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Body size overlap in industrial and artisanal fisheries for five commercial fish species in the Mediterranean Sea*

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SUMMARY: In this study we present the length frequency distributions of *Boops boops*, *Mullus barbatus*, *Scomber japonicus*, *Spicara smaris* and *Trachurus mediterraneus* caught with different gears (trawls, purse-seines, beach-seines, gill nets, trammel nets and longlines) in Cyclades during 1995-2000. Trawls generally caught the smallest sizes for four out of the five species studied (i.e. *B. boops*, *M. barbatus*, *S. smaris* and *T. mediterraneus*) and purse-seines caught individuals with intermediate sizes between those caught with trawls and small-scale gears. For *S. japonicus*, gill nets caught smaller individuals than those caught with purse-seines and trammel nets. The same general pattern was also observed comparing the seasonal length frequencies of the three most abundant species (i.e. *B. boops*, *T. mediterraneus* and *S. smaris*). Generally, trawls caught immature individuals when compared to small-scale gears and the vast majority of the individuals caught by all gears (with the exception of trammel nets for *M. barbatus*) was smaller than the optimum exploitation size, indicating that the gears examined are not appropriate for the sustainable exploitation of these resources.

Key words: length frequency distributions, artisanal and industrial gears, E Mediterranean, Aegean Sea.

RESUMEN: SOLAPAMIENTO DE TALLAS EN LA PESQUERÍA INDUSTRIAL Y ARTESANAL DE CINCO ESPECIES DE PECES COMERCIALES EN EL MAR MEDITERRÁNEO. – En este estudio presentamos la distribución de frecuencia de tallas de *Boops boops*, *Mullus barbatus*, *Scomber japonicus*, *Spicara smaris* y *Trachurus mediterraneus* capturados con diferentes artes de pesca (arrastre, cerco, artes de playa, redes de enmalle, trasmallos y palangres) en las islas Cícladas, en el periodo 1995-2000. Los arrastreros capturan, generalmente, las tallas mas pequeñas de cuatro de las cinco especies estudiadas (*B. boops*, *M. barbatus*, *S. smaris* y *T. mediterraneus*) mientras que el cerco captura individuos de tallas intermedias entre las capturadas por el arrastre y los artesanales. En el caso de *S. japonicus*, los artes de enmalle capturan individuos más pequeños que los capturados por el cerco y el trasmallo. El mismo patrón general se observó comparando la frecuencia de tallas estacional de las tres especies mas abundantes (*B. boops*, *T. mediterraneus* y *S. smaris*). Generalmente el arrastre captura individuos inmaduros cuando se compara con los artes artesanales y la mayoría de los individuos capturados por todos los artes (con la excepción del trasmallo para *M. barbatus*) son mas pequeños que la talla óptima de explotación, indicando que los artes de pesca examinados no son apropiados para la explotación sostenible de estos recursos.

Palabras clave: distribución de frecuencia de tallas, artes de pesca artesanales e industriales, Mediterráneo oriental, mar Egeo.

INTRODUCTION

Body length is the most important biological parameter, which apart from a plethora of other biological parameters (e.g., longevity and mortality: Pauly, 1980; predator-prey length relationship: Cohen *et al.*, 1993; trophic level: Froese and Pauly, 2002, FishBase online, www.fishbase.org; Pauly *et al.*, 1998a, b; Stergiou and Karpouzi, 2002; fecundity and reproductive success: Ebenman and Persson,

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1988; body girth: Stergiou and Karpouzi, 2003) is also related to a variety of fishery parameters (e.g. management risk and landing variability: Stergiou, 1998; discard rate: Machias *et al*., 2001; optimum exploitation length L_{opt}: Froese and Binohlan, 2000). Length is also commonly used in fisheries science because it is very easy to measure in comparison with other parameters, such as weight, and there are long and continuous length time-series in most fishery institutes (Pauly and Morgan, 1987). Finally, length frequency distributions are used for the estimation of size selectivity for different gears (e.g. Millar and Fryer, 1999). The latter is important for estimating gear overlap in terms of body sizes in order to identify and separate gear-specific imposed mortality rates (Chopin *et al*., 1996).

Fisheries in the Mediterranean Sea are strongly multi-species and multi-gear in nature, with many species, ranging in length from a few centimeters to more than 1 m, being exploited by different gears. Nowadays, there is an increased interest in small-scale fisheries, generally practiced with set gears, and the potential partial replacement of trawl nets by set gears, which are generally more selective, might be beneficial to fisher's livelihoods (Fabi *et al*., 2002). Despite the large number of studies concerning single-gear size-selectivity aspects (see reviews by: Hamley, 1975; Lokkeborg and Bjordal, 1992; Millar and Fryer, 1999), few comparative studies have so far been carried out on size comparisons of species exploited by both industrial and artisanal fisheries (Table 1). Such information is generally lacking for the eastern Mediterranean Sea.

In the present study we compared the length frequency distributions of five commercial fish species (*Boops boops*, *Mullus barbatus*, *Scomber japonicus*, *Spicara smaris* and *Trachurus mediterraneus)* caught with trawls, purse-seines, beach-seines, trammel nets, gill nets and longlines in the Aegean Sea (Cyclades). The five species studied abound in the study area, contributing more than 57% to the total mean landings during 1982-1997 (Stergiou *et al*., 1997). In addition, the length-frequencies were also compared against optimum exploitation length (L_{opt}), length at 50% maturity (L_{50}) and minimum landing size (MLS). All the above mentioned comparisons were used to identify potential gear overlap and competition, as well as the suitability of the different gears for sustainable exploitation.

MATERIALS AND METHODS

Stratified random samples of *Boops boops, Mullus barbatus, Spicara smaris, Scomber japonicus* and *Trachurus mediterraneus* were collected monthly (50 specimens per month) from the commercial landings of one trawl (nominal mesh size: 14 mm bar length), one purse seine (nominal mesh size: 8 mm bar length) and one beach-seine (nominal mesh size: 8 mm bar length) in the fishing ports of Naxos Island (Fig. 1) from September 1995 to December 1997. Consequently, in the laboratory individual fish

TABLE 1. – Comparative studies concerning size comparisons for different species and gears (T, trawls; B, beach seines; G, gill nets; TN, trammel nets; and L, longlines).

Study area	Year	Gear used	Study species	Aim of study	Author
West Greenland	1987 - 1989	L, T	*Gadus morhua*	Size and species selectivity	Hovgard and Riget (1992)
Greenland	1994	G, L, T	*Reinhardtius hippoglossoides*	Size selectivity	Huse *et al*. (1999)
Barents Sea	1992	G, L, T	*Reinhardtius hippoglossoides*	Size and species selectivity	Nedreaas *et al*. (1996)
North Norway	1996	G, L, T	*Gadus morhua* and *Melanogrammus aeglefinus*	Size and species selectivity	Huse *et al*. (2000)
Baltic Sea	1993	G, T	All species caught	Size and species selectivity	Lowry *et al*. (1994)
Rockall Trough, and Porcupine Bank (NE Atlantic)	1995	L, T	All species caught	Size and species selectivity	Connolly and Kelly (1996)
Emerald and LaHave (Scotian Shelf)	1991	L, T	*Gadus morhua* and *Melanogrammus aeglefinus*	Size selectivity	Halliday (2002)
Western Mediterranean	1993 - 1994	TN, T	*Mullus barbatus*	Size and species selectivity	Demestre *et al*. (1997)
Gulf of Lions	1988	G, TN, T	*Merluccius merluccius*	Species selectivity	Aldebert *et al*. (1993)
Eastern Mediterranean (Aegean Sea)	1992	G, TN, B	All species caught	Size and species selectivity	Stergiou *et al*. (1996)
Sydney (NSW Australia)	1989 - 1993	L, T	*Pagrus aurata*	Size selectivity	Otway *et al*. (1996)

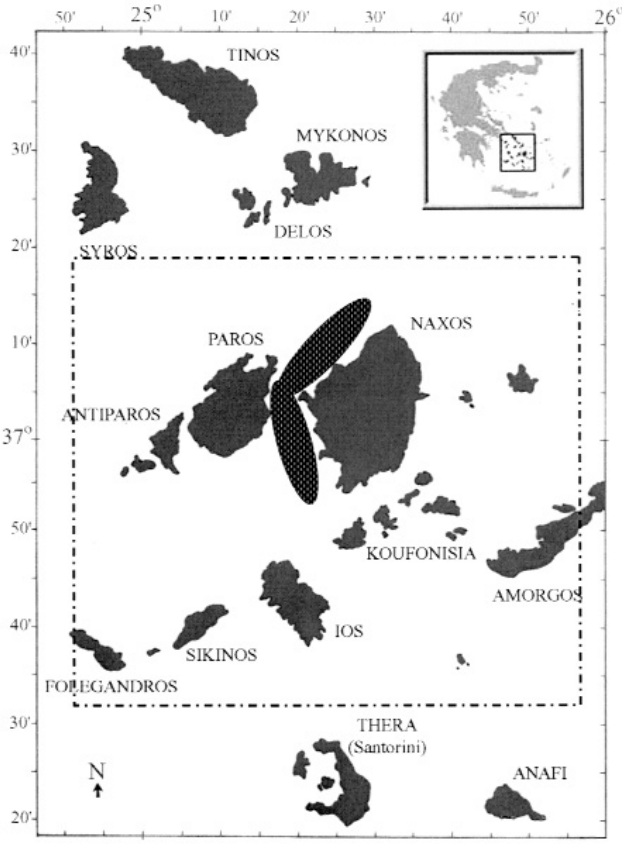

FIG. 1. – Sampling area. The shaded area indicates the fishing grounds sampled by beach-seines, gill nets, trammel nets and long-lines and the box covers the trawl and purse-seine fishing grounds.

were measured for fork length (FL, in cm). Samples were not collected for trawls and beach-seines during the period from 1 June to 30 September , and for purse-seines from 10 December to the end of February, because fishing with these gears is prohibited during these periods.

Samples of four out of five species (i.e. *B. boops, M. barbatus, S. japonicus* and *T. mediterraneus*) were also collected experimentally with trammel nets (nominal inner mesh sizes: 20, 24 and 28 mm, bar length), gill nets (nominal mesh sizes: 22, 24, 26 and 28 mm, bar length) and longlines (Mustad hook sizes: 11>12>13>15) using a chartered commercial small-scale vessel operating from October 1997 to October 1998 for gill nets (42 trials) and longlines (43 trials) and from October 1999 to September 2000 for trammel nets (41 trials). Sampling sites were selected by the fisher in the traditional local fishing grounds. More details on gear construction and sampling are given elsewhere (Stergiou *et al.*, 2001; Stergiou *et al.*, 2002; Stergiou and Erzini, 2002). Consequently, individual fish were measured for total length (TL, in cm). For the purposes of this study, the lengths of all five study species were expressed as TL (in cm), using the equations from Moutopoulos and Stergiou (2002).

Length frequency distributions were constructed for all species per gear, and for the three most abundant species (i.e. *B. boops*, *T. mediterraneus* and *S. smaris*) separately by season. Comparisons of length frequency distributions by different gears and seasons were carried out using the Kolmogorov-Smirnov test (Zar, 1999). In addition, Schoener's overlap index (1970), which is used for estimating niche overlap (*T*), was used here to estimate overlap in terms of length classes between different gears:

$$T = 1 - 0.5\sum_{i=1}^{n}\left|P_{xi} - P_{yi}\right| ,$$

where P_{xi} and P_{yi} are ratios, in terms of numbers, of each length class *i* between two different gears *x* and *y*. The value of the index ranges from 0 when there is no overlap in length classes between the two gears to 1 when there is a complete overlap between the two gears. The degree of overlap is considered to be important when *T* values are greater than 0.6 (Schoener, 1970).

Length frequencies per gear were also compared against the mean length at 50% maturity (L_{50}), the optimum exploitation length (L_{opt}) and the minimun landing size (MLS). The mean L_{50} of the five species studied was extracted from FishBase (Froese and Pauly, 2002) for all species except for *T. mediterraneus*, for which the value reported for Saronikos Gulf (Karlou-Riga, 1995) was used. The MLS values were taken from the EU Regulation 1626/1994. Finally, L_{opt} was estimated from the L_{oo} reported in Greek waters taken from Stergiou *et al.* (1997) using the empirical formula of Froese and Binohlan (2000). All the above mentioned parameters are shown in Table 2. L_{50}, L_{opt} and MLS were all expressed in TL (in cm).

TABLE 2. – L_∞ (in cm), L_{50} (length at 50% maturity, in cm), L_{opt} (optimum exploitation length, in cm) and MLS (minimum landing size, in cm) of the five species examined.

Species	L_∞[1]	L_{50}[2]	L_{opt}[3]	MLS[4]
Boops boops	33.9	19.8	20.9	11.0
Mullus barbatus	21.5	13.1	13.0	11.0
Scomber japonicus	55.4	30.7	34.9	18.0
Spicara smaris	21.0	12.9	12.7	11.0
Trachurus mediterraneus	39.9	20.0	24.8	12.0

[1]from Stergiou *et al.* (1997)
[2]from www.fishbase.org
[3]estimated from the L_∞ reported in Greek waters (values taken from Stergiou *et al.,* 1997) using the empirical formula of Froese and Binohlan (2000)
[4]from EU Regulation 1626/1994.

TABLE 3. – Descriptive statistics of total length (TL, in cm) for each species in each different gear, Cyclades 1995-2000. N is the number of individuals; Mean is the average TL; Median is the median TL; Mode is the number of main modes in length-frequencies; Minimum and Maximum are the minimum and maximum TL; SE is the standard error of TL; $\%L_{50}$ is the percentage of individuals with TL smaller than the length at 50% maturity (L_{50}); and $\%L_{opt}$ is the percentage of individuals with TL smaller than optimum exploitation length (L_{opt}).

Species/Gear	N	Mean	Median	Mode	Minimum	Maximum	SE	$\%L_{50}$	$\%L_{opt}$
Boops boops									
Purse-seines	947	18.1	17.9	1	11.8	27.1	0.077	78.2	86.5
Trawls	782	15.5	15.4	1	10.4	22.0	0.074	97.2	99.0
Trammel nets	522	19.8	19.7	1	11.5	26.3	0.097	50.4	72.6
Gill nets	106	21.7	22.0	2	14.5	28.1	0.204	14.2	25.5
Longlines	18	22.1	22.4	1	16.6	25.7	0.548	11.1	27.8
Mullus barbatus									
Trawls	836	14.9	14.9	2	10.7	22.7	0.063	16.3	15.3
Trammel nets	184	18.3	18.5	1	13.1	23.1	0.119	0.0	0.0
Gill nets	15	20.6	20.7	1	19.1	22.5	0.238	0.0	0.0
Scomber japonicus									
Purse-seines	519	26.2	26.0	1	21.3	32.8	0.093	98.7	100.0
Trammel nets	54	28.0	28.4	1	23.1	33.8	0.321	88.9	100.0
Gill nets	71	25.7	25.1	1	22.9	33.0	0.244	97.2	100.0
Spicara smaris									
Trawls	833	12.1	11.6	1	5.8	17.0	0.056	72.4	71.9
Beach-seines	636	13.0	12.8	1	6.7	17.7	0.071	51.1	48.3
Trachurus mediterraneus									
Purse-seines	576	22.3	22.0	1	12.4	32.2	0.111	21.2	79.7
Trawls	313	17.7	18.2	1	12.8	24.2	0.125	91.4	100.0
Trammel nets	355	24.1	23.7	1	18.3	33.7	0.121	0.6	66.2
Gill nets	194	24.9	24.6	1	17.3	34.1	0.209	3.6	53.6

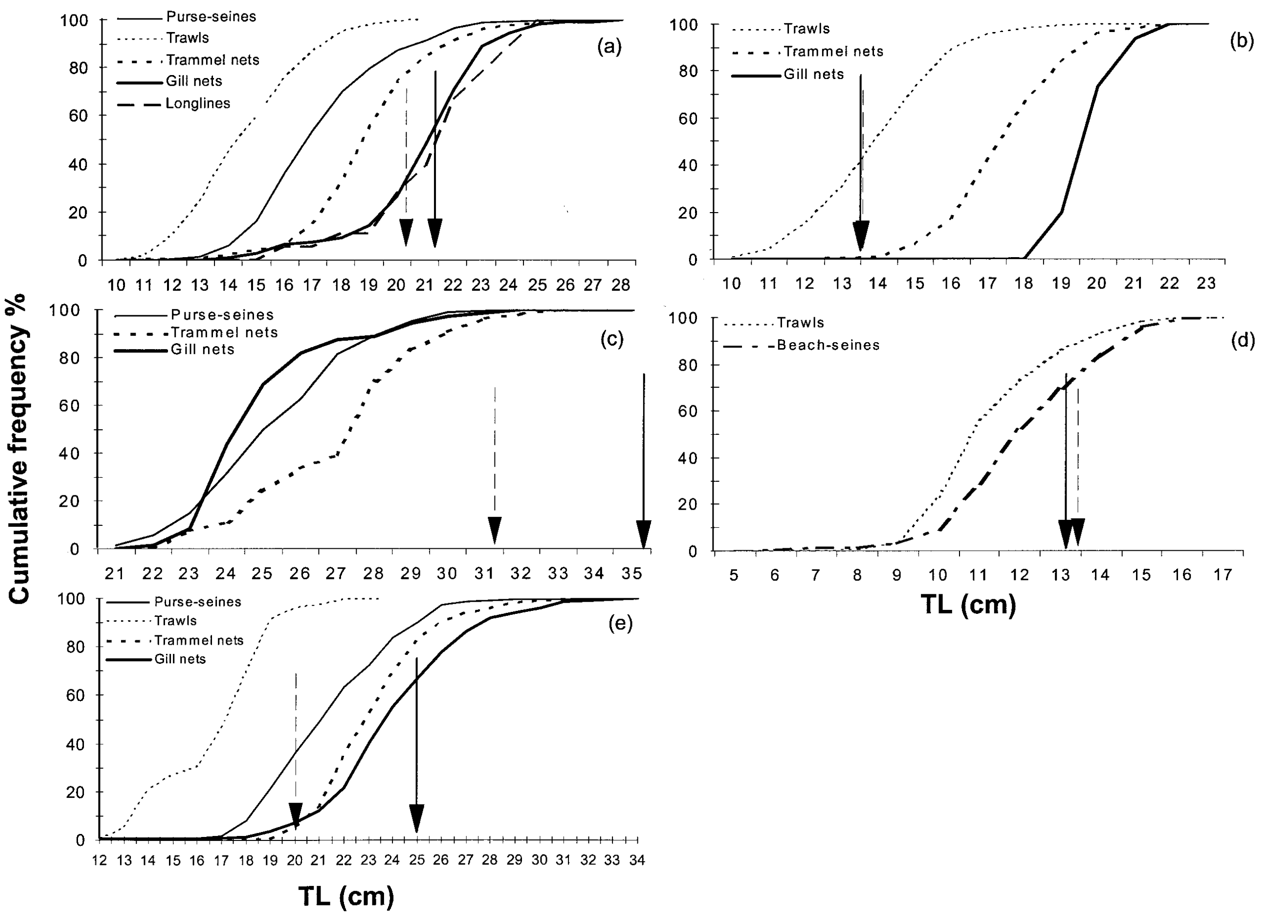

FIG. 2. – Cumulative length frequency distributions for the different gears used for: (a) *Boops boops*, (b) *Mullus barbatus*, (c) *Scomber japonicus*, (d) *Spicara smaris* and (e) *Trachurus mediterraneus*, Cyclades, 1995-2000. Dotted arrow indicates the mean length at 50% maturity (L_{50}), whereas the continuous arrow the optimum exploitation length (L_{opt}).

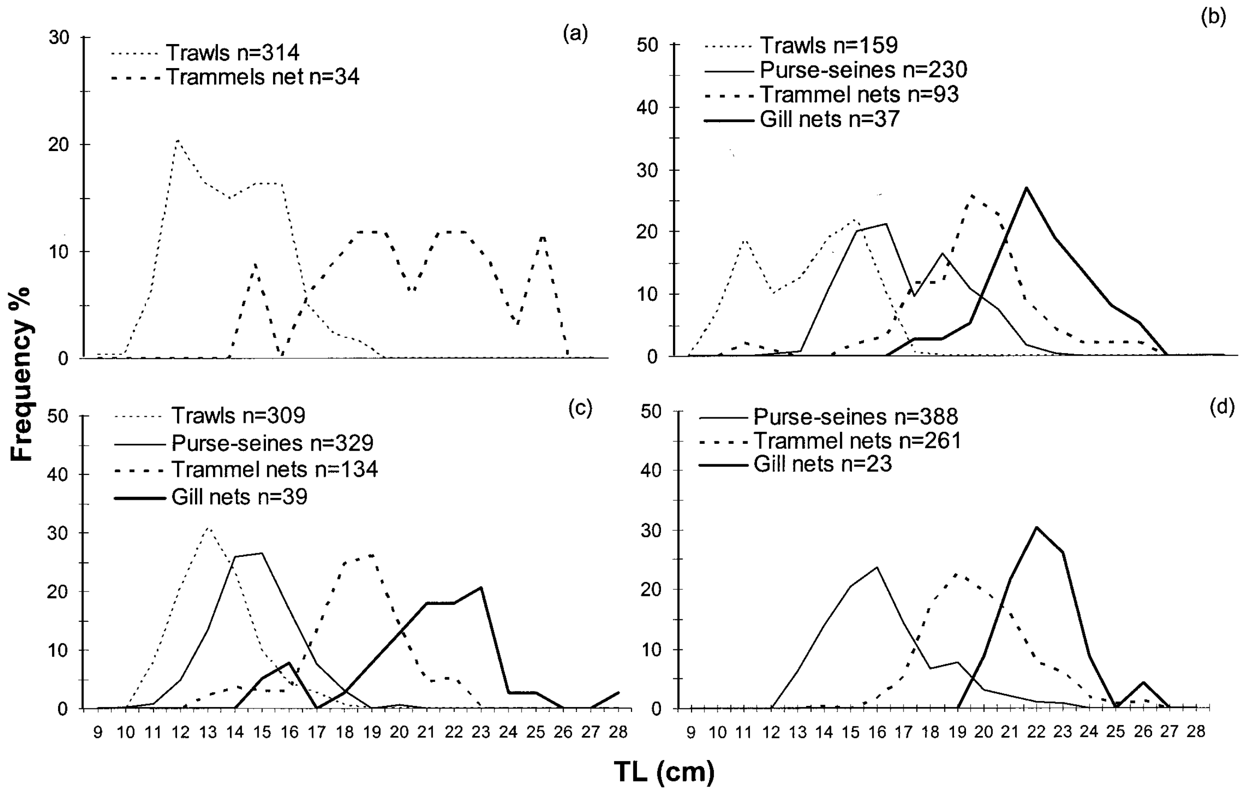

FIG. 3. – Seasonal length frequency distributions of *Boops boops* per gear used in (a) autumn, (b) winter, (c), spring and (d) summer, Cyclades, 1995-2000; n= numbers of individuals.

RESULTS

The length characteristics of the five species studied are shown in Table 3. *B. boops* was collected with all gears except beach-seines. *M. barbatus* was collected with trawls, gill nets and trammel nets, *S. japonicus* with purse-seines, gill nets and trammel nets, *S. smaris* with trawls and beach-seines and *T. mediterraneus* with purse-seines, trawls, gill nets and trammel nets. The cumulative length frequency distributions (Fig. 2) revealed that for all species trawls caught smaller individuals than all other gears (Table 3, Fig. 2). Thus, the median length of the four above-mentioned species caught with trawls were 15.4, 14.9, 11.6 and 18.2 cm respectively, compared with the median length of the individuals of the same species caught with the remaining gears that were larger than 17.9, 18.5, 12.8 and 22.0 cm respectively (Table 3, Fig. 2). For all species, purse-seines caught individuals with intermediate sizes between those caught with trawls and artisanal gears. For *S. japonicus*, the median length of the individuals caught with gill nets (25.1 cm) was smaller than those caught with purse-seines and trammel nets (26.0 and 28.4 cm respectively) (Table 3, Fig. 2).

The percentage of immature individuals (i.e. those with TL < L_{50}) was greater for trawls in all species caught with this gear (Table 3). It was lower for longlines for *B. boops*, for nets for *M. barbatus* and *T. mediterraneus*, and for beach-seines for *S. smaris* (Table 3). The only exception was *S. japonicus,* for which the percentage of immature individuals was very high for all gears studied (for all cases > 88.9%). The percentage of individuals with TL < L_{opt} (Table 3), was high for all gears and all species studied (for all cases > 50.0%), with the exception of *M. barbatus* for all gears used (i.e., < 15.3%) and *B. boops* for nets (i.e. < 27.8%).

The application of the Kolmogorov-Smirnov test indicated that for all species the length frequencies differed significantly (P < 0.001) between all pairs of gears, with the exception of the gillnet-longline pair for *B. boops* (P = 0.085). Size overlap, for *B. boops*, was great between longlines, gill nets and trammel nets and between purse-seines and trammel nets (for all cases: T > 0.50). For *T. mediterraneus* and *S. japonicus*, overlap was also great between gill nets, trammel nets and purse-seines (for all cases: T > 0.51). Finally, for *S. smaris* there was a great overlap between trawls and beach-seines (T = 0.72), whereas for *M. barbatus* the degree of overlap

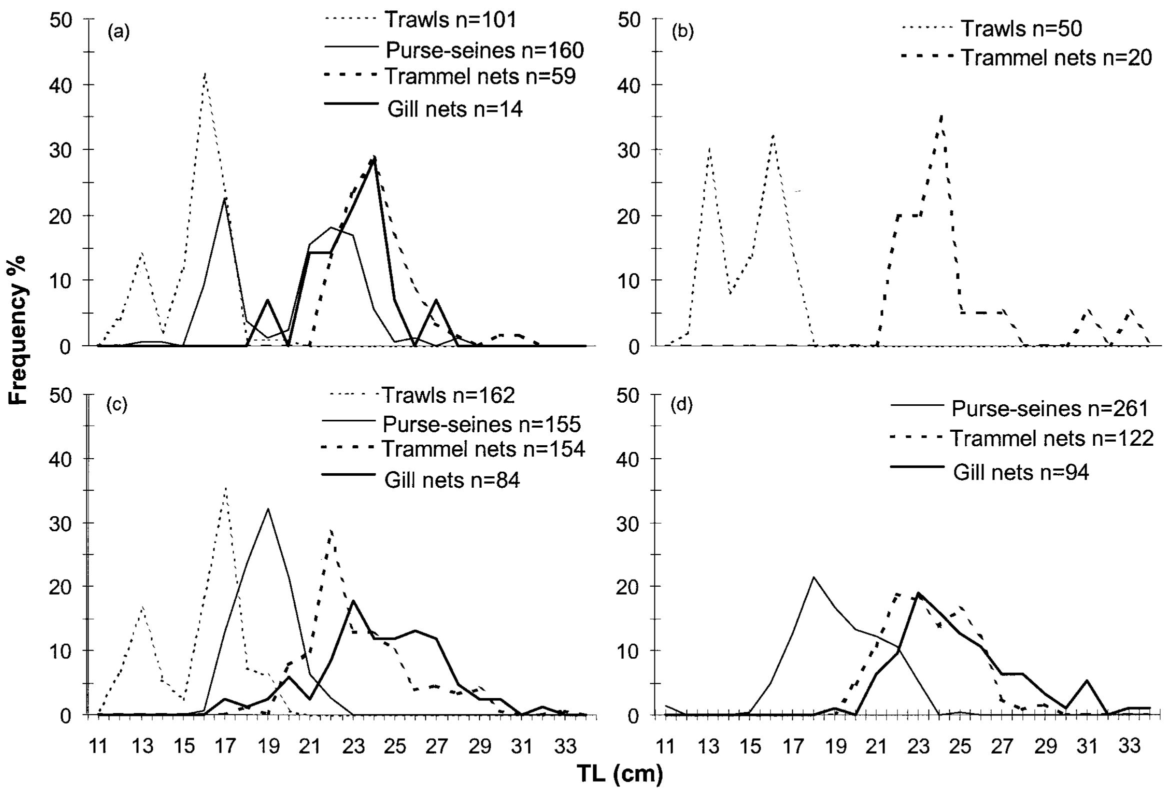

FIG. 4. – Seasonal length frequency distributions of *Trachurus mediterraneus* per gear used in (a) autumn, (b) winter, (c) spring and (d) summer, Cyclades, 1995-2000; n= numbers of individuals.

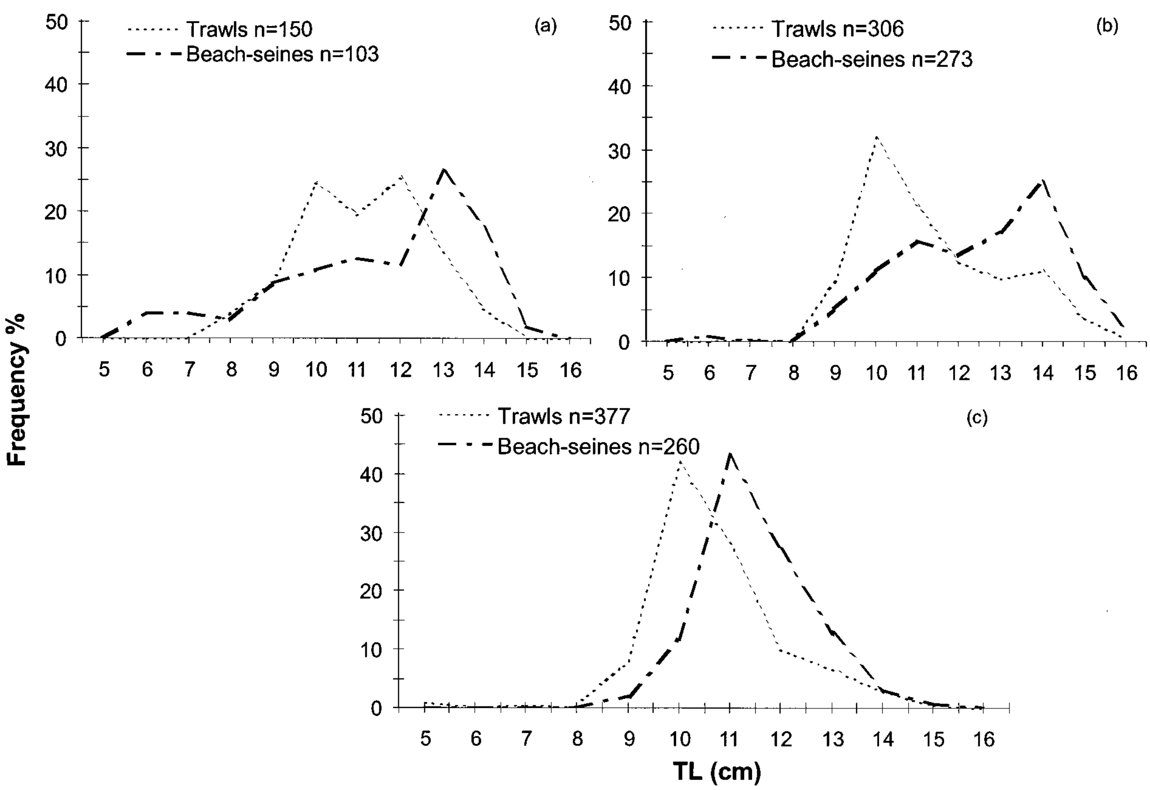

FIG. 5. – Seasonal length frequency distributions of *Spicara smaris* per gear used in (a) autumn, (b) winter and (c) spring, Cyclades, 1995-2000; n= numbers of individuals.

TABLE 4. – Results of the Kolmogorov-Smirnov test for pairs of length frequency distributions for different gear-season combinations for *Boops boops* and *Trachurus mediterraneus*, which did not differ significantly (P > 0.05) for each pair of gear-season combination.

Species	Gear/Season			
Boops boops	Trammel net	Gill net		
Gill net	Winter	Autumn	Spring	Summer
Autumn	0.146	-		
Spring	0.361	0.594	-	
Summer		0.183	0.072	-

Species	Gear/Season				
Trachurus mediterraneus	Trammel net				Gill net
Trammel net	Autumn	Winter	Spring	Summer	Spring
Winter	0.758	-			
Spring		0.032	-		
Summer		0.373		-	
Gill net					
Autumn	0.188	0.425	0.825	0.299	
Spring		0.170			-
Summer	0.073	0.303			0.674

among the different gears was not great (for all cases: T < 0.33).

The seasonal length frequencies of the three most abundant species, *B. boops*, *T. mediterraneus* and *S. smaris*, are shown in Figures 3 to 5. In general, for all species in all seasons, trawls caught smaller individuals than the remaining gears. Gill nets caught larger individuals in autumn, winter and spring for *B. boops* (Fig. 3), and in spring and summer for *T. mediterraneus* (Fig. 4), than the remaining gears, whereas beach-seines caught larger individuals of *S. smaris* (Fig. 5) in all seasons. The application of the Kolmogorov-Smirnov test for all gear (i.e. trawls, purse-seines, beach-seines, gill nets, trammel nets and longlines) and season (autumn, winter, spring and summer) combinations indicated that for *B. boops* and *T. mediterraneus* the majority of the length frequencies distributions differed significantly (P < 0.001) between all pairs of gear-season combinations, with few exceptions, which are shown in Table 4. Finally, for *S. smaris* the length frequencies differed significantly (P < 0.001) between all pairs of gear-season combinations.

DISCUSSION

Although the present study suffers from certain limitations (i.e. low number of commercial vessels sampled; small number of individuals examined per gear type and season; different years sampled by different gears), the results show certain consistent patterns. Thus, the results indicated that although significant differences (P < 0.05) were found in the size compositions for the five species (*B. boops*, *M. barbatus*, *S. japonicus*, *S. smaris* and *T. mediterraneus*) caught with trawls, purse-seines, beach-seines, gill nets, trammel nets and longlines, both within and between seasons, a fact indicating that each gear mainly targets a specific part of the stock size structure, there was a great overlap in the sizes caught with the different gears (Fig. 6). In addition, most species were caught with more than one gear (i.e. from two to five gears; multi-gear fisheries).

Our results also indicated that in general, trawls caught immature individuals when compared to artisanal gears. This is typical of the Mediterranean Sea, where trawl landings are generally composed of the smallest, immature individuals of a species, with sizes smaller than the MLS that are either discarded or marketed illegally (Stergiou *et al*., 1997; Machias *et al*., 2001). In addition, the vast majority of the individuals caught by all gears (with the exception of trammel nets for *M. barbatus*) had lengths smaller than L_{opt}, a fact indicating that these gears are not appropriate for sustainable exploitation.

However, the effect of each gear on the different species, and thus on the imposed fishing mortalities, must be evaluated based on their relative participation to the local landings. The total official number of boats registered in Cyclades amounts to 264 boats, 8 (3.1%) of which are trawlers, 13 (4.9%) purse-seiners, 18 (6.8%) beach seiners and 225 (85.2%) other small boats of lengths ranging from 3.5 to 15 m (data from the Department of Fisheries, Prefecture of Cyclades). Forty-seven (47) out of the 225 artisanal boats registered use trammel and gill nets as the main gear. The remaining 178 boats use trammel and gill nets as secondary fishing gears. With respect to landings, both artisanal and industri-

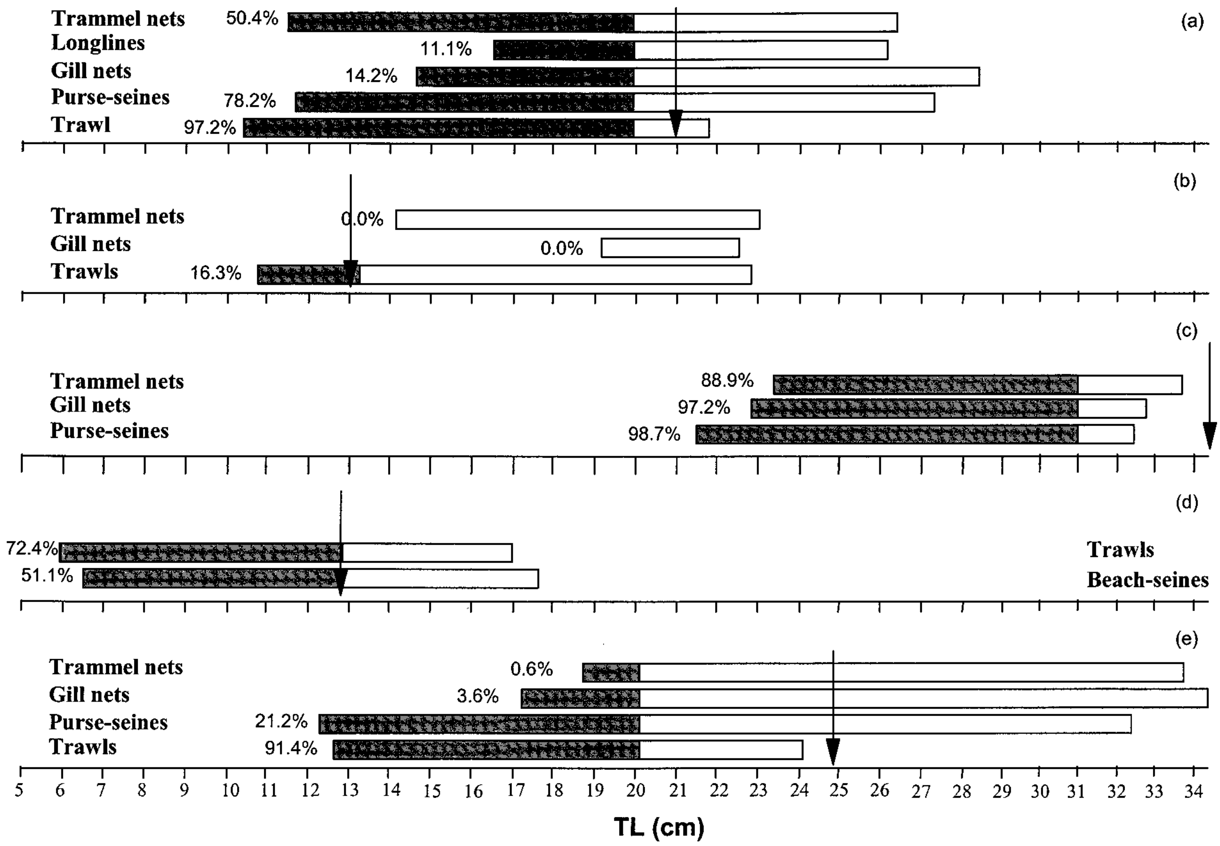

FIG. 6. – Length overlap for different gears used for: (a) *Boops boops*, (b) *Mullus barbatus*, (c) *Scomber japonicus*, (d) *Spicara smaris*, and (e) *Trachurus mediterraneus*, Cyclades, 1995-2000. The bar (dark grey and white part) represents the total size range of the species' landings, the dark grey part of the bar indicates immature individuals (i.e. those with TL smaller than L_{50}) of each species and the percentages next to each bar indicate the percentage of immature individuals caught with each gear. Arrows denote the optimum exploitation length (L_{opt}).

al fisheries share an almost equal proportion. Thus, 52% of the total reported landings are attributed to the artisanal fisheries (small-scale boats: 34%; beach-seines: 18%) and 48% to the industrial fisheries (purse-seines: 33%; trawls: 15%) (NSSH, 1997). In addition, the impact of the industrial gears on fishing mortality for four out of the five species studied (i.e., *B. boops*, *M. barbatus*, *S. smaris* and *T. mediterraneus*) seems to be more detrimental than artisanal gears, as indicated by the analysis of the mean catch per day of these species (data are not available for *S. japonicus*; Anon., 2001). Thus, in Cyclades the total mean catch (in kg) per day for *B. boops*, *M. barbatus*, *S. smaris* and *T. mediterraneus* were 314.6, 37.0, 208.1 and 113.7 kg/day respectively (Anon., 2001). The mean catch per day of *B. boops* and *Trachurus* spp. was mainly attributed to purse-seines (77.7 and 89.2% respectively) and for *M. barbatus* and *S. smaris* to trawls and beach-seines (40.2 and 28.1%; 55.6 and 24.1% respectively), whereas the mean catch per day of the artisanal gears was comparatively small (for all species: < 14.7%) (Anon., 2001). It is worthy of mention that the monthly catch per day of the four above-mentioned species in Cyclades declined significantly ($P < 0.05$) with time during the period 1996-2000 (Anon., 2001), a fact indicating that these species are overfished. Thus, the results of the present study indicated that fishing mortality rates, or the impact of the different gears, most probably differ, with those of industrial fisheries being generally higher.

It must be pointed out that the main effect of the different gears examined is generally concentrated at different fishing grounds (i.e. trawls and purse-seines: three nautical miles from the coast or at depths > 50 m; artisanal gears: at depths < 90 m) and different seasons (i.e. trawls: from October to May; beach-seines: from October to April; purse-seines: from March to 15th of December; trammel nets, gill nets and longlines: all year round). This fact, combined with the finding that each gear targets to a specific part of the length structure of each stock, indicates that there is no part of the stocks that finds refuge from fishing mortality, either in space or time, with each gear imposing different fishing mortality rates.

Given the strong multi-species and multi-gear nature of Mediterranean fisheries, which exploit a wide range of species strongly differing in their life-histories (Stergiou *et al*., 1997) and thus in their L_{opt} and L_{50}, and the difficulties in separating and estimating the different components of fishing mortality (e.g. associated with illegal and misreported landings, artisanal and recreational landings, discards, ghost fishing: Chopin *et al*., 1996), the use of single-species and traditional models for management purposes is not useful. Furthermore, the situation might get more complicated given that many species are characterised by sex-dependant growth rates (Pope *et al*., 2000). Thus, it is evident that the technical, non-scientific and non-precautionary management measures that are currently in force must be reconsidered and fisheries management must be placed under an ecosystem perspective (e.g. Pauly, 1998; Pitcher *et al*., 1998; Stergiou, 2002). In general, ecosystem objectives are satisfied by establishing large marine protected areas, where fishing is totally prohibited (Stergiou 2002). Such areas may mediate the rebuilding of highly overfished stocks (Polunin, 2002).

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