SCIENTIA MARINA 72(3)
September 2008, 527-540, Barcelona (Spain)
ISSN: 0214-8358

Gill net and trammel net selectivity in the northern Aegean Sea, Turkey

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SUMMARY: Fishing trials were carried out with gill nets and trammel nets in the northern Aegean Sea from March 2004 to February 2005. Four different mesh sizes for the gill nets and the inner panel of trammel nets (16, 18, 20 and 22 mm bar length) were used. Selectivity parameters for the five most economically important species, bogue (*Boops boops*), annular sea bream (*Diplodus annularis*), striped red mullet (*Mullus surmuletus*), axillary sea bream (*Pagellus acarne*) and blotched picarel (*Spicara maena*), caught by the two gears were estimated. The SELECT method was used to estimate the selectivity parameters of a variety of models. Catch composition and catch proportion of several species were different in gill and trammel nets. The length frequency distributions of the species caught by the two gears were significantly different. The bi-modal model selectivity curve gave the best fit for gill net and trammel net data, and there was little difference between the modal lengths of these nets. However, a clear difference was found in catching efficiency. The highest catch rates were obtained with the trammel net. Given that many discard species and small fish are caught by gill nets and trammel nets with a mesh size of 16 mm, it is clear that these nets are not appropriate for fisheries. Consequently, the best mesh size for multispecies fisheries is 18 mm. This mesh size will considerably reduce the numbers of small sized individuals and discard species in the catch.

Keywords: gill net, trammel net, selectivity, SELECT method, Aegean Sea, Turkey.

RESUMEN: SELECTIVIDAD DE ARTES DE ENMALLE (BETAS Y TRASMALLO) EN EL EGEO SEPTENTRIONAL, TURQUÍA. – Se realizaron ensayos de pesca con betas y trasmallos en el Egeo septentrional desde marzo de 2004 a febrero de 2005. Se utilizaron cuatro luces de malla distintas (16, 18, 20 y 22 mm) tanto para las betas como para el paño interno de los trasmallos. Se estimaron los parámetros de selectividad de las cinco especies más importantes capturadas por ambos artes: boga (*Boops boops*), raspallón (*Diplodus annularis*), salmonete de roca (*Mullus surmuletus*), aligote (*Pagellus acarne*) y chucla (*Spicara maena*). Se utilizó el método SELECT para la estimación de los parámetros de selectividad de varios modelos. La composición en tallas de la captura así como la proporción de las distintas especies capturadas por las betas y trasmallos fueron diferentes. La distribución de frecuencias de tallas de las especies capturadas por ambos artes fueron significativamente diferentes. El modelo de curva de selectividad bimodal fue el que mejor se ajustó a los datos de betas y trasmallos, y se encontraron muy pocas diferencias entre las longitudes modales de ambos artes. No obstante, se encontró una diferencia clara en la eficiencia de captura. Las tasas de captura más altas correspondieron a los trasmallos. Teniendo en cuenta que con betas y trasmallos de luz de malla de 16 mm se obtienen muchas especies que son posteriormente descartadas así como gran cantidad de peces pequeños, parece claro que estas redes no son convenientes para la pesquería. La luz de malla de 18 mm es la mejor para estas pesquerías multiespecíficas. El uso de paños con esta luz de malla resultaría en una reducción considerable del número de individuos de pequeña talla así como de las especies descartadas.

Palabras claves: beta, trasmallo, selectividad, método SELECT, mar Egeo, Turquía.

INTRODUCTION

Artisanal fisheries play a significant role in Turkish fisheries. Eighty-nine percent (16460) of 18396 vessels belong to the artisanal fishery (TUIK, 2005). The length of the boats ranges from 6 m to 10 m, engine power ranges from 5 to 100 HP, and crew from 1 to 3. Gill nets, trammel nets, longlines, dredges, beam trawls, hand lines and beach seine nets are used.

Gill nets are passive walls of netting that operate by wedging or entangling fish that swim into them (Von Brandt, 1984). Gill nets are chiefly used to catch fish with an almost uniform body size since the mesh size must match the fish's girth; the mesh size used depends on the species and size range being targeted. The selection curve is often assumed to be bell shaped. Trammel nets are specially designed gill nets that are constructed by joining three parallel sheets of netting. The two outer sheets are made of netting with a very large mesh size. The trammel net design enables catching fish by two different processes; (a) gilling and entangling, like conventional gill nets, and (b) trapping large fish in the bags of the inner netting (FAO, 2000). Trammel nets are generally considered to be less size selective than gill nets (FAO, 2000; Fabi *et al.*, 2002). The selection curve is skewed or multimodal and may be more appropriate than the normal curve (Hamley, 1975).

In Turkish waters, selectivity studies have focused mainly on gill nets (Aydin *et al.*, 1997; Ozekinci, 2005; Kara, 2003), and there are few reports dealing with trammel nets. The Holt (1963) method was used to estimate the selectivity of trammel nets used for the *Chalcalburnus tarichi* fisheries in Van Lake (Cetinkaya *et al.*, 1995; Sari, 1997) and the *Carassius auratus* fisheries in Egirdir Lake (Balik and Cubuk, 1998-1999). However, there is no published research on trammel nets used in Turkish seas.

The aim of this study was to determine the selectivity of multifilament gill nets and trammel nets for five important species for small scale fisheries in the northern Aegean Sea: bogue (*Boops boops*), annular sea bream (*Diplodus annularis*), striped red mullet (*Mullus surmuletus*), axillary sea bream (*Pagellus acarne*) and blotched picarel (*Spicara maena*). The selectivity of gill nets and trammel nets has rarely been compared. Fabi *et al*. (2002) compared these two nets using the Sechin model. In this study, the SELECT method (Hovgård, 1996; Millar and Fryer, 1999; Erzini *et al*. 2006) was used, which is a new and currently commonly used method that fits a variety of selectivity models (normal location, normal scale, log-normal, gamma and binormal).

MATERIALS AND METHODS

Survey area and gears

This study was conducted off Gökceada Island in the period of March 2004 to February 2005, at depths of less than 30 m. Gökceada Island, which is the largest island in the northern Aegean Sea, has a coastal length of 92 km and a total surface area of 279 km^2 (Fig. 1).

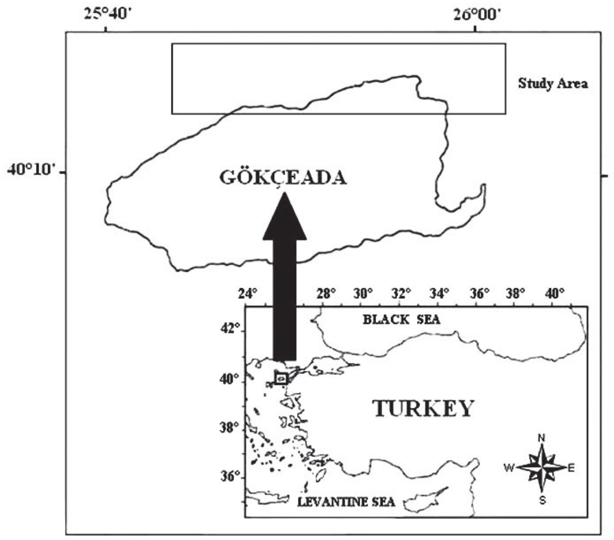

Fig. 1. – The map indicating the location of the study area in the northern Aegean Sea.

The northern Aegean Sea is affected by Black Sea waters. These waters greatly affect fish diversity and biomass, especially in Gökceada and the Saros Canal which is richer in terms of zooplankton than the southern Aegean Sea. The northern Aegean Sea is part of the migratory path of pelagic fishes (Kocatas and Bilecik, 1992). This area has 996 licensed fishing vessels with 964 set nets and longlines, 29 purse seines, 2 trawls, and 1 beach seine; 61% of total production in this region is provided by purse seines, 38.9% by set nets and longlines, 0.5% by trawl and 0.4% by beach seine vessels (Kara and Gurbet, 1999). Gill nets, trammel nets and longlines are the most widely used and important gears in the Gökceada Island fisheries. Local fishermen use gill and trammel nets every season of the year. However, in the northern Aegean Sea storms occur on an average of 31 days and strong winds average 125 days in a year, which negatively affects fishing activities (Alpaslan *et al*., 2003).

Two types of nets were used in the study: multifilament gill nets and multifilament trammel nets. Four different mesh sizes were used for gill nets and for the inner panel of the trammel nets: 16, 18, 20 and 22 mm (bar length). In terms of length, hanging ratio, twines and colours, all nets were the same, differing only in mesh size. The nets used in the research and the nets used by the local fishermen have the same characteristics. Simply, the nets used by the local fishermen are 200 m long. For gill nets and the inner panels of the trammel nets, the length was 100 m, depth was 70 meshes, the twine was 210d/2 no and orange in colour, with a hanging ratio of 0.50 on the float rope and 0.52 on the lead rope. The outer panels of the trammel nets had a mesh size of 125 mm (bar length) with depth 5.5 to 7 meshes; the twine was 210d/4 no. The vertical slack of the trammel nets ranged from 1.55 to 1.76. Total gill and trammel net length was 800 m (4 gill nets and 4 trammel nets). Gill nets and trammel nets were lowered into the sea 1to 2 hours before sunset, generally parallel to the bathymetric line, and retrieved 1to 2 hours before sunrise. The fishing trials lasted between 8 and 10 h. The Istanbul University, Faculty of Fisheries research vessel "Yunus II", 8.5 m in length with an engine power of 28 HP, was used for the trials.

A total of 12 fishing trials were carried out in the same fishing grounds used by local fishermen. The bottom types of these fishing grounds were rocky, sandy, and sea grass. All fish caught in the experimental trials were classified to species level and their length and weight measured. Total lengths (TL) was measured to the nearest millimetre, total weight was recorded in grams. The selectivity parameters of gill and trammel nets were estimated for the five most economically important species for small-scale fisheries in Gökceada Island: bogue (*Boops boops*), annular sea bream (*Diplodus annularis*), striped red mullet (*Mullus surmuletus*), axillary sea bream (*Pagellus acarne*) and blotched picarel (*Spicara maena*).

Estimating selectivity

The SELECT (share each length class catch total) method (Millar, 1992), was used to estimate the selectivity of the gill and trammel nets. This method assumes that catches (n_{lj}) by length class (l) and gear size (j) have a Poisson distribution; p_j (l) is the relative fishing intensity which is the probability that a fish of length l contacts the gear size j given that it contacts the combined gear, λ_l is the abundance of length l fish contacting the combined gear and $r_j(l)$ is the probability of retaining a fish of length l in gear size j.

$$n_{lj} \approx \text{Pois}\,(p_j \lambda_l r_j(l)) \tag{1}$$

The log-likelihood of n_{lj} is $\sum_l \sum_j$

$$\{n_l \log_e [p_j \lambda_l r_j(l)] - p_j \lambda_l r_j(l)\} \tag{2}$$

The parameters of five different models (normal location, normal scale, log-normal, gamma and bi-normal) were estimated using the GILLNET software (Millar, 1992; Millar and Holst, 1997; Constat, 1998; Millar and Fryer, 1999):

Normal location:

$$\exp\left(-\frac{(l-k.m)^2}{2\sigma^2}\right) \tag{3}$$

Normal scale:

$$\exp\left(-\frac{(l-k_1.m_j)^2}{2k_2^2.m_j^2}\right) \tag{4}$$

Log-normal:

$$\frac{m_j}{l.m_1}\exp\left(\mu-\frac{\sigma^2}{2}-\frac{\left(\log(l)-\mu-\log\left(\frac{m_j}{m_1}\right)\right)^2}{2k_2^2.m_j^2}\right) \tag{5}$$

Gamma:

$$\left(\frac{l}{(\alpha-1).k.m_j}\right)^{\alpha-1}\exp\left(\alpha-1-\frac{l}{k.m_j}\right) \tag{6}$$

Bi-normal:

$$\exp\left(-\frac{(l-k_1.m_j)^2}{2k_2^2.m_j^2}\right)+c.\exp\left(-\frac{(l-k_3.m_j)^2}{2k_4^2.m_j^2}\right) \tag{7}$$

According to the principle of geometric similarity (Baranov, 1948), in all models except normal location, the spread is proportional to mesh size. Goodness of fit was evaluated by comparing deviances and examining the deviance residual plots, with the lowest deviance value corresponding to the best fitting model.

The Kolmogorov-Smirnov test was used to compare the catch size frequency distributions of the most economically important species (*B. boops*, *D. annularis, M. surmuletus, P. acarne* and *S. maena*) caught by gill nets and trammel nets (Siegel and Castellan, 1988).

TABLE 1. – Catch data for gill net and trammel net, and for the different mesh sizes (bar length) used in the selectivity study (N: sample size, W: weight).

Mesh size (mm)	Total N	%N	Total W	%W
G16	766	31.1	22.3	21.5
G18	837	34.0	32.0	30.8
G20	550	22.3	27.2	26.1
G22	310	12.6	22.4	21.6
Total	2463	100	103.9	100
T16	870	34.3	39.9	23.9
T18	829	32.6	47.8	28.7
T20	566	22.3	41.8	25.1
T22	275	10.8	37.3	22.3
Total	2540	100	166.8	100

TABLE 2. – The 12 most abundant species in number caught by the different gill nets used in the selectivity study.

Species	Gill net mesh size (bar length) 16 mm	18 mm	20 mm	22 mm	Total
Spicara maena	285	243	100	43	671
Mullus surmuletus	76	89	40	14	219
Boops boops	17	81	57	58	213
Trachurus trachurus	28	62	78	12	180
Serranus scriba	75	66	24	12	177
Diplodus annularis	40	61	24	32	157
Pagellus acarne	6	37	83	16	142
Chromis chromis	79	20	7	-	106
Symphodus tinca	32	23	31	16	102
Spicara smaris	33	13	20	5	71
Scorpaena porcus	4	18	8	37	67
Pagellus erythrinus	4	17	3	17	41
Other species	87	107	75	48	317
Total	766	837	550	310	2463

RESULTS

A total of 5003 specimens, corresponding to 270.7 kg including fish and invertebrates, were captured with the experimental gill and trammel nets. A total of 76 species was caught (67 bony fishes, 5 crustaceans and 4 cephalopods). Catches of trammel nets and gill nets corresponded to 71 and 52 species respectively. The most abundant families were Sparidae, Centrachantidae, Mullidae, Serranidae, Scorpaenidae, Labridae, Carangidae and Sepiidae. Percent by weight (PW) and by number (PN) of the total catch of trammel and gill nets were as follows: PW, 61.6% and 38.4%; and PN, 50.8% and 49.2% respectively. Of the total 5003 individuals, 2540 individuals (166.8 kg) were caught in the trammel nets and 2463 individuals (103.9 kg) in the gill nets (Table 1). The three most abundant species captured by both fishing gears were *S. maena, M. surmuletus* and *B. boops* (Tables 2 and 3).

TABLE 3. – The 12 most abundant species in number caught by the different trammel nets used in the selectivity study.

Species	Trammel net mesh size (bar length) 16 mm	18 mm	20 mm	22 mm	Total
Mullus surmuletus	176	165	47	23	411
Spicara maena	80	77	49	20	226
Boops boops	38	97	75	5	215
Diplodus annularis	55	57	47	31	190
Pagellus acarne	49	69	46	16	180
Serranus scriba	60	31	40	7	138
Symphodus tinca	17	37	38	39	131
Scorpaena porcus	28	31	48	19	126
Chromis chromis	72	3	12	-	87
Spicara smaris	48	23	7	8	86
Mullus barbatus	14	33	18	4	69
Scorpaena notata	15	17	23	5	60
Other species	218	189	116	98	621
Total	870	829	566	275	2540

The catch size frequency distributions with the four gill net and trammel net mesh sizes for the five most abundant species (*B. boops, D. annularis, M. surmuletus, P. acarne* and *S. maena*) are given in Figure 2. The larger the mesh size of the gill nets and trammel nets, the greater the mean length of the captured fish. All mesh size combinations caught a wide size range of the five species (Table 4). The overall (all mesh sizes combined) length frequency distributions of the species caught by the two fishing gears were significantly different, with the exception of *S. maena* (Table 5).

Gill net and trammel net selectivity parameters were estimated for the five most important species caught by the two gears (*B. boops, D. annularis, M. surmuletus, P. acarne* and *S. maena*). The results of the SELECT model for the four gill net mesh sizes are given in Table 6. The bi-normal model provided the best fit for all species studied as it had the lowest deviance value.

The fitted selectivity curves for the four gill net mesh sizes for *B. boops, D. annularis, M. surmuletus*, *P. acarne* and *S. maena* are shown in Figure 3, as well as the corresponding deviance residuals for each species (Fig. 3).

The estimated modal lengths and spreads of the five species for the four gill net mesh sizes for the best model are shown in Table 7. In all the five species the modal lengths and spread values increased with mesh size.

The results of the SELECT model for trammel net selectivity are given in Table 8. The bi-normal model provided the best fit for *D. annularis, M. surmuletus* and *S. maena*. The log-normal model provided the best fit for *B. boops*, whereas the normal

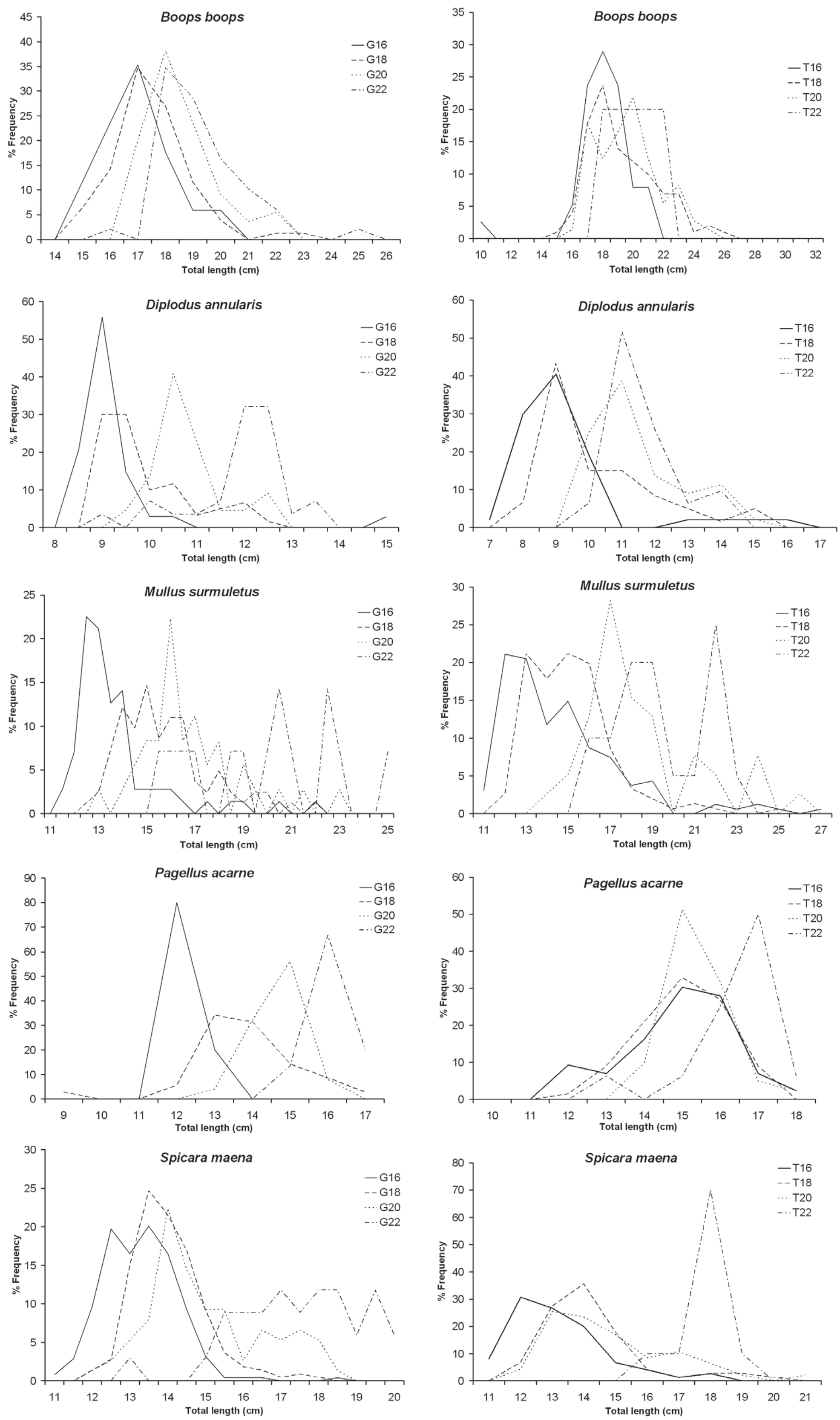

FIG. 2. – Catch size frequency distributions for the four mesh sizes of gill net and trammel net for *B. boops, D. annularis, M. surmuletus, P. acarne* and *S. maena*. Left: gill net; Right: trammel net.

TABLE 4. – The species studied, their size ranges (cm) and contribution (% of numbers) to the total catch.

Species	Gill net %	Gill net Size range	Trammel net %	Trammel net Size range
Boops boops	8.6	15.3-25.9	8.5	10.2-26.3
Diplodus annularis	6.4	8.5-15.4	7.5	7.7-16.8
Mullus surmuletus	8.9	11.8-25.3	16.2	11.3-27.7
Pagellus acarne	5.8	9.1-17.3	7.1	12.4-19.8
Spicara maena	27.2	11.0-20.3	8.9	11.5-21.9

TABLE 5. – Results of the Kolmogorov-Smirnov test used to compare gill and trammel net catch size frequency distributions.

Species	Gill net	Trammel net	D_{max}	Critical values $\alpha = 0.05$	Decision
B. boops	213	215	0.210	0.121	H0 rejected
D. annularis	157	190	0.165	0.152	H0 rejected
M. surmuletus	219	411	0.124	0.118	H0 rejected
P. acarne	142	180	0.242	0.159	H0 rejected
S. maena	671	226	0.053	0.111	H0 not rejected

TABLE 6. – The SELECT model parameter estimates for gill net selectivity.

Species	Model	Equal fishing powers Parameters	M.deviance	p	Fishing power α mesh-size (bar length) Parameters	M.deviance	p	d.f.
B. boops	Normal location	(k, σ)= (0.941, 2.181)	60.38	0.1989	(k, σ)= (0.954, 2.206)	60.01	0.2081	52
	Normal scale	(k_1, k_2)= (0.957, 0.118)	58.52	0.2485	(k_1, k_2)= (0.971, 0.117)	58.57	0.2472	52
	Gamma	(α, k)=(72.399, 0.013)	55.69	0.3377	(α, k)=(73.399, 0.013)	55.69	0.3377	52
	Log normal	(μ, σ)=(2.731, 0.116)	54.63	0.3749	(μ, σ)=(2.745, 0.116)	54.63	0.3749	52
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.955, 0.102, 1.300, 0.040, 0.166)	48.72	0.4846	(k_1, k_2, k_3, k_4, c)=(0.966, 0.102, 1.301, 0.040, 0.225)	48.72	0.4844	49
D. annularis	Normal location	(k, σ)= (0.572, 1.240)	84.74	0.0000	(k, σ)= (0.580, 1.247)	84.51	0.0000	34
	Normal scale	(k_1, k_2)= (0.583, 0.070)	98.24	0.0000	(k_1, k_2)= (0.591, 0.070)	98.45	0.0000	34
	Gamma	(α, k)=(78.977, 0.007)	83.89	0.0000	(α, k)=(79.977, 0.007)	83.89	0.0000	34
	Log normal	(μ, σ)=(2.223, 0.110)	77.72	0.0000	(μ, σ)=(2.235, 0.110)	77.72	0.0000	34
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.554, 0.031, 0.685, 0.140, 0.140)	45.73	0.0429	(k_1, k_2, k_3, k_4, c)=(0.556, 0.031, 0.713, 0.136, 0.176)	45.78	0.0424	31
M. surmuletus	Normal location	(k, σ)= (0.947, 2.402)	109.22	0.0039	(k, σ)= (0.964, 2.419)	108.11	0.0048	73
	Normal scale	(k_1, k_2)= (0.962, 0.128)	123.90	0.0002	(k_1, k_2)= (0.979, 0.126)	124.21	0.0002	73
	Gamma	(α, k)=(56.228, 0.017)	109.44	0.0037	(α, k)=(57.228, 0.017)	109.44	0.0037	73
	Log normal	(μ, σ)=(2.720, 0.135)	103.46	0.0110	(μ, σ)=(2.738, 0.135)	103.46	0.0110	73
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.855, 0.063, 1.104, 0.145, 0.520)	78.32	0.2317	(k_1, k_2, k_3, k_4, c)=(0.860, 0.063, 1.123, 0.144, 0.676)	78.35	0.2311	70
P. acarne	Normal location	(k, σ)= (0.767, 0.972)	68.90	0.0011	(k, σ)= (0.770, 0.977)	68.13	0.0014	37
	Normal scale	(k_1, k_2)= (0.772, 0.052)	72.81	0.0004	(k_1, k_2)= (0.775, 0.052)	72.81	0.0004	37
	Gamma	(α, k)=(217.98, 0.004)	73.28	0.0004	(α, k)=(218.98, 0.004)	73.28	0.0004	37
	Log normal	(μ, σ)=(2.512, 0.068)	74.32	0.0003	(μ, σ)=(2.517, 0.068)	74.32	0.0003	37
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.762, 0.031, 0.822, 0.102, 0.091)	41.86	0.1665	(k_1, k_2, k_3, k_4, c)=(0.763, 0.031, 0.834, 0.101, 0.099)	41.85	0.1670	34
S. maena	Normal location	(k, σ)= (0.846, 1.343)	75.35	0.0356	(k, σ)= (0.852, 1.348)	74.73	0.0395	55
	Normal scale	(k_1, k_2)= (0.852, 0.070)	74.23	0.0430	(k_1, k_2)= (0.858, 0.070)	74.31	0.0425	55
	Gamma	(α, k)=(140.46, 0.006)	65.71	0.1530	(α, k)=(141.46, 0.006)	65.71	0.1530	55
	Log normal	(μ, σ)=(2.612, 0.086)	63.19	0.2096	(μ, σ)=(2.619, 0.086)	63.19	0.2096	55
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.839, 0.059, 0.957, 0.122, 0.137)	52.80	0.4428	(k_1, k_2, k_3, k_4, c)=(0.843, 0.059, 0.973, 0.121, 0.157)	52.81	0.4425	52

TABLE 7. – Modal length and spread values for the best-fitting model of gill net selectivity model curves.

Species	Model	Gill net mesh size (bar length) 16 mm M.length	16 mm Spread	18 mm M.length	18 mm Spread	20 mm M.length	20 mm Spread	22 mm M.length	22 mm Spread
B. boops	Bi-modal	15.28	1.64	17.19	1.84	19.10	2.05	21.01	2.25
D. annularis	Bi-modal	8.86	0.49	9.97	0.56	11.08	0.62	12.19	0.68
M. surmuletus	Bi-modal	13.68	1.00	15.39	1.13	17.10	1.25	18.81	1.38
P. acarne	Bi-modal	12.19	0.50	13.71	0.57	15.23	0.63	16.76	0.69
S. maena	Bi-modal	13.42	0.95	15.10	1.07	16.78	1.19	18.46	1.30

location model provided the best fit for *P. acarne*. The fitted selectivity curves for the best models for the four trammel net mesh sizes for five species are shown in Figure 4, along with the corresponding deviance residuals.

The estimated modal lengths and spreads of the

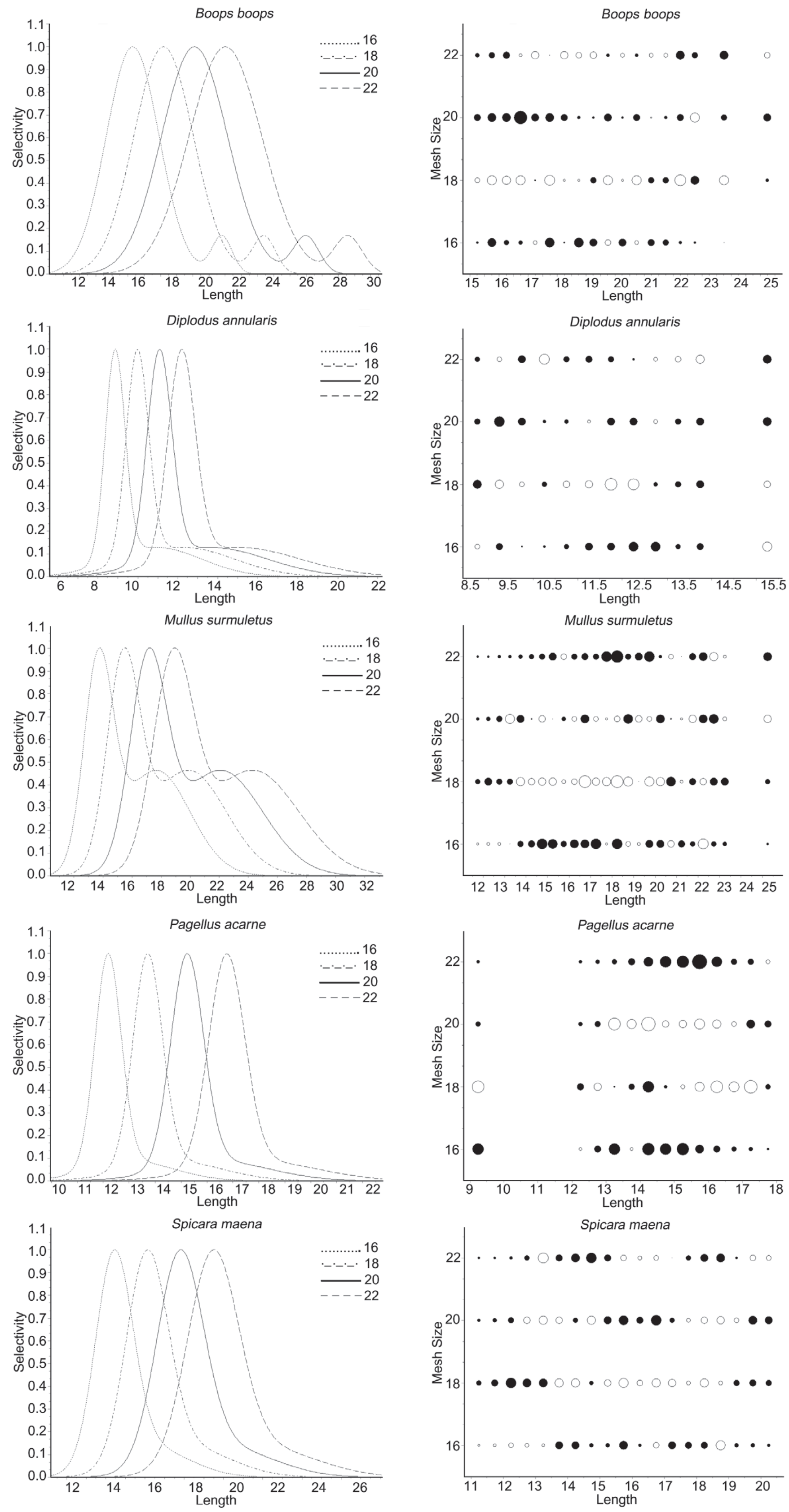

FIG. 3. – Selectivity curves of gill net for the five species and deviance residual plots. Full circle indicates a positive residual and a open circle a negative residual.

Table 8. – The SELECT model parameter estimates for trammel net selectivity.

Species	Model	Equal fishing powers Parameters	M.deviance	p	Fishing power α mesh-size (bar length) Parameters	M.deviance	p	d.f.
B. boops	Normal location	(k, σ)= (1.013, 3.267)	48.82	0.1598	(k, σ)= (1.046, 3.323)	48.18	0.1756	40
	Normal scale	(k_1, k_2)= (1.020, 0.196)	47.12	0.2042	(k_1, k_2)= (1.057, 0.193)	47.16	0.2032	40
	Gamma	(α, k)=(33.306, 0.031)	46.36	0.2266	(α, k)=(34.306, 0.031)	46.36	0.2266	40
	Log normal	(μ, σ)=(2.813, 0.169)	46.18	0.2321	(μ, σ)=(2.842, 0.169)	46.18	0.2321	40
	Bi-modal	No fit			No fit			
D. annularis	Normal location	(k, σ)= (0.610, 1.911)	116.15	0.0000	(k, σ)= (0.626, 1.936)	115.81	0.0000	49
	Normal scale	(k_1, k_2)= (0.629, 0.111)	130.80	0.0000	(k_1, k_2)= (0.648, 0.110)	131.34	0.0000	49
	Gamma	(α, k)=(38.751, 0.016)	113.74	0.0000	(α, k)=(39.751, 0.016)	113.74	0.0000	49
	Log normal	(μ, σ)=(2.292, 0.156)	105.57	0.0000	(μ, σ)=(2.316, 0.156)	105.57	0.0000	49
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.551, 0.033, 0.733, 0.127, 0.358)	65.87	0.0288	(k_1, k_2, k_3, k_4, c)=(0.553, 0.033, 0.754, 0.125, 0.482)	66.03	0.0279	46
M. surmuletus	Normal location	(k, σ)= (1.078, 3.377)	172.47	0.0000	(k, σ)= (1.109, 3.418)	171.11	0.0000	85
	Normal scale	(k_1, k_2)= (1.125, 0.181)	213.81	0.0000	(k_1, k_2)= (1.153, 0.178)	214.88	0.0000	85
	Gamma	(α, k)=(34.445, 0.032)	184.51	0.0000	(α, k)=(35.445, 0.032)	184.51	0.0000	85
	Log normal	(μ, σ)=(2.864, 0.178)	173.24	0.0000	(μ, σ)=(2.895, 0.178)	173.24	0.0000	85
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.919, 0.092, 1.384, 0.213, 1.445)	147.03	0.0000	(k_1, k_2, k_3, k_4, c)=(0.928, 0.091, 1.415, 0.209, 2.192)	147.21	0.0000	82
P. acarne	Normal location	(k, σ)= (0.885, 2.208)	61.48	0.0334	(k, σ)= (0.902, 2.241)	61.05	0.0363	43
	Normal scale	(k_1, k_2)= (0.903, 0.120)	68.55	0.0079	(k_1, k_2)= (0.919, 0.119)	68.61	0.0078	43
	Gamma	(α, k)=(54.837, 0.017)	65.23	0.0159	(α, k)=(55.837, 0.017)	65.23	0.0159	43
	Log normal	(μ, σ)=(2.675, 0.138)	63.89	0.0209	(μ, σ)=(2.694, 0.138)	63.89	0.0209	43
	Bi-modal	No fit			No fit			
S. maena	Normal location	(k, σ)= (0.875, 2.248)	78.86	0.0192	(k, σ)= (0.892, 2.268)	78.07	0.0221	55
	Normal scale	(k_1, k_2)= (0.891, 0.120)	90.91	0.0017	(k_1, k_2)= (0.907, 0.119)	91.08	0.0016	55
	Gamma	(α, k)=(53.234, 0.017)	82.95	0.0088	(α, k)=(54.234, 0.017)	82.95	0.0088	55
	Log normal	(μ, σ)=(2.651, 0.140)	79.73	0.0163	(μ, σ)=(2.671, 0.140)	79.73	0.0163	55
	Bi-modal	(k_1, k_2, k_3, k_4, c)=(0.826, 0.079, 1.083, 0.072, 0.648)	65.13	0.1044	(k_1, k_2, k_3, k_4, c)=(0.834, 0.078, 1.088, 0.072, 0.847)	65.14	0.1043	52

Table 9. – Modal length and spread values for the best-fitting model of trammel net selectivity curves.

Species	Model	Trammel net mesh size (bar length) 16 mm		18 mm		20 mm		22 mm	
		M.length	Spread	M.length	Spread	M.length	Spread	M.length	Spread
B. boops	Log-normal	16.20	2.88	18.22	3.24	20.24	3.60	-	-
D. annularis	Bi-modal	8.82	0.53	9.93	0.60	11.03	0.66	12.13	0.73
M. surmuletus	Bi-modal	14.70	1.47	16.54	1.65	18.38	1.84	20.22	2.02
P. acarne	Normal location	14.16	2.21	15.94	2.21	17.71	2.21	19.48	2.21
S. maena	Bi-modal	13.22	1.26	14.87	1.41	16.52	1.57	18.18	1.73

five species for the four trammel net mesh sizes for the best model are shown in Table 9. The modal lengths of all five species as well as the spread values increased with mesh size.

DISCUSSION

Several studies have compared the selectivity; catch composition and size-frequency distributions of different fishing gears. The gear selectivity and length frequency distributions of Greenland halibut (*Reinhardtius hippoglossoides*), cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*), caught by trawls, longlines and gill nets, have been compared by Huse *et al.* (1999; 2000). Stergiou and Erzini (2002) and Erzini *et al.* (2003) compared length frequency distribution and gear selectivity for several species captured by longlines and gill nets. In these studies, it was found that the catch proportions, length frequency distributions and gear selectivity of species caught by different fishing gears were different. There are relatively few studies that compare gill nets and trammel nets. Fabi *et al.* (2002) used

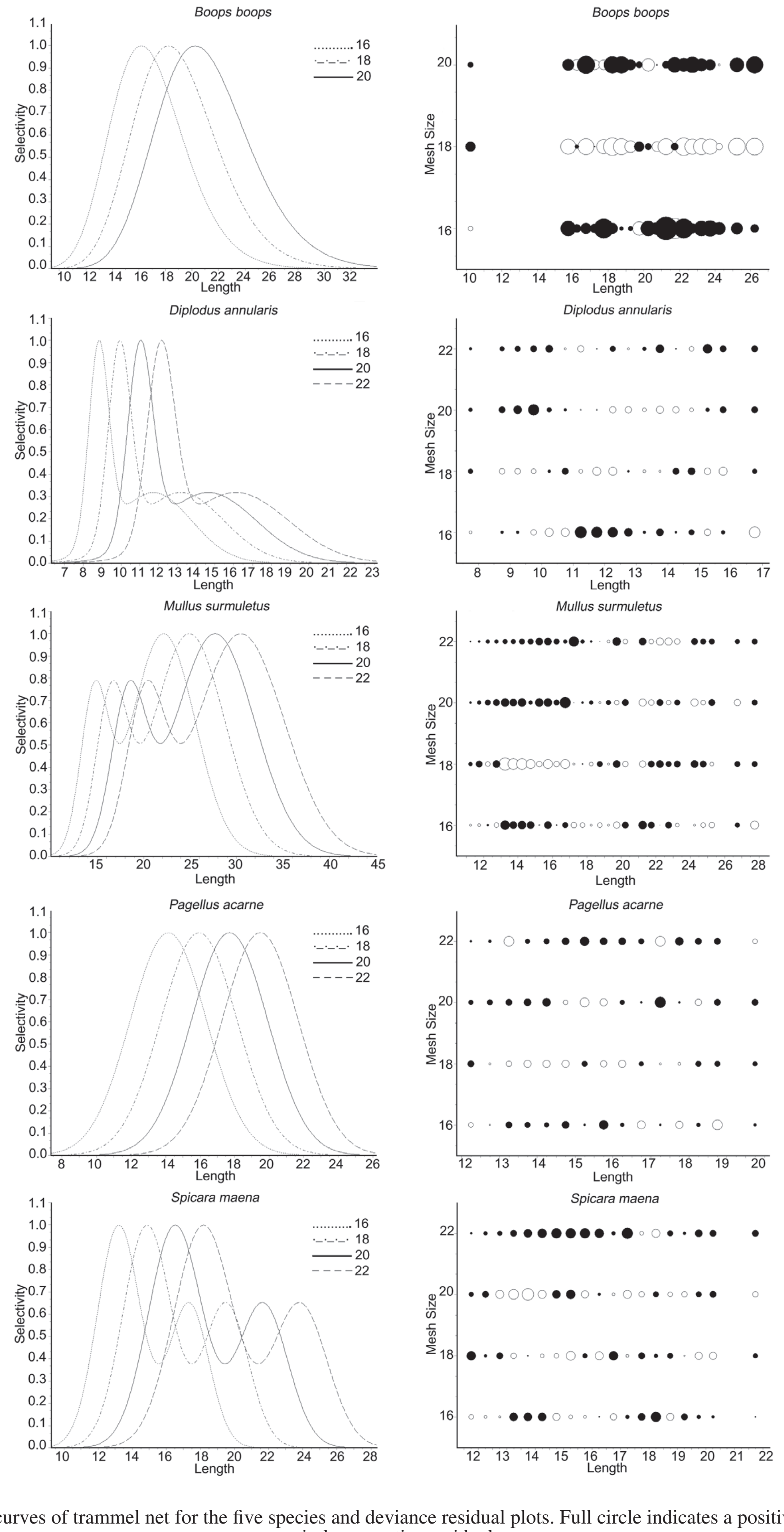

Fig. 4. – Selectivity curves of trammel net for the five species and deviance residual plots. Full circle indicates a positive residual and a open circle a negative residual.

the Sechin method to estimate the gear selectivity of *Lithognathus mormyrus*, *Diplodus annularis* and *Mullus barbatus* caught by gill and trammel nets. Fabi *et al.* (2002) reported that most fishes of the three target species were caught by gilling and/or wedging. With all gears a number of individuals were also caught due to the tangled and/or pocket effect. The proportion of fish caught in this way was smallest and generally negligible in gill nets, larger in monofilament nets and largest in the standard trammel nets. It caused a progressive widening of size-catch ranges, which confirms the low selectivity of trammel nets.

In the present study, the SELECT method was used to estimate and compare the gear selectivity of *B. boops, D. annularis, M. surmuletus, P. acarne* and *S. maena* caught by gill and trammel nets. The bi-normal model selectivity curves gave the best fit for both the gill and trammel net data. Log-normal and normal location were used to obtain the trammel net selectivity curve for *B. boops* and *P. acarne* respectively.

Normal, log-normal and gamma selection curves are useful for describing bell shaped selection curves (unimodal curves). Although in practice these expressions often lead to very similar selection curves, the latter two formulations allow a moderate amount of skewness (Millar and Holst, 1997; Hovgård *et al.*, 1999). Bi-normal models have been suggested to be particularly appropriate for situations in which the fish are caught by two different processes, e.g. typically gilled or caught by the mouth parts or tangled (Holt, 1963; Hovgård, 1996). A bi-normal selectivity curve is a mixture of two normal scale curves. This curve is very flexible and can attain a number of different shapes (Hovgård, 1996).

Several studies reported the bi-normal model as the best model to fit the gear selectivity of gill and trammel nets: Hovgård (1996; cod gill nets), Fujimori and Tokai (2001; pink salmon gill nets), Moth-Poulsen (2003; flounder trammel nets), Erzini *et al.* (2003; several species caught by gill nets), Erzini *et al.* (2006; finfish caught with monofilament trammel nets), Park *et al.* (2004; *K. punctatus* seine nets) and Sbrana *et al.* (2007; *Merluccius merluccius* gill nets). Fonseca *et al.* (2005) reported that the bi-normal model is the best fitting model for the selectivity curve of *Citharus linguatula, Mullus surmuletus, Pagellus acarne, Trachurus trachurus, Merluccius merluccius, S. canicula* and *T. luscus* in the gill net fishery.

Little difference was found between the modal lengths of the selectivity curves of gill nets and trammel nets used to catch *B. boops, D. annularis, M. surmuletus, P. acarne* and *S. maena*. However, in catching efficiency, a clear difference was found. Thomas *et al.* (2003) reported trammel nets caught on average two times more prawns than monofilament gill nets. The better catching efficiency of trammel nets compared to gill nets for prawns and finfish can be explained by their entangling capacity.

The selectivity curves of five species in the gill net and trammel net fisheries were compared and a wide selection range of 50% relative efficiency was found for trammel nets. The selectivity curve for the gill net was narrower. The modal length found using the SELECT method was greater than the expected values. It is assumed that the "Principle of Geometric Similarity" (Baranov, 1948) was probably the reason for this situation (Erzini *et al.*, 2003; Santos *et al.*, 2003). In the GILLNET software, only one model (normal location) is not based on this principal.

In Table 10 the estimated modal lengths of five species captured by gill nets are compared to those reported by several authors in the eastern Atlantic and Mediterranean. The estimated values are similar. The differences between the optimum catch sizes may have been caused by the characteristics of the nets (stretching ratio, thickness, mesh size, etc.) and different selectivity methods.

There are only two previous studies that compared gill and trammel net selectivity of the five species examined in the present study. Fabi *et al.* (2002), using the Sechin method for estimating selectivity, reported that the optimal catch size of *Diplodus annularis*, captured by gill and trammel nets with a full mesh size of 45 mm, was 12.10 cm in the Adriatic and Ligurian waters. In the present study, the optimal catch size for gill and trammel nets with a mesh size (bar length) of 22 mm was 12.13 cm and 12.19 cm total length respectively. In another study, Erzini *et al.* (2006), using the SELECT model for estimating selectivity, reported that the bi-modal model was clearly the best for *M.surmuletus, D.annularis* and *S.maena*, caught by trammel nets with full inner panel mesh sizes of 40, 48 and 56 mm. The estimated values are similar in this study and the present study.

The biology of the target species should be taken into account when implementing fishing regulations. The size at sexual maturity of the fish in the study is given in Table 11. If we consider the size at first

Table 10. – Comparative results of the selection data obtained in the present study and in other studies carried out in the north-eastern Atlantic and Mediterranean Seas.

Species	Area	Method	Length (cm)	Full Mesh size (mm)	Model length (cm)	Spread (cm)	References
B. boops	Cyclades (Greece)	SELECT/normal scale		44	22.94	1.43	Stergiou and Erzini (2002)
				48	25.02	1.56	
	North Aegean Sea (Turkey)	SELECT/bi-modal	15.3-27.8	32	15.28	1.64	Present study
				36	17.19	1.84	
				40	19.10	2.05	
				44	21.01	2.25	
D. annularis	Cyclades (Greece)	SELECT/log-normal	10-20	44	12.52	1.20	Stergiou and Erzini (2002)
				48	13.66	1.31	
				52	14.79	1.42	
				56	15.93	1.53	
	Aegean Sea (Turkey)	HOLT	8.5-14.5	36	10.08		Metin *et al.* (1998)
				40	11.20		
				42	12.32		
	Aegean Sea (Turkey)	HOLT	10-16	52	12.66		Kara (2003)
				54	13.15		
				56	13.64		
	Aegean Sea (Turkey)	SECHIN	10-17.5	52	12.50		Özekinci (2005)
				54	13.50		
				56	14.00		
	North Aegean Sea (Turkey)	SELECT/bi-modal	8.5-15.4	32	8.86	0.49	Present study
				36	9.97	0.56	
				40	11.08	0.62	
				44	12.19	0.68	
M. surmuletus	Aegean Sea (Greece)	HOLT	11-23	38	15.40	1.05	Petrakis and Stergiou (1995)
				42	17.10		
				46	18.80		
	Cyclades (Greece)	SELECT/log-normal	12-30	44	20.17	2.24	Stergiou and Erzini (2002)
				48	22.09	2.44	
	Portugal	SELECT/bi-modal	16-38	40	16.10	0.55	
				60	24.20	0.83	
				70	28.30	0.97	
				80	32.30	1.11	
	North Aegean Sea (Turkey)	SELECT/bi-modal	11.8-25.3	32	13.68	1.00	Present study
				36	15.39	1.13	
				40	17.10	1.25	
				44	18.81	1.38	
P. acarne	Aegean Sea (Greece)	HOLT	10-23	42	15.40	1.08	Petrakis and Stergiou (1996)
				46	16.90		
	South Portugal	SELECT/normal scale	13-34	50	19.26	2.28	
				60	23.11	2.73	
				70	26.96	3.19	
				80	30.81	3.64	
	West Portugal	SELECT/bi-modal	16-36	60	21.30	1.61	
				70	24.80	1.88	
				80	28.30	2.15	
				90	31.90	2.41	
	North Aegean Sea (Turkey)	SELECT/bi-modal	9.1-17.5	32	12.19	0.50	Present study
				36	13.71	0.57	
				40	15.23	0.63	
				44	16.76	0.69	
S. maena	Cyclades	SELECT/log-normal	14-24	44	18.54	1.91	Stergiou and Erzini (2002)
				48	20.23	2.08	
				52	21.92	2.25	
				56	23.60	2.43	
				44	16.76	0.69	
	North Aegean Sea (Turkey)	SELECT/bi-modal	11.0-20.3	32	13.42	0.95	Present study
				36	15.10	1.07	
				40	16.78	1.19	
				44	18.46	1.30	

sexual maturation, it seems that mesh sizes of 18, 20 and 22 mm in the gill and trammel net fisheries would be suitable in order to protect the stocks of *B. boops*, *M. surmuletus*, *P. acarne* and *S.maena* in the northern Aegean Sea. It is obvious that the gill nets and trammel nets with a mesh opening of 16 mm create a fishing pressure on the striped red mullet stocks. Gill nets with a mesh size of 27 and 28 mm (Kara, 2003; Ozekinci, 2005), and 30 mm (Santos *et al.*, 1998) were reported to be suitable for catch-

TABLE 11. – The previous size records of first maturity and minimum catch sizes of the studied species in different regions.

	Min. catch size	Size at 1st maturity	Area	Reference
B. boops	-	13 cm	W-Mediterranean	Fischer and Schneider (1987)
				Froese and Pauly (2006)
D. annularis	-	10 cm	E-Atlantic, Mediterranean	Whitehead *et al.* (1986)
		13 cm	S-Portugal	Santos *et al.* (1998)
		8-10 cm	W-Mediterranean	Fischer and Schneider (1987)
		10.3 cm (male)	Canary Islands	Pajuelo and Lorenzo (2001)
		12.8 cm (female)	Canary Islands	Pajuelo and Lorenzo (2001)
M. surmuletus	11 cm	15 cm (male)	Mediterranean	Bougis (1952)
		16 cm (female)	Mediterranean	Bougis (1952)
		14		Fischer and Schneider (1987)
		13.8		Froese and Pauly (2006)
P. acarne	-	13-18 cm	E-Atlantic, Mediterranean	Whitehead *et al.* (1986)
		11 cm	Aegean Sea	JICA (1993)
S. maena	-	9.10 cm	Greece	Mytilineou (1987)

ing the annular sea bream (all the mesh sizes are of bar length). For a sustainable fishery for annular sea bream in the northern Aegean Sea, the available data suggests that the mesh size of gill and trammel nets should be at least 27 mm (bar length).

In Turkish fishery management, despite the many legal regulations for purse-seine, bottom-trawl and longline fisheries, there are no regulations for gill and trammel net fisheries except concerning turbot, flounder and sole. It is prohibited to use gill nets with a mesh size of ≤180 mm (bar length) in the turbot fisheries and gill and trammel nets with a mesh size of ≤72 mm (bar length) in sole and flounder fishery (Anonymous, 2004). Unfortunately, there is little information on the catching efficiency and catch sizes of gill and trammel nets commonly used in Turkish waters. Control over these fisheries is very limited. In order to make regulations for better management, the gill and trammel net fisheries should be strictly controlled. Research into the selectivity of gill and trammel net fisheries is of vital importance to protect fish stocks and maintain a sustainable fishery. In Turkey the main target species of these fisheries are *M. surmuletus* and *M. barbatus*. The mesh sizes used are 16, 18, 20 and 22 mm. Fishermen call these kinds of nets “mullet nets”. However, many economically important and discard species are caught by these nets, which are actually multispecies. It is difficult to manage multispecies fisheries based only on mesh size, since the optimal mesh varies considerably for the different target species.

When considering the number of discard species and individual specimens caught by gill and trammel nets with mesh sizes of 16 and 18 mm there were 15 species and 155 individuals for the gill net with 16 mm mesh size, 24 species and 177 individuals for the trammel net with a 16 mm mesh size, 13 species and 86 individuals for the gill net with a 18 mm mesh size, and 25 species and 97 individuals for the trammel net with a18 mm mesh size. The gill nets and trammel nets with a mesh size of 18 mm caught less discard species and individuals than the nets with the other mesh sizes. Given that many discard species and small fish were caught by the gill nets and trammel nets with a mesh size of 16 mm used in this research, it is clear that these nets are not appropriate for fisheries. However, an 18 mm mesh size, which has a higher catching efficiency, is appropriate for sustaining fishery resources and reducing the number of discard species in the catch. This information is useful for improving the management of these small-scale fisheries.

ACKNOWLEDGEMENTS

This study was supported by the Research Fund of the University of Istanbul with project number 48/23012003. We are grateful to Prof. Dr. Bayram Oztürk (Istanbul University; Turkish Marine Research Foundation), Prof. Dr. Işık K. Oray (Istanbul University), Dr. Ayaka Amaha Oztürk (Turkish Marine Research Foundation, Istanbul University), J.M. Ortiz de Urbina (Instituto Español de Oceanografia, Fuengirola, Málaga), Elif Ozgür and Burcu Bilgin (Istanbul University) for their help.

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Scient. ed.: P. Martín.
Received December 13, 2006. Accepted March 6, 2008
Published online July 7, 2008.