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Research Article

Competition between static gear of the small-scale fisheries in Algarve waters (southern Portugal)

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Abstract

Parallel fishing trials with 0.30 mm diameter monofilament gill nets and longlines using small hooks were carried out in the Algarve (southern Portugal) over a one-year period, 1997-1998, with the objective of comparing species composition, catch rates, discards and size ranges. Four hook sizes of MUSTAD brand, round bent, flatted sea hooks (numbers 15, 13, 12 and 11) and four mesh sizes of 50, 60, 70, and 80 (stretched mesh) (nominal bar length) of gill nets were used in the trials. Overall, 84 species were caught, with gill nets taking 71 species and longlines 54 species and with 41 species caught by both gear types. The amount of discarding was higher for gill nets than for longlines. The catch species composition differed between the two gear types, with the commercially valuable sea breams dominating the longline catches whereas small pelagics were relatively more important in the gill nets. Multivariate analysis showed a clear separation between the different sizes of the two gear types both in terms of numbers and weights per species. Algarve gill netters and longliners fish the same species assemblage on the same fishing grounds, but have clearly different impacts in terms of catch species composition, catch rates and sizes. This information will be useful for the improved management of these small-scale, multi-species, multi-gear fisheries, where different gear types compete for scarce resources. In particular this study provides a basis for a more rational allocation of licenses and control of fishing effort.

Keywords: Gill nets; Longlines; Artisanal fishery; Catches; Gear competition; Portugal.

Introduction

Small-scale fisheries are of great importance in Portugal, with gill nets, trammel nets and longlines being the most widely used gears in the small-scale fisheries of the Algarve (ERZINI *et al.,* 2003, 2006). In 2002 for example, 871 longline, 611 trammel net and 506 gill net licences were issued in the Algarve (pers. comm. DGPA). Fishing vessels generally have a number of different gear licences, alternating between gear according to the availability of resources. Renewal of licenses is based on proof of sale at auction of a minimum number of landings in the previous year. However, the total number of licenses of each gear is not based on any scientific study of the impact of the different gear types on the resources.

Although there are various studies dealing with the major features of the small-scale fisheries in the Algarve waters (gill net catch species composition: MARTINS *et al.,* 1992; catch rates: MARTINS *et al.,* 1992; gill net selectivity: SANTOS & MONTEIRO, 1995; SANTOS *et al.,* 1995; SANTOS 1997; SANTOS *et al.,* 1998; hook catch species composition, rates and selectivity: ERZINI *et al.,* 1996a,b, 1997a, 1998a, 1998b, 1999; ghost fishing: ERZINI *et al.,* 1997b, 2008; discards: GONÇALVES *et al.,* 2007. 2008), there is a lack of information on the overlap of fixed gear types, competing for the same resources, with important socio-economic consequences (ANONYMOUS, 1995; DURAND *et al.,* 1991). This is especially true for artisanal fishers, generally characterised by a lower income when compared with those involved in industrial fisheries. The analysis of factors causing variation in the degree of vulnerability of different species and size groups to different gear types has long been recognised as important for the development of optimal harvesting strategies and the rational exploitation of living resources (CLARK, 1960).

In the present study, multivariate techniques were used to quantify species composition and gear competition in the small-scale fisheries in the Algarve waters (southern Portugal) from samples collected at different fishing grounds and seasons during 1997-1998 with four mesh sizes of gill nets and four hook sizes of longlines. Information on species composition, overlap, catch rates, and commercial vs. non commercial components of the catches will be useful for the rational management of the demersal and inshore fisheries resources in the Algarve waters, which are managed using technical measures concerning, among other things, the minimum mesh sizes used, minimum landing sizes and gear characteristics determining effort per setting of the gear (e.g. maximum length of gill nets). In particular, these results can provide the basis for improved licensing schemes, allowing adjustment of multi-gear fishing effort to the available resources.

Material and Methods

Fishing grounds

Experimental fishing was conducted in the central-western part of the Algarve (southern Portugal: Fig. 1) in 1997-1998 using gill nets and longlines, at depths between 15 and 60m. Compared to the eastern part of the Algarve that is dominated by soft bottom, the central-western part consists of a mixture soft bottom and natural reefs, along with artificial reefs.

Sampling design

Two chartered commercial small-scale fishing vessels were used (boat length 6.2 m; engine horsepower 60 HP). Sampling depths ranged from 15 to 60 m and fishing started in July 1997 and ended in June 1998. Overall, 40 experimental fishing trials were conducted simultaneously in the same area with gill nets and longlines (10, 10, 9 and 11 trials, for both gear types in summer 1997, autumn 1997, winter 1997-1998 and spring 1998, respectively). Each fishing trial consisted of one gill net and one longline set.

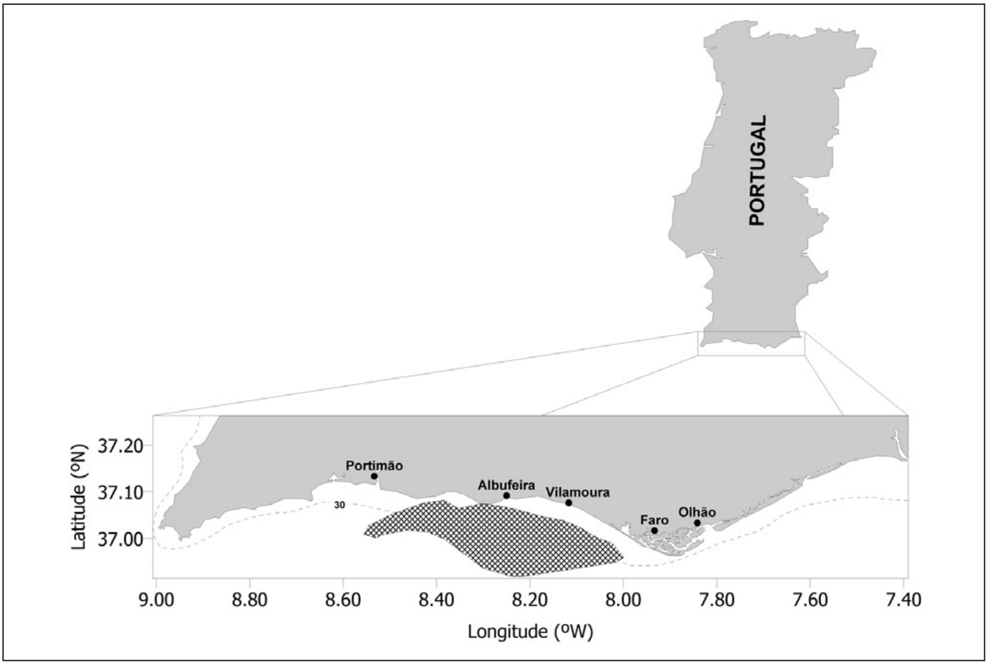


Fig. 1: The sampling area (hatched).

Four hook sizes of MUSTAD round bent flatted hooks were used (hook numbers: 15, 13, 12 and 11; 500 hooks per size), with the number 13 hook being the most commonly used in Algarve waters. Gill nets of 50, 60, 70 and 80 mm stretched mesh were used (750 m of each mesh size), with 60 and 80 mm meshes being the minimum legal sizes depending on the season and fishing area. Except for hook number 15 and gill nets of 50 mm stretched mesh size, all other hook and mesh sizes are used by the local commercial fishers. All gear used was similar to that used by local fishers. For a detailed technical description of the fishing gear types used see ERZINI *et al.* (2003).

The experimental gill nets consisted of approximately 250 m sections of each mesh size in a random sequence, with each section separated by a 20 m rope. The total length of gillnets was approximately 3220 m (12 fleets of 250 m, with 11 ropes of 20 m between them). With respect to longlines, five longline tubs were used, each containing a longline with four 100-hook sections of the four hook sizes used. The total length of the longline of 2000 hooks was approximately 3400 m.

Both the longlines and the gill nets were fished on the bottom with anchors at both ends in the case of the gill nets and weights at both ends of the longline and at regular intervals along the longline. The minimum distance between gill nets and longlines was less than 0.5 km and the maximum was approximately 2 km.

The fishing grounds were selected by the fishers in traditional fishing areas in order to ensure the highest possible catches of the most commercially important species participating in the local gill net and longline fisheries. Although the two commercial fishing vessels were free to choose the fishing ground, they were required to always fish the two different gear types in close proximity (between 0.5 and 2 km distance). Normal fishing practices were followed, with the gear types fished one to three hours either before sunrise or sunset and retrieved one to two hours after sunrise or sunset, respectively. The standard bait was a piece of sipunculid worm. After hauling, the catch was removed and separated by hook and mesh size. The number of specimens and the total weight per species were recorded.

Data analysis

Consequently, the following measures were computed for each gear: number of species, Shannon-Wiener diversity index H', Margalef's D index of richness and Pielou's J measure of evenness (MAGURRAN, 1988). In addition, matrices comprising the numbers and weights (expressed per 1000 m for gill nets and per 500 hooks for longlines) of each species from each gear and each season were constructed. These matrices were subjected to multidimensional scaling (MDS) and cluster analysis using the Bray-Curtis coefficient (BRAY & CURTIS, 1957). Data were transformed using the double square root transformation (FIELD *et al.,* 1982). In order to check whether the different fishing efficiency (i.e. dissimilarities in catch/effort units between gill nets and longlines) affects the formation of groupings, the analysis was also applied to standardised, untransformed data. All the above-mentioned analyses, which have been successfully applied to similar experimental fisheries data from the Cyclades and the Algarve (e.g. STERGIOU *et al.,* 2002; 2006), were carried out using the PRIMER algorithms (CARR, 1997).

Overall differences in total catches in numbers and in weight between gears, mesh sizes and seasons were evaluated by general linear models (SAS Institute Inc., 1988). Finally, the commercial/total catch ratio (C/T), in terms of both weight and number, was calculated separately for each individual gear, gear size and season. The fate of the catch (commercial, discard or self-consumption) was based on the sorting of the catch by the fishermen, not by the on board observers. Comparisons of mean diversity indices by gear size and season were done using t-test and one-way analysis of variance (ANOVA) and Fisher's Least Significance Difference (LSD) test (ZAR 1999).

Results

A total of 19059 specimens were caught weighing 2713 kg, belonging to 84 species (79 fish species, 2 crustacean species and 3 cephalopod species) (Tables 1 and 2). Forty-one out of the 84 species were caught using both types of gear, 13 species were caught only by longlines and 30 species only by gill nets (Table 1). Fishes made up the major part of the catch (more than 99% by both numbers and weight for both types of gear).

The total catches (number and weight) by gear, gear size and season are summarized in Table 2. General linear models showed that there were no significant differences between the four gill net mesh sizes in terms of catch in numbers ($F = 0.59$, $p = 0.636$) and in weight ($F = 0.15$, $p = 0.93$). For longlines, there was a significant difference in numbers ($F = 14.49$, $p = 0.006$), with decreasing numbers caught with increasing hook size, but no difference in weight ($F = 2.68$, $p = 0.104$), catch rate in numbers ($F = 2.68$, $p = 0.012$) and in weight ($F = 0.85$, $p = 0.497$). Overall, there was a significant difference between seasons in terms of gill net total catches and catch rates in numbers and in weight ($p < 0.0001$),

Table 1
Species caught per gear and gear size, species overlap between the two gear types and use of species (C = commercial, D = discarded and SC = self-consumption, includes fishes that are not auctioned but for various reasons were taken by the fishermen for their own use). * cephalopod, ** crustacean.

Species	Mesh Size (mm)				Hook Size				Use
	25	30	35	40	15	13	12	11	
Acantholabrus palloni	0	0	0	0	0	1	0	0	D
Alosa alosa	0	3	2	0	0	0	0	0	D
Alosa fallax	0	4	0	2	0	0	0	0	D
Anthias anthias	2	0	0	0	0	0	0	0	D
Argyrosomus regius	0	0	1	0	0	0	0	0	C
Aspitrigla obscura	8	5	2	2	0	0	1	0	D
Balistes carolinensis	0	0	0	0	0	1	0	0	D
Boops boops	134	22	8	6	170	123	63	44	D
Bothus podas	1	2	0	0	0	0	0	0	D
Callionymus lyra	8	1	1	0	0	1	0	0	D
Caranx rhonchus	7	12	20	14	8	2	3	7	SC
Chromis chromis	6	0	0	0	0	0	0	0	D
Citharus linguatula	29	20	23	10	0	0	2	0	C
Conger conger	1	2	0	1	60	65	101	83	D
Coris julis	1	0	0	0	1	0	0	0	D
Dentex gibbosus	0	2	1	7	0	0	0	0	C
Dentex macrophthalmus	0	0	0	0	5	2	3	2	C
Dentex maroccanus	0	0	0	0	1	0	0	0	C
Dicentrarchus labrax	0	0	0	0	0	2	1	1	C
Dicentrarchus punctatus	0	0	0	0	0	1	0	0	C
Dicologoglossa cuneata	17	19	38	24	0	0	0	0	C
Diplodus annularis	4	1	4	8	23	4	1	1	SC
Diplodus bellottii	533	544	228	71	338	113	56	51	SC
Diplodus cervinus	0	0	0	1	1	0	1	3	C
Diplodus puntazzo	0	0	0	2	0	0	0	0	C
Diplodus sargus	0	0	0	1	82	93	104	89	C
Diplodus vulgaris	92	161	196	95	724	498	329	203	C
Gobiidae	0	0	0	0	2	8	6	2	D
Halobatrachus didactylus	0	0	1	1	0	0	3	1	SC
Labrus bimaculatus	0	2	0	1	0	0	0	0	D

(continued)

Table 1 (continued)

Species	Mesh Size (mm)				Hook Size				Use
	25	30	35	40	15	13	12	11	
Labrus spp.	0	1	0	0	0	0	0	0	D
Lithognathus mormyrus	9	24	6	33	2	1	1	1	C
Liza aurata	0	11	40	6	0	0	0	0	D
Liza ramada	0	1	10	21	0	0	0	0	D
Loligo vulgaris	2	0	1	0	0	0	0	0	SC
Macroramphosus scolopax	27	2	0	0	0	0	0	0	D
Maja squinado	0	0	1	4	0	0	1	0	SC
Merluccius merluccius	23	12	7	11	0	0	0	0	SC
Microchirus ocellatus	6	5	4	0	0	0	0	0	D
Mullus barbatus	7	17	2	0	0	0	0	0	C
Mullus surmuletus	335	166	54	24	0	0	0	0	C
Muraena helena	0	1	1	0	2	6	1	1	SC
Oblada melanura	0	0	0	0	2	6	0	0	D
Octopus vulgaris	9	1	3	1	0	0	0	0	SC
Pagellus acarne	320	191	150	69	431	403	319	310	C
Pagellus bellottii	0	1	3	5	0	1	1	0	C
Pagellus erythrinus	183	182	80	65	110	100	100	78	C
Pagrus auriga	0	3	3	7	2	1	1	4	C
Pagrus pagrus	11	21	19	32	36	37	32	22	C
Parapristipoma octolineatum	6	6	19	3	0	0	1	0	SC
Penaeus kerathurus	2	0	3	1	0	0	0	0	SC
Phycis phycis	1	2	4	0	5	13	10	8	C
Plectorhinchus mediterraneus	0	5	8	17	3	1	0	1	C
Pomadasys incisus	0	0	0	0	0	1	0	0	C
Pteromylaeus bovinus	0	0	0	0	0	0	1	0	SC
Raja clavata	0	0	0	0	0	0	0	1	SC
Raja spp.	0	0	0	1	0	0	0	0	SC
Sarda sarda	0	1	1	0	0	0	0	0	SC
Sardina pilchardus	349	70	129	153	0	0	0	1	SC
Scomber japonicus	497	544	992	1312	59	42	30	32	D
Scomber scombrus	17	5	15	6	0	0	0	1	SC
Scorpaena notata	696	190	55	22	89	158	114	93	D
Scorpaena scrofa	0	1	0	0	1	0	0	0	D

(continued)

Table 1 (continued)

Species	Mesh Size (mm)				Hook Size				Use
	25	30	35	40	15	13	12	11	
Scyliorhinus canicula	1	0	0	0	0	0	0	0	D
Sepia officinalis	23	9	6	6	0	1	1	0	SC
Serranus atricauda	2	0	0	0	0	0	2	0	D
Serranus cabrilla	76	21	10	5	48	53	32	37	D
Serranus hepatus	2	1	0	1	22	11	0	0	D
Solea senegalensis	0	0	0	0	0	1	1	0	C
Sparus aurata	0	0	0	1	5	5	2	1	C
Spicara flexuosa	1	0	0	0	0	0	0	0	D
Spicara maena	57	7	1	0	0	0	0	0	D
Spondyliosoma cantharus	82	62	83	45	349	296	226	154	C
Symphodus bailloni	13	5	5	0	0	0	0	0	D
Torpedo torpedo	0	0	0	1	0	0	0	0	D
Trachinotus ovatus	0	0	1	0	3	1	0	3	D
Trachinus draco	65	11	13	14	27	17	22	28	SC
Trachurus picturatus	0	0	1	0	1	0	0	0	C
Trachurus trachurus	331	179	213	225	9	6	6	6	C
Trigla lucerna	0	0	0	0	0	2	0	0	D
Trigloporus lastoviza	17	14	9	4	0	3	1	0	D
Trisopterus luscus	40	12	16	2	4	4	3	1	C
Umbrina canariensis	0	1	0	0	0	0	0	0	D
Uranoscopus scaber	4	5	2	13	0	0	0	0	SC
Total	4057	2590	2495	2356	2625	2084	1582	1270	
Total Species	46	52	50	47	33	39	37	32	

with considerably greater catches in the summer than in the other seasons, while the opposite was found for longlines (total catch in numbers: F = 0.30, p = 0.825, catch rate in numbers: F = 0.44, p = 0.730, total catch in weight: F = 1.16, p = 0.37, catch rate in weight: F = 3.11, p = 0.076), with catches more much more evenly distributed over the four seasons. Finally, analysis for both gear types by season showed that catches and catch rates in numbers (F = 4.37, p = 0.012) and in weight (F = 3.57, p = 0.0264) differed significantly.

Catch species composition differed greatly with mesh and hook size. *Scorpaena notata, Diplodus bellottii* and *Scomber japonicus* numerically dominated the total catch of the 50 mm gill net, making up 17.2%, 13.1% and 12.3%, respectively, whereas *D. bellottii* and *S. japonicus* were the main species of the 60 mm gill net, each making up 21.0% of the total catch, followed by *Pagellus acarne,*

Table 2
Total number (Total N) and weight (Total W) of individuals, numbers (N) and weights (W) per 1000 m of nets and per 500 hooks (N and W, respectively), and their percentages (%N and %W) per gear size (G25=25 mm gill net, H11=longline with hook size 11, etc.) and season (S; A=Autumn, W=Winter, SP=Spring and SU=Summer).

Gear size	S	Total N	N	%N	Total W	W	%W
G25	A	1053	140.4	9.0	97.6	13.0	8.8
G30	A	517	68.9	4.4	64.3	8.6	5.8
G35	A	368	49.1	3.1	75.4	10.0	6.8
G40	A	250	33.3	2.1	65.7	8.8	5.9
G25	W	638	94.5	6.0	42.9	6.4	4.3
G30	W	479	71.0	4.5	44.5	6.6	4.4
G35	W	432	80.0	5.1	45.4	8.4	5.7
G40	W	436	64.6	4.1	48.7	7.2	4.9
G25	SP	527	63.9	4.1	40.7	4.9	3.3
G30	SP	367	44.5	2.8	37.2	4.5	3.0
G35	SP	298	36.1	2.3	40.1	4.9	3.3
G40	SP	268	32.5	2.1	23.1	2.8	1.9
G25	SU	1839	245.2	15.7	131.9	17.6	11.9
G30	SU	1227	163.6	10.4	101.7	13.6	9.1
G35	SU	1397	186.3	11.9	95.4	12.7	8.6
G40	SU	1402	192.1	12.3	134.5	18.4	12.4
Total		11498	1565.9	100.0	1089.0	148.3	100.0
H11	A	286	28.6	3.6	71.3	7.1	4.2
H12	A	306	30.6	3.9	76.4	7.6	4.5
H13	A	380	38.7	4.9	80.2	8.2	4.8
H15	A	589	58.9	7.5	103.9	10.4	6.1
H11	W	411	49.3	6.3	107.8	12.9	7.6
H12	W	458	54.4	6.9	114.0	13.5	8.0
H13	W	628	74.5	9.5	150.0	17.8	10.5
H15	W	691	83.7	10.6	145.7	17.6	10.4
H11	SP	297	27.8	3.5	74.9	7.0	4.1
H12	SP	397	36.6	4.7	101.9	9.4	5.5
H13	SP	531	50.5	6.4	111.3	10.6	6.2
H15	SP	672	61.1	7.8	118.9	10.8	6.4
H11	SU	276	28.2	3.6	60.2	6.1	3.6
H12	SU	421	42.4	5.4	84.5	8.5	5.0
H13	SU	545	54.8	7.0	102.0	10.3	6.0
H15	SU	673	67.3	8.5	120.8	12.1	7.1
Total		7561	787.2	100.0	1624.0	170.0	100.0

P. erythrinus and *S. notata* (Table 3). In contrast, *S. japonicus* accounted for the greater part of the catches of the 70 mm and 80 mm gill nets, representing 39.8% and 55.7% of the total catch respectively, followed by *Trachurus trachurus,* representing 8.5% and 9.6% respectively (Table 3). In terms of weight, *S. notata* and *Mullus surmuletus* dominated the total catch of the 50 mm gill net (12.9% and 12.7%, respectively), *D. bellottii* and *S. japonicus* were the dominant species of the catch of the 60 mm gill net (15.2% and 11.8%, respectively), *Liza aurata* and *S. japonicus* of the 70 mm gill net (14.5% and 12.7%, respectively) and, finally, *S. japonicus* and *L. ramada* that of the 80 mm gill net (34.7% and 9.7%, respectively) (Table 3).

For longlines, *D. vulgaris, P. acarne* and *Spondyliosoma cantharus* were the three numerically dominant species of the catches with all hook sizes, making up from 12.1% to 27.6% of the total catch depending on hook size and species, followed by *S. notata* for hook sizes 11, 12 and 13 (7.3%, 7.2% and 7.6%, respectively) and by *D. bellottii* (12.9%) for hook size 15 (Table 3). In terms of weight (Table 3), *D. vulgaris* and *P. acarne* accounted for the greater part of the longline catch for all hook sizes studied with percentages ranging from 17,7% to 29.2%, depending on hook size and species.

The number of species caught was lowest (16 species) for the longline with hook sizes 12 and 15 in winter 1997 and highest (35 species) for the gill net of 60 mm mesh in summer 1997 (Table 4). The mean number of species and the mean richness both differed significantly (for both cases: t values > 4.16, $p < 0.001$) between gill nets and longlines. In contrast, the mean evenness and the mean Shannon-Wiener diversity did not differ significantly between the two gear types (for both cases $t < 1.2$, $p > 0.1$).

The classification of the numerical matrix (all species) X (two gear types x four gear sizes x four seasons), based on double square root transformation, indicated that, at the 50% similarity level, the 32 gear/size/season combinations clearly fall into two main groups, corresponding to all gill net and all hook size combinations (Fig. 2a). The results of the ordination (MDS) of these 32 gear/size/season combinations fully agreed with cluster analysis (Fig. 2b). Within the two main groups, the different combinations formed subgroups mainly by season, especially for longlines (i.e. all hook sizes in autumn), although this was not consistent in all cases. The results of classification and ordination of the same matrix, based on standardised, untransformed data indicated, at about the 30% similarity level, the same two groups with the only exception being the gill nets 70 and 80 mm in autumn 1997 that were grouped with the longlines (figures not shown here). The same pattern was also found for the weight matrices based on both transformed and standardised, untransformed data (figures not shown here). In all cases, the resulting stress values for the two-dimensional plots were very low (<0.10), implying the adequacy of the MDS representations in these two dimensions.

The numerical species compositions of the catches of the groups identified by multivariate analyses differed considerably, with gill net catches being more diverse and composed of both demersal and pelagic species, the latter occasionally completely dominating the catches. In contrast, the longline catches were composed mainly of demersal species, dominated by Sparidae, although pelagic species were also caught in relatively small percentages. Thus, *S. japonicus* dominated the overall catch for gill nets in terms of both numbers (29%) and weight (17%), followed by *D. bellottii* (12% numerically)

Table 3
Catch species composition in terms of numbers (N%) and weight (W%) for the different mesh size of gill nets and size of hooks of longlines, Algarve, 1997–1998.

Gillnets				Longlines			
N%		W%		N%		W%	
25 mm				No 11			
Scorpaena notata	17.2	*Scorpaena notata*	12.9	*Pagellus acarne*	24.4	*Pagellus acarne*	24.3
Diplodus bellottii	13.1	*Mullus surmuletus*	12.7	*Diplodus vulgaris*	16.0	*Diplodus vulgaris*	17.7
Scomber japonicus	12.3	*Scomber japonicus*	10.5	*Spondyliosoma cantharus*	12.1	*Diplodus sargus*	14.4
Sardina pilchardus	8.6	*Trachurus trachurus*	9.4	*Scorpaena notata*	7.3	*Spondyliosoma cantharus*	11.3
Mullus surmuletus	8.3	*Pagellus acarne*	9.3	*Diplodus sargus*	7.0	*Pagellus erythrinus*	10.8
Others	40.6	Others	45.2	Others	33.1	Others	21.5
30 mm				No 12			
Diplodus bellottii	21.0	*Diplodus bellottii*	15.2	*Diplodus vulgaris*	20.8	*Diplodus vulgaris*	21.1
Scomber japonicus	21.0	*Scomber japonicus*	11.8	*Pagellus acarne*	20.2	*Pagellus acarne*	20.2
Pagellus acarne	7.4	*Mullus surmuletus*	11.2	*Spondyliosoma cantharus*	14.3	*Diplodus sargus*	13.4
Scorpaena notata	7.3	*Pagellus acarne*	10.6	*Scorpaena notata*	7.2	*Spondyliosoma cantharus*	12.7
Pagellus erythrinus	7.0	*Pagellus erythrinus*	8.9	*Diplodus sargus*	6.6	*Pagellus erythrinus*	11.9
Others	36.3	Others	42.4	Others	31.0	Others	20.7
35 mm				No 13			
Scomber japonicus	39.8	*Liza aurata*	14.5	*Diplodus vulgaris*	23.9	*Diplodus vulgaris*	24.3
Diplodus bellottii	9.1	*Scomber japonicus*	12.7	*Pagellus acarne*	19.3	*Pagellus acarne*	21.3
Trachurus trachurus	8.5	*Pagellus acarne*	11.9	*Spondyliosoma cantharus*	14.2	*Spondyliosoma cantharus*	13.6
Diplodus vulgaris	7.9	*Diplodus vulgaris*	10.0	*Scorpaena notata*	7.6	*Diplodus sargus*	11.3
Pagellus acarne	6.0	*Diplodus bellottii*	8.6	*Boops boops*	5.9	*Pagellus erythrinus*	10.3
Others	28.7	Others	42.2	Others	29.1	Others	19.3

(continued)

Table 3 (continued)

Gillnets				Longlines			
N%		W%		N%		W%	
40 mm				No 15			
Scomber japonicus	55.7	*Scomber japonicus*	34.7	*Diplodus vulgaris*	27.6	*Diplodus vulgaris*	29.2
Trachurus trachurus	9.6	*Liza ramada*	9.7	*Pagellus acarne*	16.4	*Pagellus acarne*	20.1
Sardina pilchardus	6.5	*Diplodus vulgaris*	6.9	*Spondyliosoma cantharus*	13.3	*Spondyliosoma cantharus*	13.0
Diplodus vulgaris	4.0	*Pagellus acarne*	6.3	*Diplodus bellottii*	12.9	*Pagellus erythrinus*	7.9
Diplodus bellottii	3.0	*Pagellus erythrinus*	6.1	*Boops boops*	6.5	*Diplodus sargus*	7.5
Others	21.2	Others	36.3	Others	23.4	Others	22.3

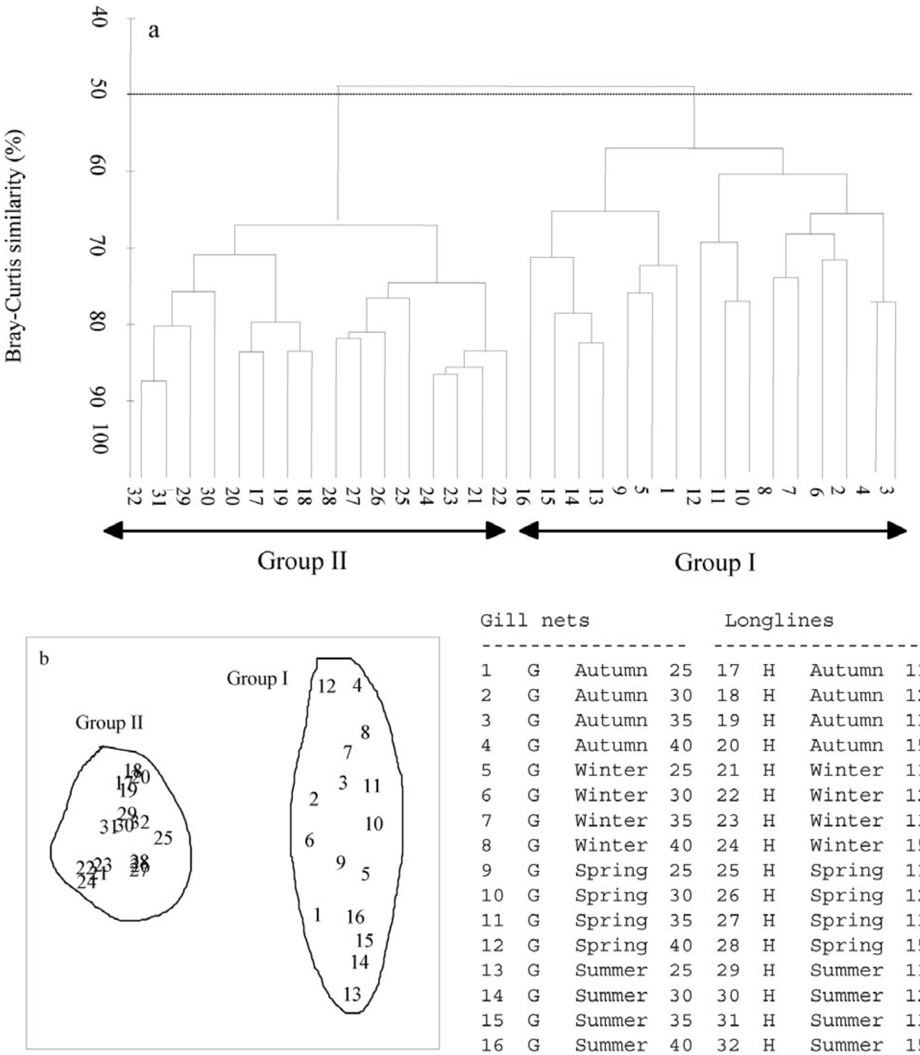
and *P. acarne* and *D. bellottii* (9% by weight). In contrast, *D. vulgaris* and *P. acarne* accounted for most of the overall longline catch in terms of both numbers, 23% and 19% respectively, and weight, 24% and 21% respectively, followed by *S. cantharus* (14% by number and 13% by weight).

A total of 35 species out of the 85 caught were non-commercial (Table 1). The differences in the C/T catch ratios between longlines and gill nets were considerable (Table 5). Thus, the C/T ratio ranged between 0.41 and 0.67 by number and between 0.51 and 0.74 by weight for gill nets and between 0.77 and 0.83 by number and 0.88 and 0.91 by weight for longlines (Table 5). The differences in the C/T ratios by gear size were relatively small for mesh sizes 50 and 60 mm, being greater for the 70 and 80 mm mesh sizes. For hook sizes, these differences were relatively small (Table 5).

Discussion

Multivariate analysis showed two groups, the different mesh sizes of gill nets, and the different hook sizes on the longlines, which also differed from each other in species composition, species diversity, and commercial/total catch ratios. The effect of season and gear size on group formation was not very clear. Although it seems that the season effect was stronger than the gear size effect, this aspect requires further studies.

Several comparative fishing studies have been carried out in a number of fisheries, but in most cases the studies have focused on one or two species (ENGAS *et al.,* 1993; ELLIOTT & BEAMESDERFER, 1990; NEDREAAS *et al.,* 1993; ROLLEFSEN, 1953; RUSSELL *et al.,* 1988; YANG & GONG, 1988) with a few examples of a multi-species assemblage (STERGIOU *et al.,* 1996; 2002; 2006; ERZINI *et al.* 1996b). ERZINI *et al.* (1996b) compared small hook



Gill nets				Longlines			
1	G	Autumn	25	17	H	Autumn	11
2	G	Autumn	30	18	H	Autumn	12
3	G	Autumn	35	19	H	Autumn	13
4	G	Autumn	40	20	H	Autumn	15
5	G	Winter	25	21	H	Winter	11
6	G	Winter	30	22	H	Winter	12
7	G	Winter	35	23	H	Winter	13
8	G	Winter	40	24	H	Winter	15
9	G	Spring	25	25	H	Spring	11
10	G	Spring	30	26	H	Spring	12
11	G	Spring	35	27	H	Spring	13
12	G	Spring	40	28	H	Spring	15
13	G	Summer	25	29	H	Summer	11
14	G	Summer	30	30	H	Summer	12
15	G	Summer	35	31	H	Summer	13
16	G	Summer	40	32	H	Summer	15

Fig. 2: Dendrogram for group-average clustering and (b) multidimensional scaling (MDS) ordination, based on Bray-Curtis similarities between catch numbers (transformed data) for all species per gear/size/season combinations. Combinations 1 to 32 are shown in the legend.

longline catches with those of monofilament gill nets in Algarve waters and found pronounced differences in terms of catch composition, catch rates and size ranges. However, the study of ERZINI *et al.* (1996b) was based on experimental fishing trials carried out at different times. The present study confirmed the results of ERZINI *et al.* (1996b). In addition, the same is also generally true for fish caught in the Cyclades with hooks having similar hook sizes as in the present study (STERGIOU *et al.*, 2002).

The different ecological indices gave conflicting results, with the mean number

Table 4
Total number of individuals (N), total number of species (R), richness (D), diversity (H’) and evenness (J) for each season (S; A=Autumn, W=Winter, SP=Spring and SU=Summer) per gear and gear size (G for gill nets, H for hooks, numbers identify gear size).

Gill nets	S	N	R	D	H′	J	Hooks	N	R	D	H′	J
G25	A	140.4	31	6.1	2.5	0.7	H11	28.6	18	5.1	2.4	0.8
G30	A	68.9	28	6.4	2.6	0.8	H12	30.6	22	6.1	2.4	0.8
G35	A	49.1	29	7.2	2.7	0.8	H13	38.7	19	4.9	2.4	0.8
G40	A	33.3	25	6.8	2.8	0.9	H15	58.9	23	5.4	2.1	0.7
G25	W	85.1	28	6.1	2.3	0.7	H11	41.9	18	4.6	1.8	0.6
G30	W	63.9	24	5.5	2.0	0.6	H12	46.1	16	3.9	1.8	0.6
G35	W	57.6	24	5.7	2.0	0.6	H13	63.2	19	4.3	1.8	0.6
G40	W	59.7	29	6.9	1.6	0.5	H15	69.1	16	3.5	1.7	0.6
G25	SP	78.1	26	5.7	2.6	0.8	H11	35.7	20	5.3	2.2	0.7
G30	SP	54.4	27	6.5	2.5	0.8	H12	47.1	22	5.5	2.3	0.7
G35	SP	55.2	25	6.0	2.4	0.7	H13	63.0	28	6.5	2.4	0.7
G40	SP	39.7	20	5.2	1.7	0.6	H15	81.4	20	4.3	2.3	0.8
G25	SU	222.9	32	5.7	2.5	0.7	H11	25.8	20	5.9	2.4	0.8
G30	SU	148.7	35	6.8	2.3	0.6	H12	38.8	24	6.3	2.3	0.7
G35	SU	169.3	34	6.4	1.9	0.5	H13	51.8	25	6.1	2.3	0.7
G40	SU	169.9	31	5.8	1.5	0.4	H15	61.2	23	5.4	2.2	0.7
Min		33.3	20	5.2	1.5	0.4	Min	25.8	16	3.5	1.7	0.6
Max		222.9	35	7.2	2.8	0.9	Max	81.4	28	6.5	2.4	0.8
Mean		93.5	28.0	6.2	2.2	0.7	Mean	48.9	21	5.2	2.2	0.7

Table 5
Total catch in numbers (N) and weights (W, kg) of commercial (C) and discarded (D) species, their percentages (%C and %D) and commercial/total (C/T) catch ratio per gear and gear size.

Mesh size (mm)		C	%C	D	%D	C/T	Hook size		C	%C	D	%D	C/T
25	N	2501	61.6	1556	38.4	0.62	No 11	N	976	76.9	294	23.1	0.77
	W	209.8	67.0	103.2	33.0	0.67		W	277.1	88.2	37.2	11.8	0.88
30	N	1745	67.4	845	32.6	0.67	No 12	N	1232	77.9	350	22.1	0.78
	W	182.4	73.6	65.3	26.4	0.74		W	333.9	88.6	43	11.4	0.89
35	N	1355	54.3	1140	45.7	0.54	No 13	N	16.9	77.2	475	22.8	0.77
	W	169.5	66.1	86.8	33.9	0.74		W	399.2	90.0	44.3	10.0	0.90
40	N	972	41.3	1384	58.70	0.41	No 15	N	2168	82.6	457	17.4	0.83
	W	137.4	50.5	134.6	49.5	0.51		W	443.1	90.5	46.3	9.5	0.91

of species and mean Margalef D index of richness differing significantly for the two types of gear, while no significant differences were found for mean Shannon-Wiener diversity H′ or the Pielou J index of evenness. This is due to the fact that the Shannon-Wiener diversity H′ takes into account the relative abundance of the species while the Margalef D index is a measure of species richness that is roughly normalized for sample size. Nevertheless, it is clear that gill nets caught more species, particularly several pelagic species not susceptible to longlines and catch composition was significantly different even when pelagic species were not considered. Some of the most important commercial species such as *M. surmuletus* and *Diplodus sargus* were only caught by one type of gear, gill nets and longlines respectively. For most species caught by both gear types, there were also clear differences in size selectivity (see in: ERZINI *et al.* (2003).

The only other gear catch and catch rate comparison study for Portugal is that of SANTOS (1997), who used three gear types to monitor fish populations on the first artificial reefs to be deployed in Portuguese waters: gill nets, traps and longlines. SANTOS (1997) also find that gill nets were least selective in terms of species, while longlines catch fewer species than the other two gear types (gill nets: 74 species, 35 exclusive; traps: 29 species, 3 exclusive; longlines: 13 species).

In the Algarve region, gill net studies have been carried out by MARTINS *et al.* (1992), SANTOS & MONTEIRO (1995) and SANTOS (1997). MARTINS *et al.* (1992) fished with 20, 30 and 40 mm monofilament gill nets of the same type used in the present study. The total number of species caught in the above gill net studies was similar to that in the present study. MARTINS *et al.* (1992) reports a total of 64 fish species with the three mesh sizes, while SANTOS (1997) reports 74 species overall and 57 species for the 30 mm mesh net used as the main sampling gear. While the number of species caught was similar in all studies, the species composition differed considerably. Thus, although the catches in numbers and in weight were dominated by the same few species, the main differences were in terms of the species that were caught in small numbers.

In contrast with the present study, overall catch rates in weight decreased with increasing mesh size, with average catches of 11.08, 3.91 and 2.07 kg per 10 nets of 40, 60 and 80 mm mesh size, respectively (MARTINS *et al.,* 1992). Likewise, STERGIOU *et al.* (2006) who quantify the species composition and catch rates for different mesh sizes of trammel nets in southern European waters also find that the number of specimens declines significantly with mesh size in all areas. In the present study, average catch rates in weight for approximately equivalent lengths of net (500 m) ranged from lowest values in the spring of 2.45 kg, 2.25 kg, 2.45 kg, and 2.40 kg for mesh sizes 50, 60, 70, and 80 mm respectively, to 8.80 kg, 6.80 kg, 6.35 kg, and 9.2 kg for the same mesh sizes in the summer. Mean catch rates in the artificial reef monitoring study with a 60 mm mesh size gill net ranged from 1.27 kg per 500 m of net to 3.94 kg per 500 m at eight sampling locations (SANTOS, 1997).

Longlines using small hooks have been previously studied by ERZINI *et al.* (1996a, 1998a). Three of the same hook sizes, numbers 15, 13, and 11 were used by ERZINI et al. (1998a) in 28 longline sets in the same area as the present study. A total of more than 36 species were caught for a total of 33,600 hooks fished. As in the present study, five sea bream species accounted for 79%

of the catch by weight, with four of the most important species being the same in both studies (*D. vulgaris, P. acarne, P. erythrinus* and *S. cantharus*).

As in previous longline studies in the Algarve (ERZINI *et al.,* 1996a; 1998a) and southern Aegean (STERGIOU *et al.,* 2002), a decrease in catch rate with increasing hook size was found in the present study, with the smallest hook (number 15) catching approximately twice as many fish per 100 hooks as the largest hook (number 11). ERZINI *et al.* (1998a) report overall catch rates of 13.3, 10.3 and 6.1 fish per 100 hooks for the number 15, 13 and 11 hooks respectively. In the present study catch rates ranged from 5.4 fish per 100 number 11 hooks in the spring fishing trials to 16.7 fish per 100 number 15 hooks in the winter fishing trials.

As reported by ERZINI *et al.,* (2003), catch size frequency distributions for the species caught by both gears were generally significantly different, with longlines catching larger fish and a wider size range than gill nets. Significant numbers of undersized fish were caught by gill nets, especially those of 50 mm and 60 mm mesh sizes, relatively few if any undersized fish of most commercially important species were caught by longlines. From the management and conservation perspective these results suggest that the longline fishery is more sustainable than the gillnet fishery.

The results of the present study also showed that discarding for gill nets was higher than longlines. This was due mainly to the large quantities of small pelagics, particularly *S. japonicus* that have little or no value. In a previous study of discarding practices in five Algarve types of gear (i.e., trammel nets, demersal purse seine, pelagic purse seine, fish trawl, and crustacean trawl), BORGES *et al.* (2001) find that crustacean trawls had the lowest C/T ratio (>0.30) while trammel nets have the highest C/T ratio (0.87). However, GONÇALVES *et al.* (2007) find that trammel nets of different mesh sizes fished in the same area showed high discard rates (49%) due to small pelagic fishes. Hence, the results of the present study indicated that gill nets have C/T ratios between trawl and trammel nets, whereas longlines have by far the highest C/T ratios of all gears. Thus, static gear such as gill nets, trammel nets and longlines catch a smaller number of species than active gear such as trawlers and generally have higher C/T ratios. This is also true of the eastern Mediterranean (STERGIOU *et al.,* 1996, 2004).

The results of this study show that two of the most widely used types of fishing gear used in southern European waters, gill nets and longlines, exploit many of the same species but have different impacts in terms of catch composition, catch rates, size ranges and discards. This information can be used to improve management by providing the scientific basis for a rational licensing programme and for determining the optimal effort allocation and hook and mesh sizes in these gillnet and longline fisheries.

For gear such as longlines that have logistic type selectivity (ERZINI *et al.,* 1998a, 2003), the optimal hook size can be determined based on yield-per-recruit analysis, considering changes in yield resulting from changes in selectivity functions (GULLAND, 1961, 1963; PAULY, 1988). Several approaches extend the single species to the multi-species case by grouping species with similar life history parameters (PAULY, 1988; SAINSBURY, 1984; PAULY *et al.,* 1989). The weighted average of different hook sizes corresponding to the optimal lengths-at-capture of different species or species groups can be calculated (SAINSBURY *et al.,* 1979), or summation functions used to maximize aggregate yield per recruit for a combination of species or species groups (SAINSBURY, 1984; SILVESTRE & SORIANO, 1988). Multi-species yield-per-recruit analysis can be used to evaluate different management policies, including the optimal allocation of fishing effort and gear size (MURAWSKI, 1984; PIKITCH, 1987; MARCHAL & HORWOOD, 1996). Since gillnet selectivity curves are unimodal, the classic yield-per-recruit analysis approach can not be used to evaluate optimal mesh size. However, EHRHARDT & DIE (1988) show how size-structured yield per recruit analysis can be used to evaluate the effects of changes in gillnet mesh size and fishing mortality rate.

Improved management and conservation could be achieved in artisanal inshore fisheries by determining the optimal gear sizes and effort for each of the different types of gear, taking also into account the impact of each gear in terms of discarding and value of the catch. Although this is beyond the scope of this study, these data will be used with this objective in mind as a continuation of our research into the small-scale artisanal fisheries of southern Europe. Seasonality in the catch composition may also be the basis for controlling the fishing effort of the two gear types and also for temporal closures and licensing. This study is the first step in this direction.

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