLNET© Software (Constat, 1998) that is based on the SELECT method (Share Each LEngthclass's Catch Total). This is a general statistical model that estimates gill-net selection curves (i.e. retention probabilities) from comparative gill-net catch data. In this method, the expected catch proportions are fitted to the observed catch proportions using maximum likelihood, under the assumption that catches are Poisson random variables (Millar, 1995). Further details of the SELECT and GILLNET methods are provided in a number of publications (Millar & Holst, 1997; Millar & Fryer, 1999). Goodness of fit was evaluated by comparison of deviances and examination of the deviance residuals plots. The model providing the best fit, corresponding to the smallest value for the ratio deviance/degrees-of-freedom, was adopted. Data used for the selectivity study were those collected in zone A (Figure 1).

Data analysis

The maturity data for females were fit to the logistic function:

$$P = \frac{a}{1 + e^{[-(TL - TL_{50})/b]}}$$

where, P is the proportion mature in each size-class, b is a parameter controlling the shape of the curve and TL_{50} is the size at 50% maturity. The parameters were estimated by fitting a general linear model with binomial variance function and the logit link using S-PLUS 4 (Mathsoft, 1997), as the experimental fishing took place just during spring and summer 2004. In order to cover a wider period samples for the maturity study were also obtained from the local commercial landings from spring 2004 to summer 2006.

In order to investigate spatial differences along the study area, the catch size–frequency distributions and mean sizes for the 50 mm mesh size gill-net catches (pooled data) from 3 zones were compared. The Kolmogorov–Smirnov test was used to compare the catch size–frequency distributions and the Student's t-test was applied to compare the mean sizes. Catches in weight from the different gears and mesh sizes were compared by means of the Wilcoxon's matched pair test (Snedecor & Cochran, 1989). Testing was performed with a 95% interval of confidence.

RESULTS

Sex-ratio, spawning season and length at first maturity

A total of 3524 specimens were sampled, of which 1912 were females, 1510 males and the remainder undetermined. The overall sex-ratio (F/M) was 1.33, but males dominate until the 16 cm size-class. Female dominance was particularly evident for the larger sizes (≥24 cm size-class) showing a sex-ratio of 2.4–3.0.

The spawning period ranged from December to June, showing two peaks, respectively in March and May (Figure 2). The obtained maturity ogive showed that 50% of females were sexually mature (TL_{50}) at a total length of 18.51 cm (Figure 2), whereas the observed minimum size of maturity was 16.6 cm.

Catches and fishing yield

Tangle nets: a total of 6409 wedge soles were caught by the tangle nets, ranging in size from 11 to 23 cm, 14 to 24 cm and 14 to 25 cm for the 40, 45 and 50 mm mesh sizes, respectively (Figure 3). The Kolmogorov–Smirnov test showed significant differences between all catch size–frequency distributions. Although most specimens were wedged, there was a small fraction (<5%) that was entangled (held in the net by maxillaries, without necessarily penetrating the mesh). However, no clear relationship with mesh size was noted for the tangled specimens. The overall mean total lengths were 16.58 (±1.04), 17.79 (±1.20) and 18.90 (±1.50) cm for the 40, 45 and 50 mm nominal mesh sizes, respectively (Table 1). All comparisons of mean total lengths between the different mesh sizes showed significant differences. The modal classes corresponding to the three catch size distributions were 16.0–16.9, 17.0–17.9 and 18.0–18.9 cm, for the 40, 45 and 50 mm nominal mesh sizes, respectively. The percentage of undersized fishes (<15 cm TL) caught by the different nets varied between 7.4% and 0.1% as mesh size increase, whereas the percentage of specimens caught under the size at first maturity ranged from 96.7% to 55.0%. Both proportions of undersized and undersize at first maturity, decreased with mesh size increase (Table 1). The mean fishing yields decreased with the mesh size increase, ranging from 3.341 to 1.536 kg/750 m net. The results of the Wilcoxon's matched pairs test showed significant differences for the fishing yields comparisons between all mesh sizes. As regards the comparison between the two seasons, testing showed differences for most cases, the exception being the case of the mean total lengths for the 50 mm net. In terms of the percentages of fish under the minimum legal size and under the size at first maturity for females, the results were similar for both seasons (Table 1).

Gill-nets: a total of 3024 fish were caught, with size distributions ranging from 12 to 21 cm, 13 to 24 cm, 14 to 26 cm and 15 to 28 cm for the 40, 50, 60 and 70 mm mesh sizes, respectively (Figure 4). The Kolmogorov–Smirnov test showed significant differences between all catch size–frequency distributions (Table 1). The mean total lengths were 17.58 (±1.55), 17.99 (±1.70), 20.08 (±1.77) and 21.80 (±2.00) cm for the 40, 50, 60 and 70 mm nominal mesh sizes, respectively (Table 2). The comparisons of mean total lengths observed for all mesh sizes showed significant differences. The modal classes corresponding to the four catch size distributions were 16.0–16.9, 18.0–18.9, 19.0–19.9 and 21.0–21.9 cm, for the 40, 50, 60 and 70 mm nominal mesh sizes, respectively. The percentage of undersized fish caught, ranged from 4.1% to 0% with the mesh size increase, whereas the percentage of specimens caught under the size at first maturity ranged from 71.3% to 5.1% (Table 1). The mean fishing yields varied between 1.533 and 0.374 kg/750 m for the 40 and 70 mm mesh size nets, respectively. The results of the Wilcoxon's matched pairs test showed significant differences between the fishing yields for all mesh sizes. As in the case of the tangle nets, the comparisons between the records for the two seasons showed significant differences. Again, the exception being the case of the fishing yield, which were similar for the two smaller mesh sizes and respective mean total lengths. As for the tangle nets similar results were observed for both seasons in terms of the percentages of fish under the minimum legal size and under the size at first maturity for females (Table 1).

Different zones: the comparisons between the observed catches for the 50 mm mesh size gill-net for the 3 zones, showed significant differences both in terms of the size–frequency distributions and mean sizes (Table 1). The mean total lengths were 18.34 (±1.48), 20.53 (±1.58) and 21.45 (±1.44) cm, while the modal classes corresponding to the catch size distributions for the 3 zones were 18.0–18.9, 20.0–20.9 and 21.0–21.9 cm, for the A (eastern), B (central) and C (western) zones, respectively (Table 1; Figure 5).

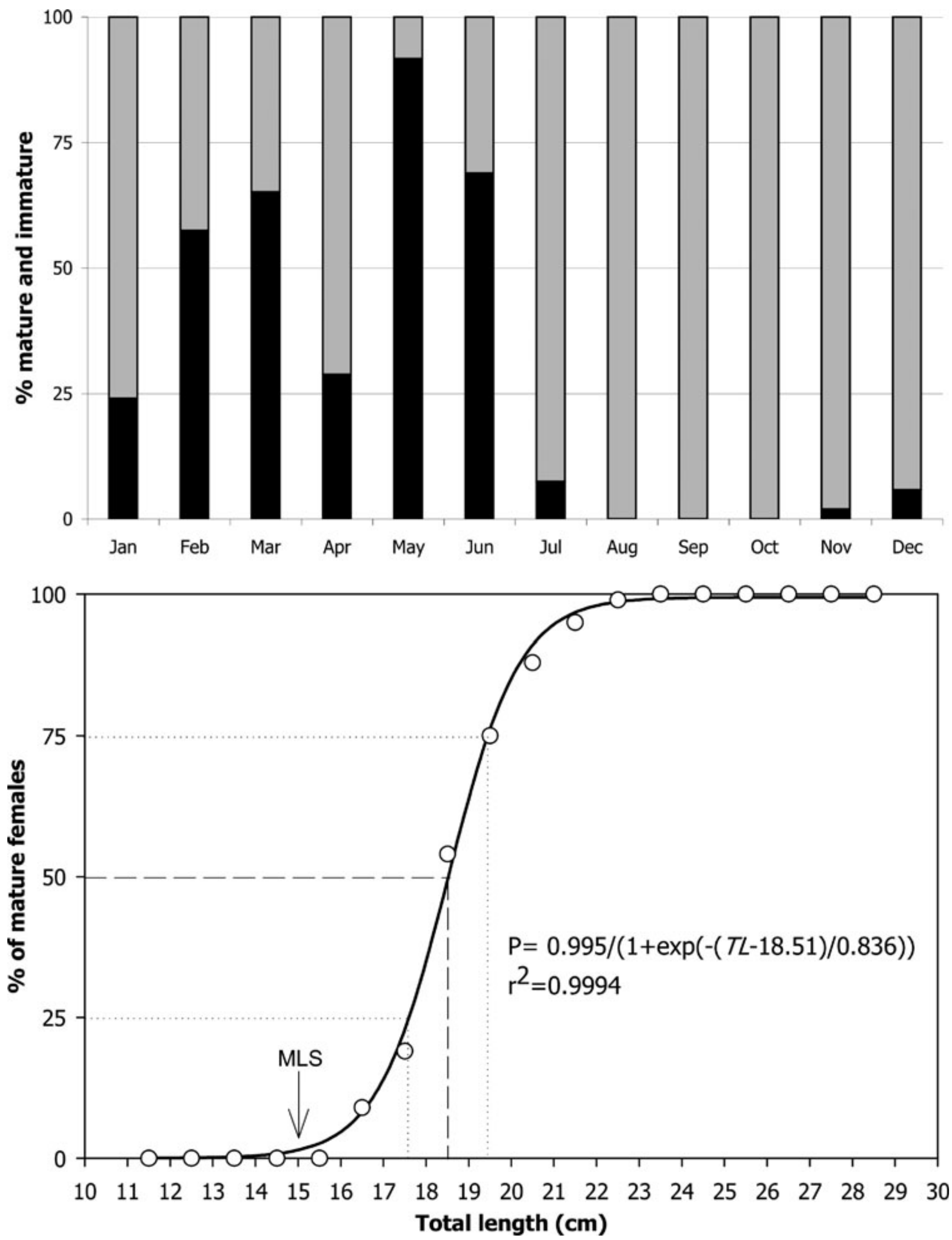

Fig. 2. Top: percentage of mature and immature females of *Dicologoglossa cuneata* by month off the southern coast of the Algarve (Portugal). Bottom: ogive of 1st maturity for females. MLS, minimum landing size.

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Different size distributions for tangle nets and gill-nets of the same mesh size (40 and 50 mm) were obtained in the eastern part of the study area.

Tangle net and gill-net selectivity

The results of the SELECT model fits for all models are given in Tables 2 & 3. In both cases the log-normal model with effort proportional to mesh size gave the best fit, as indicated by the ratio deviance/degrees-of-freedom and the analysis of the residual plots which showed that the fit is satisfactory.

The observed catch size–frequency distributions and the fitted log-normal selectivity curves are shown in Figures 3 & 4. The estimated modal lengths and spreads were 15.87 (±1.50), 17.85 (±1.69) and 19.83 (±1.88) cm, for the 40, 45 and 50 mm tangle nets mesh sizes; and, 14.59 (±2.86), 18.24 (±3.58), 21.87 (±4.30) and 25.53 (±5.01) cm, for the 40, 50, 60 and 70 mm gill-nets mesh sizes. While all the estimated

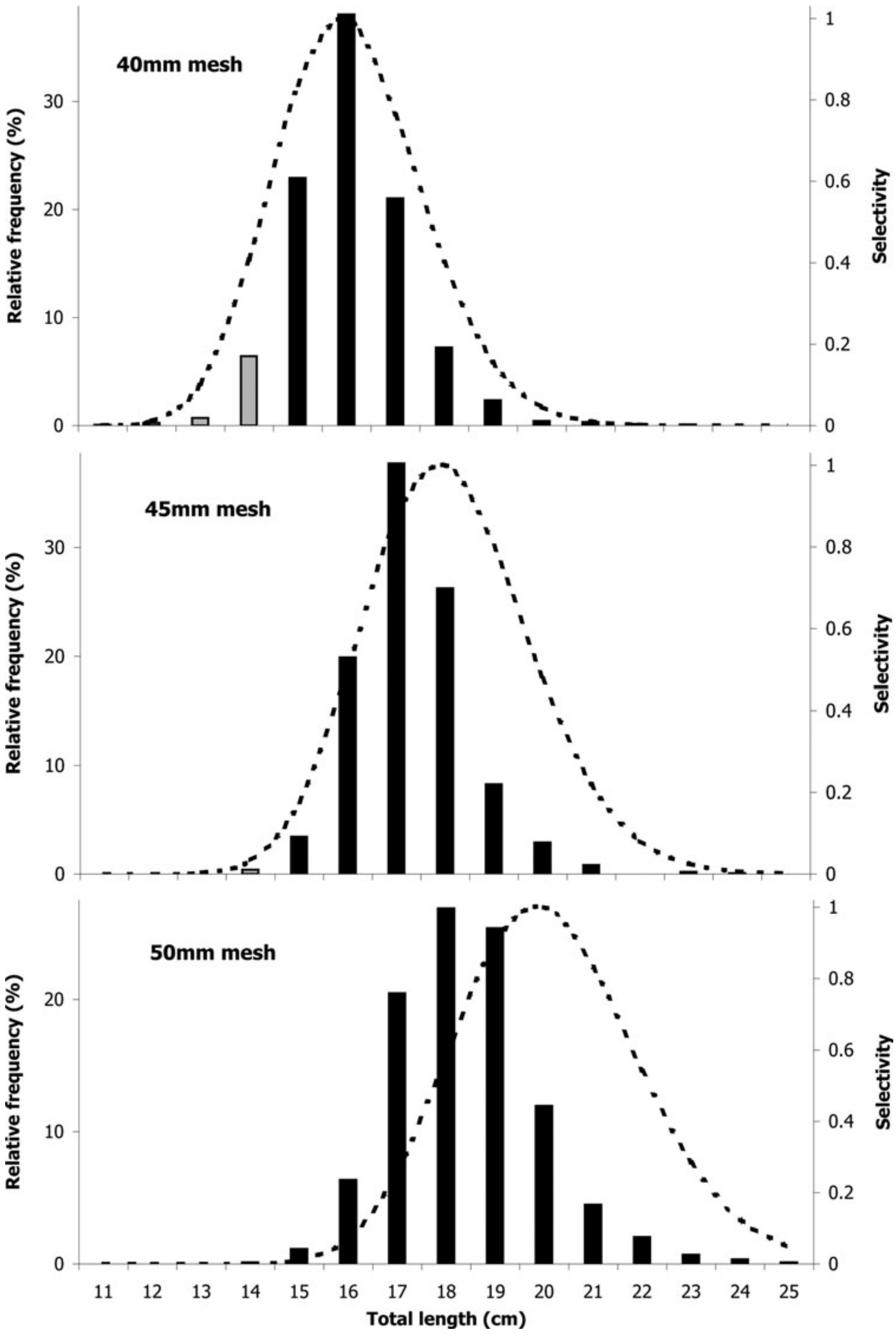

Fig. 3. Observed catch size–frequency for *Dicologoglossa cuneata* and fitted selectivity curves based on the log-normal model, for tangle nets of different mesh sizes (40, 45 and 50 mm) in the south-eastern Algarve waters. Grey bars corresponding to undersized specimens.

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Table 1. Summary table for several aspects of the tangle and gill net *Dicologoglossa cuneata* catches in zone A (eastern—Monte Gordo Bay), for the different mesh sizes and seasons (Sp, spring; S, summer). MLS, minimum landing size (15 cm of total length); S1stMat, size at first maturity for females; SD, standard deviation.

Nominal mesh size (mm)	**Tangle nets**			
	40	**45**	**50**	
Overall number of fish caught (Sp and S)	2924 (1627 and 1297)	2209 (1157 and 1052)	1276 (760 and 516)	
Overall mean total length (cm) (±SD)	16.58 (±1.04)	17.79 (±1.20)	18.90 (±1.50)	
Sp	16.60 (±0.71)	17.84 (±1.33)	18.97 (±1.56)	
S	16.56 (±1.22)	17.73 (±1.04)	18.80 (±1.40)	
Overall modal class of the catch (cm) (Sp and S)	16.0-16.9	17.0–17.9	18.0–18.9 (17.0–17.9 and 18.0–18.9)	
Overall % of specimens < MLS (Sp and S)	7.4 (7.8 and 7.0)	0.4 (0.7 and 0.1)	0.1 (0.2 and 0)	
Overall % of specimens < S1stMat (Sp and S)	96.7 (96.2 and 97.2)	87.7 (85.2 and 90.5)	55.0 (54.1 and 56.2)	
Overall mean fishing yield (±SD) (kg/500 m net)	3.341 (±2.320)	2.418 (±1.579)	1.536 (±1.133)	
Sp	3.940 (±2.158)	2.607 (±1.455)	2.393 (±1.392)	
S	2.988 (±2.402)	2.307 (±1.681)	1.033 (±0.515)	
Nominal mesh size (mm)	**Gill-nets**			
	40	**50**	**60**	**70**
Overall number of fish caught (Sp and S)	1459 (843 and 616)	1009 (490 and 518)	367 (188 and 179)	189 (93 and 96)
Overall mean total length (cm) (±SD)	17.58 (±1.55)	17.99 (±1.70)	20.08 (±1.77)	21.80 (±2.00)
Sp	17.63 (±1.59)	18.01 (±1.79)	20.10 (±1.80)	21.81 (±2.00)
S	17.52 (±1.49)	17.97 (±1.62)	20.07 (±1.74)	21.78 (±2.01)
Overall modal class of the catch (cm) (Sp and S)	16.0-16.9	18.0–18.9	19.0–19.9	21.0–21.9
Overall % of specimens < MLS (Sp and S)	2.8 (3.0 and 2.65)	4.1 (4.3 and 3.9)	0.2 (0.3 and 0.2)	0.0
Overall % of specimens < S1stMat (Sp and S)	71.3 (70.0 and 73.0)	62.2 (61.8 and 62.8)	17.3 (16.7 and 17.6)	5.1 (5.1 and 5.0)
Overall mean fishing yield (±SD) (kg/500 m net)	1.533 (±0.855)	1.107 (±1.061)	0.564 (±0.340)	0.374 (±0.245)
Sp	1.813 (±0.895)	1.410 (±1.056)	0.595 (±0.291)	0.440 (±0.300)
S	1.369 (±0.812)	0.929 (±1.054)	0.546 (±0.374)	0.333 (±0.240)

selectivity curves are uni-modal, only those corresponding to the gill-nets became wider with increasing mesh size.

DISCUSSION

One of the priorities for fisheries managers is to promote the use of selective fishing gears. Tangle nets and gill-nets are highly size selective fishing gears, that generally catch fish in a relatively narrow size-range, consisting of few or no fish with lengths 20% less than or 20% greater than the optimum length of a particular mesh size (Hamley, 1975). Furthermore, as mentioned by Fonseca *et al.* (2005) an advantage of gill-nets is that by a careful choice of the mesh size it is not only possible to tackle the problem of catch of undersized fish, but also to control the catch of bigger fish in situations where recruitment overfishing is an issue. Thus, numerous selectivity studies have been carried out worldwide, aiming to define the use of minimum mesh size for fisheries management purposes. However, to the authors' best knowledge, the present study is one of the few concerning gill-net selectivity and the first concerning tangle net selectivity for the wedge sole. Moreover, it is the first study comparing tangle net and gill-net wedge sole selectivity and catches for the same area, aiming to help management of the local fishery.

The species was caught in slightly different size-ranges by the different mesh sizes and net type used in the fishing trials. In fact, the size-range of the catch increased with the mesh size for the gill-nets, but became narrower for the tangle nets. As suggested by Santos *et al.* (2003), the first scenario is the case when, while most specimens were wedged (held tightly by a mesh around the body or gilled), some significant proportion of the catches within each mesh size were entangled. Nevertheless, the catch size distributions for both net types clearly showed that there was size selectivity, with an increase in mean fish size and modal classes with greater mesh size. As a consequence, the percentage of undersized specimens and the percentage of fish under the size at 1st maturity decreased with increasing mesh size. When a species is caught mainly by wedging or by being gilled, the estimated selectivity curves are bell-shaped (Hamley, 1975). In this study the estimated selectivity curves were normal in shape uni-modal, although wedging, gilling and tangling were all occurring. From the management perspective, when the three methods of retention occur, we could face a problem that cannot be resolved by a minimum mesh size regulation. However, in the present case, entangling was much less important than wedging, which accounted for the majority of the catch (>85%). Moreover, entangling occurred mainly in the case of gill-nets and no relation between mesh size and fish size was noted. Thus, for management purposes this is not a source of major concern.

The comparative catch and yields of different mesh sizes depend on the size distribution of the population available in the fishing area. In the present study the catches were pooled over two seasons and therefore should closely reflect the size-range captured by the commercial fleet and respective fishing yields. For the tangle nets the estimated curve for the 40 mm nominal mesh overlapped the observed catch size–frequency distribution. However, with increasing mesh

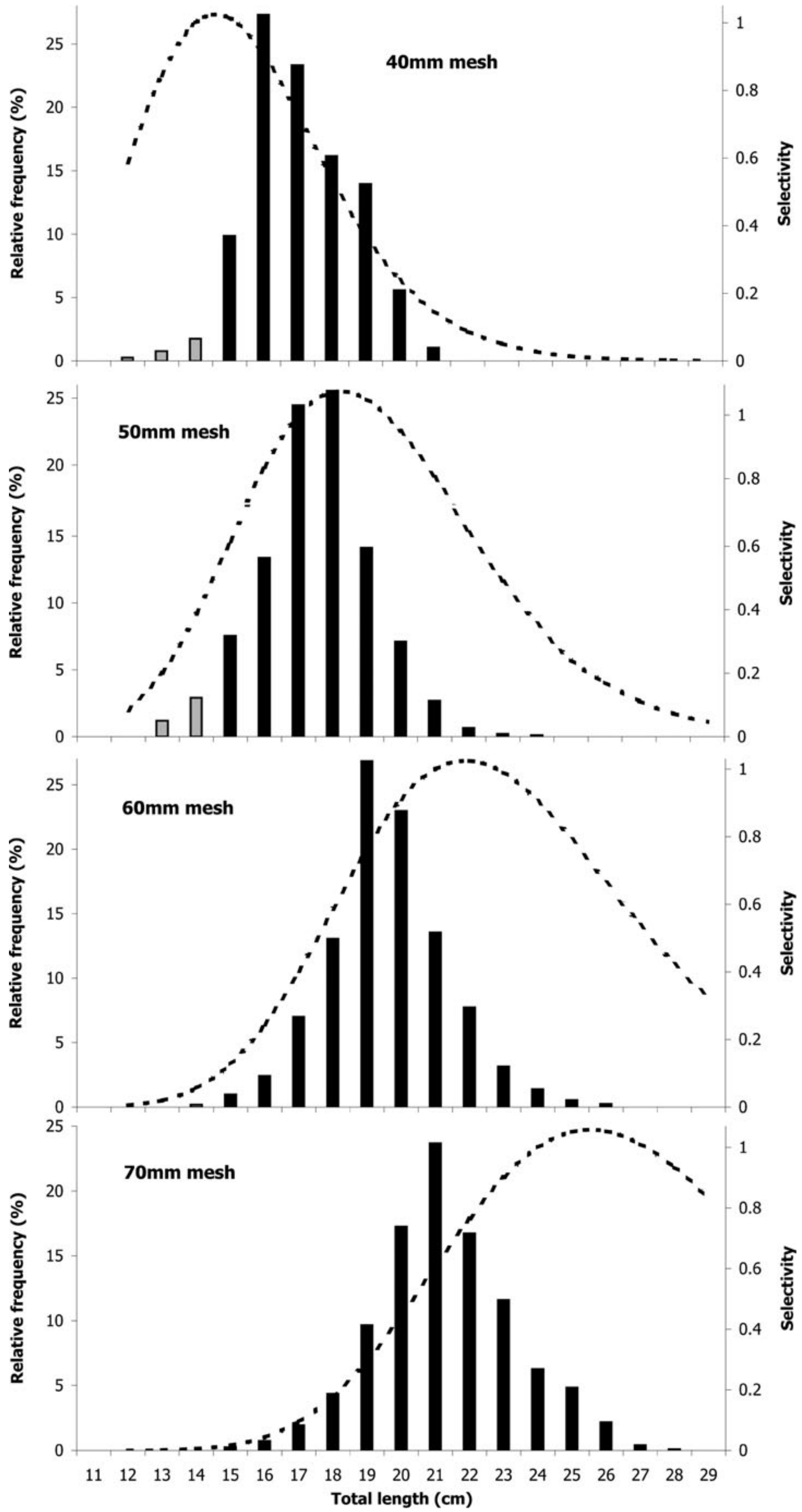

Fig. 4. Observed catch size–frequency for *Dicologoglossa cuneata* and fitted selectivity curves based on the log-normal model, for gill-nets of different mesh sizes (40, 50, 60 and 70 mm) in the south-eastern Algarve waters. Grey bars corresponding to undersized specimens.

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Table 2. Results of fitting different models with the SELECT method for the estimation of tangle net selectivity for *Dicologoglossa cuneata*.

	Model	df	Equal fishing power			Fishing power α mesh size		
			Parameters	Model deviance	*P* value	Parameters	Model deviance	*P* value
Normal location	Spread α m_j	28	$k_1 = 0.3958\ (\pm 0.0008)$ $k_2 = 1.6444\ (\pm 0.0251)$	225.20	<0.001	$k_1 = 0.3993\ (\pm 0.0008)$ $k_2 = 1.6524\ (\pm 0.0254)$	229.09	<0.001
Normal scale	Fixed spread	28	$k = 0.4004\ (\pm 0.0008)$ $\sigma = 0.0365\ (\pm 0.0005)$	265.55	<0.001	$k = 0.4037\ (\pm 0.0008)$ $\sigma = 0.0363\ (\pm 0.0005)$	266.32	<0.001
Gamma	Spread α m_j	28	$\alpha = 117.6219\ (\pm 3.3364)$ $k = 0.0034\ (\pm 0.0001)$	189.33	<0.001	$\alpha = 118.6219\ (\pm 3.3663)$ $k = 0.0034\ (\pm 0.0001)$	189.33	<0.001
Log-normal	Spread α m_j	28	$\mu = 2.7730\ (\pm 0.0021)$ $\sigma = 0.0933\ (\pm 0.0014)$	163.65	<0.001	$\mu = 2.7817\ (\pm 0.0021)$ $\sigma = 0.0933\ (\pm 0.0014)$	163.65	<0.001

size, there was a shift to the right of the fitted selectivity curves in relation to the corresponding catch distributions. Thus, for the larger mesh sizes, the modal lengths of the selectivity curves based on the SELECT model were generally greater than those of the observed catch size–frequency distributions. The modes of the estimated selectivity curves were 0.96 smaller and 1.02 and 1.07 cm greater than those of the length–frequency distributions of the catch, for the 40, 45 and 50 mm nominal mesh sizes, respectively. In the case of the gill-nets only the left arm of the estimated curve for the 50 mm nominal mesh overlapped the observed catch size–frequency distribution. Again for the larger mesh sizes (60 and 70 mm), the modal lengths of the selectivity curves were greater (1.12 and 1.19, respectively) than those of the observed catch size–frequency distributions. According to Santos *et al.* (2003) this is probably due to the fact that the Baranov principle of geometric similarity (i.e. the modal lengths are proportional to mesh size) was observed for all but one of the models fitted using the SELECT method in the GILLNET software. This may also contribute to greater modal lengths than expected, especially in the case of overlapped catch distributions.

The present study has shown that the wedge sole are caught in distinct size-ranges by the different mesh sizes, but with similar size-ranges and size distributions among tangle nets and gill-nets of the same mesh size. In fact, the differences found were mostly due to the availability of larger quantities of smaller fish in the eastern area, rather than a selectivity issue. Although all mesh sizes evaluated showed a low percentage of specimens caught under the minimum legal size, all but the 70 mm mesh size gill-net caught a high percentage of juveniles.

However, the catch per unit of effort of the two larger mesh sizes was very low. The tangle nets were more efficient than the gill-nets for catching the wedge sole. In fact, the fishing yields provided by the tangle nets were 39% and 118% higher than those observed for the 50 and 40 mm mesh sizes gill-nets, respectively. The fact behind the latter results was probably related to the way the two gears fish, as the tangle nets tend to move and have a larger area of the panel close to the bottom, while the gill-nets tend to stand more vertically due to the existence of floats. As a result, during spring when the sea is generally rougher than in summer, the tangle nets sweep the bottom providing better fishing yields.

It has been observed that flatfish spawning grounds are species-specific and their position in the bathymetric gradient results from a combination of its environmental preferences, namely related with the estuarine dependence. Despite greater eurythermia and less sensibility to hydrologic variations than adults, the relatively low estuarine dependence of wedge-sole juveniles constricts their nursery grounds to areas near to estuarine environments (Lagardère, 1982). According to García-Isarch *et al.* (2006) the shallow waters of the basin of the Guadiana River is a major spawning and nursery area for the species on the southern Iberian coast. Our results corroborate these findings, as most juveniles were caught in shallow waters closer to the Guadiana estuary. Moreover, the largest adults were found on deeper waters off the continental shelf, which indicates that the demographic structure of the wedge sole is depth-related. In addition, an increase in the mean size of the wedge sole caught in the 50 mm mesh size gill-nets was observed from east to west, together with a decrease in the size-range and a shift of the catch distribution towards the right.

The wedge sole gonad maturation begins earlier in warmer regions where it is considered a winter spawner in Argelia (Marinaro *et al.*, 1979) and Atlantic Moroccan coast (Belghyti, 1990). In the Gulf of Cádiz, Jiménez *et al.* (1998) reported a spawning period similar to that found in the present study. According to Dinis (1986) off the west Portuguese coast the peak spawning occurs between March and June, while in the Bay of Biscay it is classified as a summer spawner (Lagardère, 1982).

As regards to the female size at first maturity, it was reported to be 14 cm in the Bay of Biscay (Lagardère, 1982), 17 cm on the west coast of Portugal (Dinis, 1986), whereas in the Gulf of Cádiz it is 18.2 cm (preliminary results by Jiménez *et al.*, 1998). Our results corroborate the latter figure of female size at first maturity, as well as a latitudinal gradient (increase with latitude) along its distribution range along the north-eastern Atlantic European waters.

As there is a gap between the current minimum legal size (15 cm) and the estimated size at first maturity for females, it would be advisable to increase it to at least 18 cm. The current minimum mesh size (60 mm) does not provide fishing yields that would sustain a target fishery. On the other hand, the tangle nets are much more species selective than the gill-nets, as they fish much closer to the substrate, catching mostly benthic species and a reduced number of demersal species (IPIMAR, unpublished data). Thus, if managers are willing to enhance the wedge sole fishery, it would be advisable to use tangle nets with a minimum mesh size of 50 mm, which have a selectivity peak at 20 cm and LT25 at approximately 18 cm. Moreover, a time–area closure

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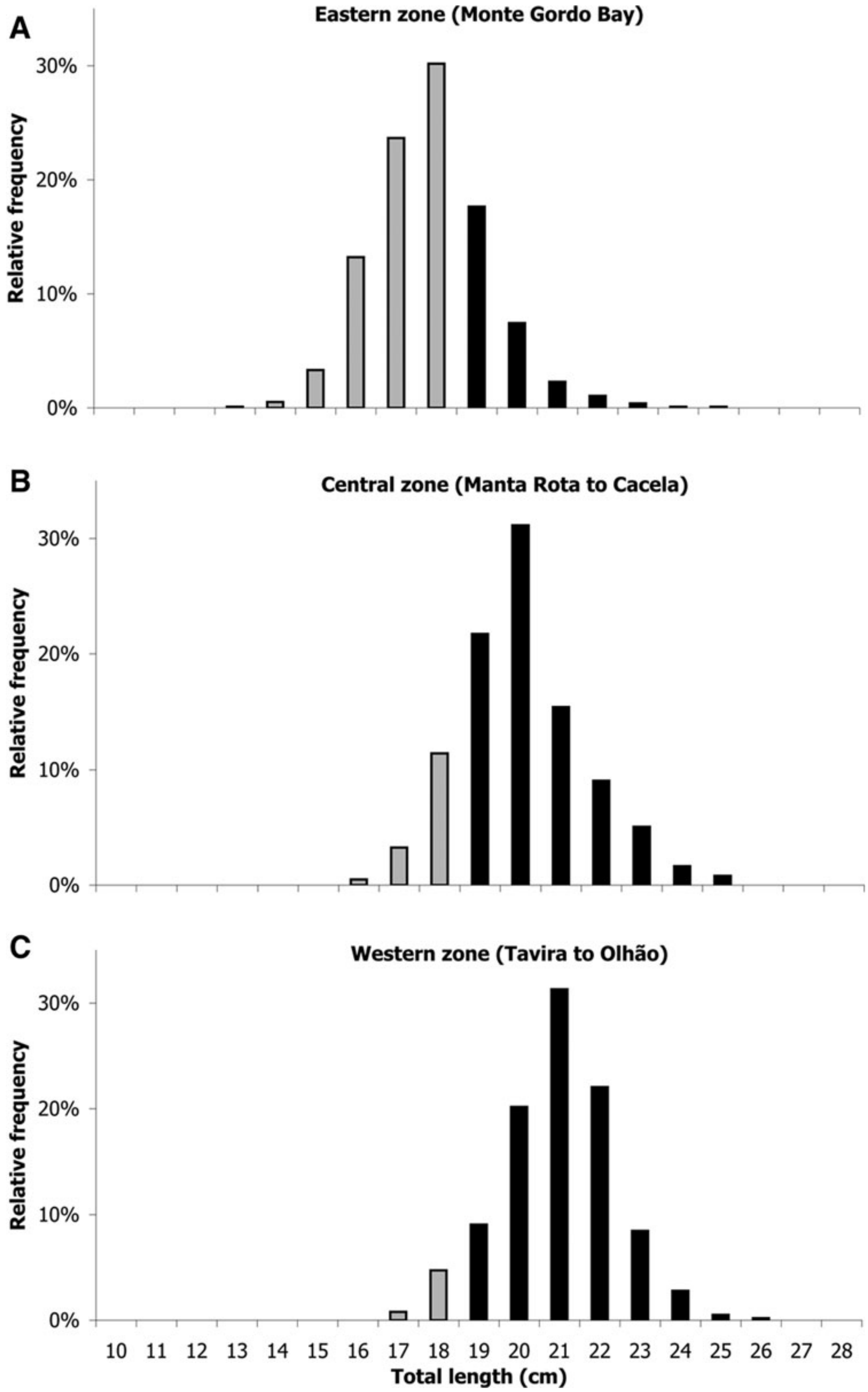

Fig. 5. Observed relative size–frequency (%) of *Dicologoglossa cuneata* caught with a 50 mm mesh size gill-net in 3 areas off the Algarve coast: (A) eastern area; (B) central-eastern area; (C) central-western area. Grey bars corresponding to relative size–frequency (%) below the size at 1st maturity for females.

should be implemented, between February and May in the neighbouring shallow waters off the Guadiana river mouth. These precautionary measures would ensure that a greater part of the catch would consist of wedge sole larger than the estimated size-at-maturity, allow spawning and provide acceptable fishing yields. Moreover, it would contribute to the goals of conservation and sustainability of both the fishing resource and the local artisanal set nets fishery. However, to assess the impact on the fishery and wedge sole population of such management measures, an assessment of stock status, level of exploitation or Y/R should be conducted.

Table 3. Results of fitting different models with the SELECT method for the estimation of gill-net selectivity for *Dicologoglossa cuneata*.

Model		df	Equal fishing power			Fishing power α mesh size		
			Parameters	Model deviance	*P* value	Parameters	Model deviance	*P* value
Normal location	Fixed spread	82	$k = 0.3497$ (± 0.0009) $\sigma = 3.5557$ (± 0.0412)	1577.76	<0.001	$k = 0.3602$ (± 0.0010) $\sigma = 3.6814$ (± 0.0447)	1783.42	<0.001
Normal scale	Spread α m_j	82	$k_1 = 0.37812$ (± 0.0009) $k_2 = 0.0648$ (± 0.0007)	1751.86	<0.001	$k_1 = 0.3890$ (± 0.0009) $k_2 = 0.0637$ (± 0.0006)	1760.87	<0.001
Gamma	Spread α m_j	82	$\alpha = 31.5195$ (± 0.6221) $k = 0.0121$ (± 0.0003)	1557.24	<0.001	$\alpha = 32.5195$ (± 0.6406) $k = 0.0121$ (± 0.0003)	1557.24	<0.001
Log-normal	Spread α m_j	82	$\mu = 2.7146$ (± 0.0029) $\sigma = 0.1849$ (± 0.0020)	1508.64	<0.001	$\mu = 2.7488$ (± 0.0031) $\sigma = 0.1849$ (± 0.0020)	1508.64	<0.001

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