University of Montpellier II
-
University of the Aegean

Master 2 Ecologie et Biodiversité – BIODIV Biodiversity Conservation

Research Project

2013-2014

Effects of trammel net mesh size on fish stocks and fishing productivity: evidence from small scale artisanal fisheries in Southern Ionian Sea

BAAN Dorian

Supervisor :

Dr. DIMITRIADIS Charalambos

National Marine Park of Zakynthos

Abstract Recent publications have shown that a considerable proportion of the landings in the Mediterranean are constituted of illegal individuals with length below their minimum landing size (MCRS, former MLS) and of even more immature individuals that have not reached their length at first maturity (L_m) and thus were not able to spawn even once, stressing the inadequacy of the actual fisheries management measures applying in the Mediterranean and their unefficiency to protect the fish stocks. In this study, the ecological and economical effects of 4 different inner panel mesh sizes of trammel nets in artisanal fisheries in Zakynthos island (Ionian Sea, Greece) were investigated. The length compositions of the landings were thus compared to L_m and MCRS with respect to the different mesh sizes, and differences in catch rate, income and species compostition were also tested. The high percentages of individuals under L_m in every mesh sizes indicated that the stocks are facing a strong growth overfishing and that the current management measures are not able to maintain the stocks at a sustainable level. We also demonstrated that the 21mm mesh size showed significantly higher percentage of undersized individuals than every other mesh sizes, and significantly lower catch rate and income. This mesh size should thus be bannished from the fisheries if we are to set management plans that are both ecologically and economically sustainable. Our findings should finally help setting up future management plans for the MPA of the National Marine Park of Zakynthos, that aim to be ecologically and socio-economically sustainable, through a combination of efficient and meaningful technical measures and ecosystem-based approaches.

***

1. Introduction

Small-scale artisanal fisheries generally refers to the small-capital exploitation of marine biological resources near the coast, using a large number of gears and providing landings to the markets for local consumption or export (Farrugio *et al*., 1993 ; Papaconstantinou & Farrugio, 2000, Tzanatos *et al*., 2005; FAO 2005). Small scale fisheries are usually considered to be more sustainable than large scale ones (Jacquet & Pauly, 2008) while in the Mediterranean they present a high sociocultural value (Farrugio *et al*., 1993; Matić-Skoko *et al.,* 2011). In the later region, small scale fisheries constitutes an important part of the total fishing activity, providing in some countries more than the half of the whole fisheries production and total income (Tzanatos *et al*., 2005; 2006). Moreover, the Mediterranean small-scale fishing sector is characterised by a great diversity of fishing gears and techniques, a large variety of species targeted as well as a high spatio-temporal variation of the fishing pressure, as a result of fishermen effort to maximize their catches and profits (Stergiou *et al.*, 2009 ; Tzanatos *et al*., 2005).

Nowadays, there is no doubt that fishing stocks are rapidly declining worldwide (Pauly et al., 2002) and hence there is an urgent need to monitor and regulate the fishing activity in order to ensure the sustainability of both the fishing stock and the fishing sector. However, small-scale fisheries management in the Mediterranean is rather ineffective, since it is based on effort control and technical restrictions that are not necessarily in line with scientific findings (Lleonart & Maynou, 2003; Stergiou *et al*., 2004; Stergiou *et al*., 2009), whereas enforcement is costly and problematic to implement. Papaconstantinou & Farrugio (2000) also stressed that effort limitation, when applied, is not based on a formal resource assessment and that provisions concerning technical measures like minimum mesh-size regulation and limitation on minimum size of certain species can be arbitrary and are usually lower than the recommendations from the scientific community.

There is growing evidence that single-species management measures by themselves are not sufficient in protecting the fish stocks and they should be complemented with other measures, like the location and implementation of Marine Protected Areas (MPAs) (e.g. Bohnsack, 2000 ; Froese *et al*., 2008 ; Guidetti *et al*., 2010; Matić-Skoko *et al*., 2010). MPAs, and especially those that are including no–take reserves, can be considered as an integrated fisheries management tool that has the potential to restore the declining fish stocks, enhance the local fishing yields and ensure the sustainability of the fishing sector, while protecting and conserving marine biodiversity and habitat quality at the same time (e.g. Francour *et al*., 2001; Goñi *et al*., 2008; Harmelin-Vivien *et al*., 2008; Mosquera *et al*., 2000; Polunin, 2002). In this respect, MPAs are in line with Ecosystem Based Fisheries Management objectives that single-species technical measures are not able to reach, provided that they designed, managed and enforced properly (Brodziak & Link, 2002; Fenberg et al., 2012; Gislason *et al*., 2000; Polunin, 2002; Stergiou, 2002).

Establishment of Minimum legal Landing Size of the exploited stocks (MLS) has been long used as an explicit measure against overfishing in the framework of single - species fisheries management (e.g. EU Regulation 1967/2006). However, in order for MLS to be ecologically meaningful and efficient, it should take into account the life-history parameters of the involved species, with size at maturity (i.e. L_m: the mean length at which individuals of a population become sexually mature and are thus able to spawn for the first time) (Froese & Binohlan, 2000; Tsikliras & Stergiou, 2013) being probably one of the most fundamental ones. In this respect, MLS should be equal or even be slightly higher than L_m in the framework of a more precautionary approach (Froese & Pauly, 2014; Stergiou *et al*., 2009,). In the recent reform of the European Union common fisheries policy (CFP), MLS has been replaced by Minimum Conservation Reference Sizes (MCRS: '*the size of a living marine aquatic species taking into account maturity, as established by Union law, below which restrictions or incentives apply that aim to avoid capture through fishing activity*', EU Regulation 1380/2013). However, no fundamental change in the size limits has been adopted and therefore MLS and MCRS remained the same, while minimum landing size is not yet available for many species. This is especially relevant for the Mediterranean stocks, as the size limitations are mainly based on Atlantic stocks measurements whereas most of the Mediterranean counterparts are smaller in size (Tzanatos *et al.*, 2008 ; Stergiou *et al.*, 2009), and for which, most of the size limitations are under the corresponding L_m (see Stergiou et al., 2004, 2009; Tsikliras & Stergiou, 2013).

In the framework of the systematic monitoring of small scale artisanal fisheries in the Southern Ionian Sea, including the MPA of the National Marine Park of Zakynthos (N.M.P.Z.), and also taking into account that trammel nets is the most frequently employed fishing gear in small-scale fisheries in the Southern Europe (Tzanatos *et al.,* 2005; Erzini *et al.*, 2006), the present study aims to detect whether there are differences in catches, species composition and profits of small scale artisanal trammel net fishing when different inner panel mesh sizes are compared. In addition, given that recent publications have demonstrated that a considerable amount of the landings in the Mediterranean Sea were below L_m and MCRS (former MLS) (e.g. Stergiou *et al.* 2004; 2009), the length composition of the catches was compared against L_m and MCRS with respect to the different mesh sizes of the trammel nets. The results of this study, which are including both ecological and economical aspects, will contribute to the better understanding of the impacts of small scale trammel net fisheries as well as to the development of good fishing practices towards the sustainable management of the fishing activity, especially when MPAs are considered.

2. Materials and Methods

2.1. Study area and sampling surveys

The study area is located around the coastal zone off Zakynthos Island (Southern Ionian Sea, Eastern Mediterranean) (Figure 1), including the MPA of NMPZ. Sampling was carried from November of 2012 until May of 2014 onboard small scale artisanal fishing vessels operating with trammel nets. Sampling took place in traditional fishing grounds used for decades by local artisanal fisheries and which are composed by mixed types of habitats (i.e., combination of *Posidonia oceanica* beds, reefs, and soft bottoms). During the 35 fishing trips, sampling frequency and location was random, following fishers fishing habits whereas the inner mesh size of the sampled trammel nets ranged from 21mm to 36mm (knot to knot) (i.e., 21, 22, 26, 28, 30 and 36mm). However, due to the preference of the local fishermen for particular mesh sizes, the obtained data from the 22mm and 30mm ones were insufficient and thus excluded from the analysis. Thus, a total of 63800m of trammel nets and 448 hours of effective fishing (i.e., time that the nets remained immersed into the water) at depths ranging from 5 to 35m were incorporated in data analysis.

During the onboard data collection, catch and fishing effort were recorded alongside with location, depth, date, mesh size of the net for each fishing set and current price of each species in the local market. All the collected individuals were identified to species, counted, weighted (wet weight in gr) and measured (total length -TL- in cm). The fishing effort was recorded through the length of the net (in m) and the fishing duration, i.e. the duration for which the net was immerged (in h).

2.2. Data handling and Statistical Analyses

Catch (in biomass in g), effort (in net length x fishing duration, m x h) and length composition (TL in cm) data were analysed to detect whether: (a) species composition, (b) percentage of undersized individuals (L_m and MCRS) in the total catch and for 8 commercially important species for local fisheries, and (c) averaged CPUE (calculated as: g/(mxh) for each species in each mesh size which was then summed and weighted by the number of fishing sets corresponding to the respective mesh size) and income per unit of effort (IPUE) (calculated as: mean market price in €/kg of each species multiplied by its respective CPUE) of the total catch, were changing between the different mesh sizes.

The MCRS values were taken from the most recent European and Greek legislation, depending on which one applies the most for each species, i.e. the EU Regulation N° 1380/2013 and the FEK 1012B/11-12-1995 respectively (Table 1). The L_m values and their standard errors were directly taken from Stergiou *et al.* (2009) when applicable, or calculated from the mean asymptotic length (L_∞, which is the mean length individuals of a population would reach if they were able to grow indefinitely) of the closest to Ionian Sea available stocks (i.e. the geographically closest stocks from Ionian Sea) given in Stergiou & Karachle (2006) for Greek waters or calculated from all the Mediterranean records in the electronic database FishBase (Froese & Pauly, 2014 ; www.fishbase.org), using the empirical relationship between these two parameters found in Froese and Binohlan (2000) :

$$\log(L_m) = 0.8979*[\log(L_\infty)]-0.0782$$

$$r^2 = 0.888 \; ; \; SE = 0.127$$

when L_∞ values were not available, they were estimated from the mean maximum length (L_{max}) of Mediterranean stocks records, as close as possible to Zakynthos island, found in various sources (i.e.,mainly peer-reviewed publications but also grey literature like technical reports, and electronic database) using the equation of their empirical relationship for Greek stocks as cited in Stergiou & Karachle (2006) :

$$L_\infty = 1.6013+1.0575*L_{max}$$

$$r^2 = 0.99 \; ; \; SE = 0.016$$

Species that were exclusively caught in 22mm and 30mm mesh sizes (i.e., *Dicentrarchus labrax*, *Epinephelus marginatus*, *Labrus mixtus* and *Symphodus ocellatus*), were excluded from the analyses whereas information concerning MCRS and L_m was gathered for the other 58 fish species. (Table 1 and Table 2, respectively).

Univariate permutational one way ANOVA (called hereafter PERMANOVA) based on Euclidean distance (Anderson, 2001) was employed in order to detect significant differences of the examined parameters with respect to the different mesh sizes.

In order to detect the overlap in the catch composition between the compared mesh sizes, a matrix of species CPUE by mesh size (including replication) was constructed based on the forth root transformed CPUE data so as to down weight the effect of the dominant species (Field *et al.*, 1982). This matrix was then converted to a triangular similarity matrix through the calculation of the Bray–Curtis similarity (Bray & Curtis, 1957) coefficient values between every pair of the sampled mesh sizes. Non-metric Multidimensional Scaling (MDS) ordination plot was further employed to visualize the emerged patterns. One-way multivariate permutational analysis of variance (PERMANOVA) (Anderson, 2001a) based on Bray – Curtis similarity index derived from the fourth rooted transformed CPUE data was employed to detect significant differences in the catch composition between the different mesh sizes.

Finally, 8 species were chosen for further analysis following certain criteria: a) commercial importance in artisanal fisheries, b) their contribution to the total collected biomass (their combined biomass contribution representing 34.5% of the total species landings and about 48% of the total fish landings) and c) their presence in every mesh size counting for the study. For these 8 species, Wilcoxon signed-ranked test (Zar, 1984) was used so as to detect if the median size of the fished individuals for each species significantly departs from the corresponding L_m value within each of the sampled mesh sizes.

Statistical analyses were performed by means of PRIMER 6 + PERMANOVA (Anderson et al., 2008) and SPSS v20 (IBM, 2012) software.

3. Results

3.1. Species Number, CPUE, IPUE, L_m and MCRS

A total of 1936 individuals belonging to 63 species (58 fish species, 3 Cephalopods and 2 species of Crustacean) were caught during the fishing trips (Appendix 1). The most abundant species were *Sepia officinalis* (13.3%), *Scorpaena scrofa* (8.6%), *Siganus luridus* (8.1%), *Mullus surmuletus (*8%), *Symphodus tinca (*7.6%) and *Scorpaena porcus* (7%) accounting for more than 50% of the total catches. On the other hand, *Sepia officinalis* (20.8%), *Scorpaena scrofa* (10.7%), *Sparisoma cretense* (6.3%), *Phycis phycis* (4.4%), *Mullus surmuletus* (4.4%) and *Symphodus tinca (*4.3%) covered more than 50% of the total exported biomass.

In terms of number of species, the 26mm mesh size caught the most species (n=47) followed by 21mm (n=42), 28mm and 36mm ones (n=28 and n=25 respectively). However, PERMANOVA results indicated that there were no statistically significant differences in the average number of species caught between the compared mesh sizes (Table 3, Fig. 2). With respect to community CPUE, the 36mm mesh size presented the highest average value and the 21mm the lowest one (Fig. 3). The PERMANOVA results suggested that the average CPUE values differed significantly when the different mesh sizes are compared (Table 3). Pair–wise tests further indicated that the latter differences were mainly attributed to the comparison of 36mm mesh size with the 21mm and 26mm ones ($p<0.05$ in both cases). Considering the IPUE, no significant differences were detected between the compared mesh sizes (Table 3), with the only exception of the pair-wise comparison between 21mm and 36mm mesh sizes ($p<0.05$).

Overall, 40 fish species (covering 92.2% and 94.6% of the total fished biomass and abundance, respectively) presented at least one individual with TL lower than L_m whereas for the remaining 14 ones all the collected individuals were beyond their respective L_m value. The percentages of individuals for which the total length was smaller than L_m were rather high, reaching at least 50% for 29 out of the 54 species encountered in the analyses within all mesh sizes. The mean percentage of individuals under L_m (averaged across all undersized species) was gradually declining from 21mm mesh size samples (66.1%) to the 28mm ones (16.9%) followed by an increase for the case of the 36mm (40.3%) (Fig. 4). The former pattern was further confirmed by the results obtained from PERMANOVA test, since significant differences were evident when the different mesh sizes were compared (Table 3) (Pair–wise test results: $p<0.05$ in all cases except for the comparisons between 26 and 36mm mesh sizes). Considering MCRS, 7 species (covering 9.2% and 14.3% of the total fished biomass and abundance, respectively) were found to have at least one individual below MCRS. The mean percentage of individuals with total length below MCRS (averaged across all undersized species) ranged from 77.2% to 17.9% for 21mm and 36mm mesh sizes, respectively (Fig. 5). PERMANOVA test results indicated that there were significant differences in percentage of individuals with total length below MCRS when the different mesh sizes are compared (Table 3). The former differences were mainly induced by the comparison of the 21mm mesh size with the rest ones (Pair–wise test results: $p<0.05$ for the reported cases).

3.2. Catch composition structure per mesh size

MDS ordination plot suggested a pattern of separation of 21mm and 36mm mesh sizes with the remaining ones (Fig. 6). In this respect, three main groups of similar catch composition can be distinguished: the first includes the 21mm mesh size, the second gathers the mesh sizes of 26 and 28mm whereas the third incorporates the 36mm mesh size. The former grouping of catch composition with respect to the mesh size was further confirmed by the results of PERMANOVA (Table 3).

3.3. Selected Species

The percentages of individuals with TL lower than L_m per mesh size for 8 species are presented in Figure 7 and Table 4. These percentages represent the number of individuals with length lower than L_m per mesh size as well as the range of the TL in cm for each species. The total percentages of undersized individuals (i.e., for all mesh sizes) were generally very high for the selected species, exceeding 80% of the total catch, except for *Sparisoma cretense*, for which the total undersized individuals calculated to 47.5%. The results of the Wicoxon tests showed that all the selected species, presented median size values significantly smaller than their respective L_m, L_m–SE and L_m+SE when the 21mm mesh size is considered (Table 5). The mesh size of 26mm seemed to be the threshold under which *Mullus surmuletus*, *Sparisoma cretense* and *Scorpaena porcus* presented significantly lower median size than their respective L_m, L_m–SE and L_m+SE values. On the other hand, for *Phycis phycis* the latter threshold seemed to be the 28mm mesh size whereas for the rest of the species lower than L_m sizes are found in the 36mm nets (Table 4, 5).

Only two species (i.e., *Diplodus sargus* and *Pagrus pagrus*) had individuals below their MCRS, with percentages ranging from 66.7% for 21mm mesh size, to 2.1% for 36mm, while the total individuals under MCRS on the total catch represented 83.3% for *Diplodus sargus* and 39.3% for *Pagrus pagrus*. The mean percentages of individuals under MCRS for the total 8 species per mesh size ranged from 10.6% for 21mm, to 0.3% for 36mm, with a total mean percentage for every mesh size of 15.3% (Table 4).

4. Discussion

In the Mediterranean, fisheries are generally strongly multispecies and this is especially true for the artisanal fisheries that use a high variety of techniques and occure in diverse habitat that allow them to catch a very wide range of species. The high number of species caught in this study (59 species in total) showed that this is also true in Zakynthos and supports the « balanced exploitation » characteristic of small-scale fisheries, having a smaller impact on evenness and species richness of the community than more species selective fisheries (Lloret *et al.*, 2012). However, this also stresses the need of a strong biological knowledge for these numerous species and for the Mediterranean populations in general in order to implement effective managment measures, since a lack of informations on the exploited species may underestimate the impact of fishing activities on the species itself, but also on the entire communities and coastal ressources (see Lloret *et al.*, 2012). Hence, proper scientific studies on species biological parameters like spawning periods, fecundity, reproductive strategies, spwaning and nursery grounds, etc., should be conducted prior to implementation and enforcement of any managment measures, and especially in the Mediterranean, where fisheries management is generally based on single-species approach (Tsikliras & Stergiou, 2013).

Among biological parameters that should be considered prior to any fisheries managment measures, length at maturity (L_m) is also one of the most important since it is relatively easy to obtain through empirical relationships with other species life traits involving body length, which is ofently and easily recorded, and since it is a good predictor of vulnerability of the exploited species to fishing (Tsikliras & Stergiou, 2013). Moreover, overexploitation of immature individuals that have not reach L_m may lead to the growth overfishing of the stock and may have detrimental consequences on future recruitment, stocks, communities and ecosystems conservation, and thus on their supported fisheries (Froese & Pauly, 2014 ; Jennings et al., 1999 ; Stergiou et al., 2009). For that matter, Stergiou *et al.* (2007) stressed the role of growth overfishing combined with the modernisation of the fishing fleet, to explain the persistent decline of the Greek demersal fish stocks for the last 20 years. The results of this study showed that the overall proportion of individuals caught under their size at maturity was really high, reaching more than the half of the catch for

44.4% of all fish species caught (24 on a total of 54 species), ranging from 0 to 100% depending on the species and with a mean percentage of 46.6% for all fish species. In other words, the mean proportion of individuals that were not able to reach their sexual maturity and thus not able to spawn even once represented almost 50% of the total catch (taking into account every species caught in all mesh sizes). Among these species, some of the most commercially important and dominant species in term of landings in artisanal fisheries of Zakynthos presented also very high percentages of undersized individuals, reaching 84.2%, 91.7% and even 96.4% for *Mullus surmuletus*, *Diplodus sargus* and *Pagrus pagrus* respectively, 3 very important species in the market, and 86.1% for *Scorpaena scrofa*, the dominant species in term of abundance and biomass in the total catch. These results, agreeing and renforcing the same conclusions about overexploitation of immature individuals in the same area presented in Stergiou *et al.* (2009) and Dimitriadis *et al.* (2013), illustrate the mass removal of immature individuals and stress the strong growth overfishing occuring in small-scale fisheries in Zakynthos.

Besides, these results demonstrated also the shortcomings of the current legislation on MCRS, as it was emphasized by Stergiou *et al.* (2009). The main and first objective of setting minimum landing size measures in fisheries managment is indeed to avoid the growth overfishing by the removal of immature fish (Froese & Pauly, 2014), and thus should be always harmonized with the life-history of the species, and especially with L_m, being at least equal or even slightly bigger, regardless of species and stocks, allowing the individuals to spawn and avoiding the decline of the stocks (Froese & Pauly, 2014 ; Stergiou *et al.*, 2009 ; Tsikliras & Stergiou, 2013). However, despite the fact that the practice of minimum landing sizes for the Mediterranean fisheries is not new (European Commission, 1994. (EC) No.1926/94) and has been recently re-established (the name changing notably from Minimum Landing Size to Minimum Conservation Reference Size) through the EU Regulation No. 1380/2013, the values have not changed since 1996 and are for most of them below the respective L_m of the species, when only mimimum landing size exist, which the case for very few species in the Mediterranean (Stergiou *et al.*, 2009 ; Tsikliras & Stergiou, 2013 ; Tzanatos *et al.*, 2008). Indeed, on the total of 58 fish species caught during the sampling operations of this study, only 17 have minimum landing size through the different legislation applying (i.e., FEK 25A/26-1-1954, EC No. 1967/2006 and EC No. 1380/2013), and only 6 of them are presenting minimum landing size beyond their L_m, which are *Diplodus annularis*, *Diplodus sargus*, *Diplodus vulgaris*, *Epinephelus costae*, *Lithognathus mormyrus* and *Pagellus bogaraveo*. Thus, the minimum landing sizes being way below their respecitve L_m for the great majority of the species, our results showed very low percentages of illegal catch for the total landings, where not even one individual was below its legal size limit for 87% of the species accounted (47 of 54 species), and with a total mean of only 9.5% of the total catch being illegal. In the contrary, the percentages of illegal catches were high for all the species with a legal size bigger than their respective L_m, ranging from 62.8% for *Diplodus vulgaris*, to 100% for *Epinephelus costae* and *Pagellus bogaraveo*. This showed clearly that very few species are benefiting from the MCRS measure and also demonstrated, in the one hand, the actual ecological inefficiency of this measure since most of the MCRS values were below their respective L_m, and in the other hand, its pratctical inadequacy, since every illegal catches were caught with completely legal means in term of localisation (closed areas, distance from the coast, depth), period of the year (temporal closure) and above all, gear used (mesh sizes) (Stergiou *et al.*, 2009). Hence, for the actual fisheries managment schemes, there is a need of a shift and an expand of the minimum landing size values for all targeted species, that are based on sound ecological parameters like L_m. Also, as Tsikliras & Stergiou (2013) advocated, fisheries managment based on minimum landing sizes should be dynamic and stock specific, since key parameters like L_m can vary in space (i.e., between stocks or populations) and time (evolutionary response to overfishing or environmental change), and since the level of compliance with size limit regulations depends on the type of fisheries (i.e., artisanal, semi-industrial, industrial), the type and number of targeted species, and finally the type of fishing gear used and its selectivity.

On this latter matter, our study aimed to find any pattern and differences in catch and revenue with respect to different inner mesh sizes of trammel nets, and also to compare the compliance of these mesh sizes with L_m and MCRS. Indeed, for improved management and conservation measures, and given the importance of static gears and especially of trammel nets in small-scale fisheries in the Mediterranean, a better understanding of the impact of different gears or mesh sizes is vital (Erzini *et al.*, 2006). Several studies have shown that inner panel mesh sizes have generally significant effect on size selectivity and catch rate, with modal length generally increasing and number of specimen caught declining with the mesh size (e.g. Erzini *et al.*, 2006 ; Stergiou *et al.*, 2006). Our results confirmed a general pattern between the mesh sizes, since the species composition analysis showed significant difference within mesh sizes, involving that different mesh size caught different species. However, if the mean species number were declining with bigger mesh sizes, these differences were not significant according to the statistical tests. Rather than in specimens abundance, we also investigated the distribution of specimens biomass per mesh sizes through the analysis of the CPUEs. A clear increase in mean CPUE was noted in respect with mesh sizes, but the mesh size effect was negligible between the small mesh sizes (i.e., 21mm, 26mm and 28mm) and between the two biggest mesh sizes (i.e., 28mm and 36mm) but significant comparing the two smallest 21mm and 26mm with the biggest 36mm. This result seems to contradict the reduction of catch rate with mesh size assumption, since bigger mesh sizes caught *per se* less specimens (28mm and 36mm represented only 15.5% and 14.9% of the total landings, respectively), but generally of bigger size and weight, making, in our case, the catch rate in terms of biomass and effort significantly bigger for the 36mm than the smaller ones.

The income a fisherman will get from his fishing session depends greatly on the market trends and on his catch species composition, some species being more valuable than others, and length-weight composition, where individuals of larger size and weight attain generally higher prices and represent production forgone (Jennings *et al.*, 1999 ; Stergiou *et al.*, 2009). Nevertheless, this was not confirmed in our study since the higher incomes per unit of effort that were found in bigger mesh sizes were not significant. The only non-negligible increase in revenue was found between 21mm and 36mm mesh size.

Finally, the level of compliance of each mesh sizes with L_m and MCRS showed that there was indeed a reduction of mean percentage of immature and undersized individuals caught as inner panel mesh size increased. A significant increase in the percentage of individuals under L_m between 28mm and 36mm mesh size was yet noticed (with a value of immature individuals in 36mm comparable to the one in 26mm) and could be attributed to the difference in catch species composition of this latter mesh size, 36mm catching larger species with higher values of L_m, and fishing location, since 36mm was used by only one fishing vessel that was fishing in specific locations. Thus, the 28mm mesh size caught in our case significantly less immature individuals than any other mesh size. The reduction in mean percentage of individuals under MCRS was constant with respect of mesh sizes, however, analysis clearly showed that only the 21mm mesh size caught significantly higher percentages of illegal individuals.

These different results emphasized the difficulty of finding a good and effective compromise between mesh sizes in terms of catch efficiency and income maximisation in the one hand, and ecological and legal concerns with protection of juveniles and respect of minimum landing size, in the other hand. Hence, while 36mm inner panel mesh size seemed to significantly maximise the catch rate but not the profit, it also showed a significant increase in proportion of immature individuals caught, where 28mm should in this case be preferred. However, in every cases, 21mm mesh size proved to be innapropriate, showing significantly higher percentages of individuals under L_m and MCRS than any other mesh sizes, and significantly lower catch rate and profit. Therefore, according to this present study, the banishment of the 21mm mesh size of the artisanal fisheries could be an interesting option for single-species managment in order to reduce the growth overfishing by the mass removal of immature individuals, without actually impacting the yield and the income of the fishermen.

The actual single-species management measures that apply in the Mediterranean are facing some ecological and practical problems, given the strong multi-species and multi-gear characteristic of its fisheries. The very small number of existing minimum landing sizes, their ecological inadequacy, the variability of life-history parameters like L_m between the numerous species and the difficulty of the monitoring and the enforcement of such measures, especially in small-scale fisheries, are some of the many argument that are now questionning the efficiency of these actual fisheries managment schemes (e.g., Bohnsack, 2000 ; Tzanatos *et al.*, 2008 ; Stergiou *et al.*, 2004). The combination of these technical measures with others ecosystem-based approaches like implementation of MPAs and no-take zones is now rather advocated (e.g., Froese *et al.*, 2008 ; Guidetti *et al.*, 2010 ; Stergiou *et al.*, 2009). Hence, the precise technical measures like minimum landing size can potentially provide some community and ecosystem benefits and are valuable tools when they are applied to many species and are combined with other measures, and their effectiveness depends on their effective enforcement (which is easier to do in MPAs), but also on the compliance of the fishermen (Bohnsack, 2000). This latter point seems for that matter to grow in importance in the scientific and MPAs managers community, who emphasize the benefits of an adaptative co-managing approach involving MPA's stakholders, scientists and fishermen (see Guidetti & Claudet, 2010 and Guidetti *et al.*, 2010). It has thus been pointed out that not only the use of MPAs in combination with technical measures are more than compatible, but also that a partial protection of coastal areas together with a co-management plan may greatly benefit both ecosystems and fishermen (Guidetti & Claudet, 2010 ; Guidetti *et al.*, 2010). Guidetti & Claudet (2010) put even forward that involving fishermen in the management plan could represent a necessity in the success of fisheries managment, since it increases their compliance to the managment schemes and the likelihood they will respond positvely to no-take zones and alleviates their skepticism towards scientists and MPAs managers and is an essential attribute of a proper managment scheme that should embrace all ecological, economical and socio-cultural aspects.

The results of the present study contributes to a better understanding of the effect of small-scale fisheries on the fish stocks in Zakynthos, and an insight of the effectiveness of the actual fisheries management measures. Along with the promising co-managment approach cited above, these results should also help in building future management plans for the MPA of the National Marine Park of Zakynthos that aim to be ecologically and socio-economically sustainable. These future management plans should notably include (1) the implementation of a year-round no-take zone, in order notably to respond to the strong growth overfishing that is occuring, (2) the development of a co-management protocol that sets a number of technical measures in aggrement with the local fishermen, like the banishment of the 21mm mesh size, the implementation of certain quotas and minimum landing size and the application of temporal and/or spatial closures, and finally (3) a systematic and consistent monitoring and enforcement, along with the promotion of an active participation and cooperation of the local community through the raising of awareness on the potential benefits of the MPA, that could ultimately improve the attitudes, the perceptions and the compliance regarding the MPA and its regulations.

References

Anderson, M., Gorley, R., Clarke, K., n.d. PERMANOVA+ for PRIMER: guide to software and statistical methods (2008) PRIMER-E. Plymouth, UK.

Anderson, M.J., 2001a. Permutation tests for univariate or multivariate analysis of variance and regression. Canadian Journal of Fisheries and Aquatic Sciences 58, 626–639.

Anderson, M.J., 2001b. A new method for non‐parametric multivariate analysis of variance. Austral ecology 26, 32–46.

Bohnsack, J.A., 2000. A comparison of the short-term impact of no-take marine reserves and minimum size limits. Bulletin of Marine Science 66, 635–650.

Bray, J.R., Curtis, J.T., 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological monographs 27, 325–349.

Brodziak, J., Link, J., 2002. Ecosystem-Based Fishery Management: What is it and how can we do it? Bulletin of Marine Science 70, 589–611.

Dimitriadis, C., Sini, M., Gerovasileiou, V., Poursanidis, D., Evagelopoulos, A., Fournari-Konstantinidou, I., Badouvas, N., Lekkas, V., Giourgis, E., Akritopoulou, E., Bakopoulos, V., Koutsoubas, D., 2013. Management Measures for Fisheries in the Marine Protected Area of the National Marine Park of Zakynthos (Final report). MedPAN North Project, Mytilini.

Erzini, K., Gonçalves, J.M.S., Bentes, L., Moutopoulos, D.K., Casal, J.A.H., Soriguer, M.C., Puente, E., Errazkin, L.A., Stergiou, K.I., 2006. Size selectivity of trammel nets in southern European small-scale fisheries. Fisheries Research 79, 183–201.

FAO, 2005. Fisheries and Aquaculture topics. Small-scale and artisanal fisheries. (FAO Fisheries and Aquaculture Department [online]). FAO, Rome.

Farrugio, H., Oliver, P., Biagi, F., 1993. An overview of the history, knowledge, recent and future research trends in Mediterranean fisheries. Scientia Marina 57, 105–119.

Fenberg, P.B., Caselle, J.E., Claudet, J., Clemence, M., Gaines, S.D., Antonio Garcia-Charton, J., Gonçalves, E.J., Grorud-Colvert, K., Guidetti, P., Jenkins, S.R., 2012. The science of European marine reserves: Status, efficacy, and future needs. Marine Policy 36, 1012–1021.

Field, J.1, Clarke, K., Warwick, R., 1982. A practical strategy for analysing multispecies distribution patterns. Marine ecology progress series 8.

Francour, P., Harmelin, J.-G., Pollard, D., Sartoretto, S., 2001. A review of marine protected areas in the northwestern Mediterranean region: siting, usage, zonation and management. Aquatic Conservation: Marine and Freshwater Ecosystems 11, 155–188.

Froese, R., Binohlan, C.B., 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology 758–773.

Froese, R., Pauly, D., 2014. FishBase. World Wide Web electronic publication [WWW Document]. URL http://www.fishbase.org/

Froese, R., Stern-Pirlot, A., Winker, H., Gascuel, D., 2008. Size matters: How single-species management can contribute to ecosystem-based fisheries management. Fisheries Research 92, 231–241.

Gislason, H., Sinclair, M., Sainsbury, K., O'Boyle, R., 2000. Symposium overview: incorporating ecosystem objectives within fisheries management. ICES Journal of Marine Science: Journal du Conseil 57, 468–475.

Goñi, R., Adlerstein, S., Alvarez-Berastegui, D., Forcada, A., Reñones, O., Criquet, G., Polti, S., Cadiou, G., Valle, C., Lenfant, P., Bonhomme, P., Pérez-Ruzafa, A., Sánchez-Lizaso, J., García-Charton, J., Bernard, G., Stelzenmüller, V., Planes, S., 2008. Spillover from six western Mediterranean marine protected areas: evidence from artisanal fisheries. Marine Ecology Progress Series 366, 159–174.

Guidetti, P., Bussotti, S., Pizzolante, F., Ciccolella, A., 2010. Assessing the potential of an artisanal fishing co-management in the Marine Protected Area of Torre Guaceto (southern Adriatic Sea, SE Italy). Fisheries Research 101, 180–187.

Guidetti, P., Claudet, J., 2010. Comanagement practices enhance fisheries in marine protected areas. Conservation Biology 24, 312–318.

Harmelin-Vivien, M., Ledireach, L., Baylesempere, J., Charbonnel, E., Garciacharton, J., Ody, D., Perezruzafa, A., Renones, O., Sanchezjerez, P., Valle, C., 2008. Gradients of abundance and biomass across reserve boundaries in six Mediterranean marine protected areas: Evidence of fish spillover? Biological Conservation 141, 1829–1839.

Jacquet, J., Pauly, D., 2008. Funding priorities: big barriers to artisanal fisheries. Conservation and Policy, 832–835.

Jennings, S., Greenstreet, S.P.R., Reynolds, J.D., 1999. Structural change in an exploited fish community: a consequence of differential fishing effects on species with contrasting life histories. Journal of Animal Ecology 617–627.

Lleonart, J., Maynou, F., 2003. Fish stock assessments in the Mediterranean: state of the art. Scientia Marina 67, 37–49.

Lloret, J., Muñoz, M., Casadevall, M., 2012. Threats posed by artisanal fisheries to the reproduction of coastal fish species in a Mediterranean marine protected area. Estuarine, Coastal and Shelf Science 113, 133–140.

Matić-Skoko, S., Stagličić, N., Pallaoro, A., Kraljević, M., Dulčić, J., Tutman, P., Dragičević, B., 2011. Effectiveness of conventional management in Mediterranean type artisanal fisheries. Estuarine, Coastal and Shelf Science 91, 314–324.

Mosquera, I., Côté, I.M., Jennings, S., Reynolds, J.D., 2000. Conservation benefits of marine reserves for fish populations. Animal Conservation 321–332.

Papaconstantinou, C., Farrugio, H., 2000. Fisheries in the Mediterranean. Mediterranean Marine Science 1, 5–18.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R., Zeller, D., 2002. Towards sustainability in world fisheries. Nature 418, 689–695.

Polunin, N.V.C., 2002. Marine Protected Areas, Fish and Fisheries, in: Hart, P.J.B., Reynolds, J.D. (Eds.), Handbook of Fish Biology and Fisheries. Blackwell Science Ltd, Oxford, pp. 293–318.

Stergiou, K., Moutopoulos, D., Tsikliras, A., 2007. Spatial and temporal variability in Hellenic marine fisheries landings. State of Hellenic Fisheries 141–150.

Stergiou, K.I., 2002. Overfishing, tropicalization of fish stocks, uncertainty and ecosystem management: resharpening Ockham's razor. Fisheries Research 55, 1–9.

Stergiou, K.I., Karachle, P.K., 2006. A review of various biological parameters for fish from the Greek Seas. Journal of Biological Research 199–211.

Stergiou, K.I., Moutopoulos, D.K., Armenis, G., 2009. Perish legally and ecologically: the ineffectiveness of the minimum landing sizes in the Mediterranean Sea. Fisheries Management and Ecology 16, 368–375.

Stergiou, K.I., Moutopoulos, D.K., Krassas, G., 2004. Body size overlap in industrial and artisanal fisheries for five commercial fish species in the Mediterranean Sea. Scientia Marina 68, 179–188.

Stergiou, K.I., Moutopoulos, D.K., Soriguer, M.C., Puente, E., Lino, P.G., Zabala, C., Monteiro, P., Errazkin, L.A., Erzini, K., 2006. Trammel net catch species composition, catch rates and métiers in southern European waters: A multivariate approach. Fisheries Research 79, 170–182.

Tsikliras, A.C., Stergiou, K.I., 2013. Size at maturity of Mediterranean marine fishes. Reviews in Fish Biology and Fisheries 1–50.

Tzanatos, E., Dimitriou, E., Katselis, G., Georgiadis, M., Koutsikopoulos, C., 2005. Composition, temporal dynamics and regional characteristics of small-scale fisheries in Greece. Fisheries Research 73, 147–158.

Tzanatos, E., Dimitriou, E., Papaharisis, L., Roussi, A., Somarakis, S., Koutsikopoulos, C., 2006. Principal socio-economic characteristics of the Greek small-scale coastal fishermen. Ocean & Coastal Management 49, 511–527.

Tzanatos, E., Somarakis, S., Tserpes, G., Koutsikopoulos, C., 2008. Catch length analysis, relation to minimum landing sizes and management implications from a Mediterranean small-scale fishery (Patraikos Gulf, Greece). Fisheries Research 93, 125–134.

Zar, J.H., 1984. Biostatistical analysis. 2nd. Prentice Hall USA.

List of Figures

List of Tables

Table 1. Estimated mean length at maturity (Lm) and minimum landing size of 58 fish species, Zakynthos Island 2012-2014

Species	Common name	Size at maturity (L_m)	Minimum Landing Size Hellenic National Legislation (1954) *	Minimum Landing Size European Council Legislation (2006) †	Minimum Conservation Reference Size European Council Legislation (2013) §
Auxis rochei	Bullet tuna	31.5 cm	-	-	-
Boops boops	Bogue	17 cm	**10 cm**	-	-
Bothus podas	Wide-eyed flounder	21 cm	-	-	-
Chelidonichthys lucerna	Tub gurnard	27.5 cm	-	-	-
Coris julis	Mediterranean rainbow wrasse	16.2 cm	-	-	-
Dactylopterus volitans	Flying gurnard	29.5 cm	-	-	-
Dasyatis pastinaca	Common stingray	62.2 cm	-	-	-
Dentex dentex	Common dentex	35.7 cm	-	-	-
Dicentrarchus labrax	Sea bass	38.5 cm	23 cm	25 cm	**25 cm**
Diplodus annularis	Annular seabream	13.9 cm	**15 cm**	12 cm	12 cm
Diplodus sargus	White seabream	20.9 cm	15 cm	23 cm	**23 cm**
Diplodus puntazzo	Sharpsnout seabream	27.5 cm	-	18 cm	**18 cm**
Diplodus vulgaris	Two-banded seabream	17.2 cm	-	18 cm	**18 cm**
Epinephelus costae	Gold-blotched grouper	39.1 cm	-	45 cm	**45 cm**
Epinephelus marginatus	Dusky grouper	68.1 cm	-	45 cm	**45 cm**
Euthynnus alletteratus	Little tunny	67.5 cm	-	-	-
Labrus merula	Brown wrasse	21.8 cm	-	-	-
Labrus mixtus	Cuckoo wrasse	22.1 cm	-	-	-
Labrus viridis	Green wrasse	24.3 cm	-	-	-
Lithognathus mormyrus	Sand steenbras	19.1 cm	-	20 cm	**20 cm**
Merluccius merluccius	Hake	40.3 cm	20 cm	20 cm	**20 cm**
Mugil cephalus	Common grey mullet	31.1 cm	**16 cm**	-	-
Mullus barbatus	Striped mullet	16 cm	11 cm	11 cm	**11 cm**
Mullus surmuletus	Red mullet	20.1 cm	11 cm	11 cm	**11 cm**
Muraena helena	Mediterranean moray	40.6 cm	-	-	-
Oblada melanura	Saddled seabream	20 cm	-	-	-
Pagellus bogaraveo	Blackspot seabream	27.2 cm	-	33 cm	**33 cm**
Pagellus erythrinus	Common pandora	21.5 cm	12 cm	**15 cm**	-
Pagrus pagrus	Red porgy	29.1 cm	18 cm	**18 cm**	-
Phycis phycis	Forkbeard	29 cm	-	-	-
Raja asterias	Mediterranean starry ray	28.1 cm	-	-	-
Raja miraletus	Brown ray	47.4 cm	-	-	-
Sarpa salpa	Salema	21.5 cm	-	-	-
Sciaena umbra	Brown meagre	30 cm	-	-	-
Scorpaena notata	Small red scorpionfish	11.1 cm	-	-	-
Scorpaena porcus	Black scorpionfish	15.1 cm	-	-	-
Scorpaena scrofa	Red scorpionfish	26.6 cm	-	-	-
Seriola dumerili	Greater amberjack	47.2 cm	-	-	-
Serranus cabrilla	Comber	14.4 cm	-	-	-
Serranus hepatus	Brown comber	9.8 cm	-	-	-
Serranus scriba	Painted comber	17.9 cm	-	-	-
Siganus luridus	Dusky spinefoot	15.3 cm	-	-	-
Solea solea	Common sole	22 cm	20 cm	20 cm	**20 cm**
Sparisoma cretense	Parrotfish	20.7 cm	-	-	-
Sparus aurata	Gilthead seabream	29.1 cm	20 cm	20 cm	**20 cm**
Sphyraena sphyraena	European barracuda	30.7 cm	-	-	-
Spicara maena	Blotched picarel	14.5 cm	-	-	-
Spicara smaris	Picarel	11.9 cm	-	-	-
Spondyliosoma cantharus	Black seabream	31.6 cm	-	-	-
Symphodus mediterraneus	Axillary wrasse	10.3 cm	-	-	-
Symphodus ocellatus	Ocellated wrasse	6.9 cm	-	-	-
Symphodus tinca	Peacock wrasse	16.8 cm	-	-	-
Synodus saurus	Atlantic lizardfish	21.2 cm	-	-	-
Trachinus draco	Greater weever	23.8 cm	-	-	-
Trachinus radiatus	Starry weever	14.4 cm	-	-	-
Trigloporus lastoviza	Streaked gurnard	19.5 cm	-	-	-
Uranoscopus scaber	Stargazer	18.7 cm	-	-	-
Zeus faber	John dory	35.5 cm	-	-	-

* Greek Royal Decree FEK 25A/26-1-1954
† European Regulation (EC) No 1967/2006
§ European Regulation (EC) No 1380/2013

Table 2. Estimated length at maturity (Lm) and mean asymptotic length (L∞) and their standard error of 58 fish species caught in Zakynthos island, 2012-2014

Species	L_∞	SE of L_∞	L_m	SE of L_m	N	Sources
Auxis rochei	47.2	-	31.5	5.0	2	*5 ; 16*
Boops boops	28.1	1.6	17.0	0.9	9	Stergiou et al. (2009) [14]
Bothus podas	27.4	-	21.0	-	1 (328)	Tsikliras & Stergiou (2013) [15]
Chelidonichthys lucerna	49.2	4.9	27.5	2.5	9	Froese & Pauly. FishBase (2014) [5]
Coris julis	27.2	-	16.2	-	1	Froese & Pauly. FishBase (2014) [5]
Dactylopterus volitans	53.0	-	29.5	-	1	Morey et al. (2003) [8]
Dasyatis pastinaca	121.5	-	62.2	-	1	Froese & Pauly. FishBase (2014) [5]
Dentex dentex	66.3	8.9	35.7	3.9	1	*4. ; 5. ; 7. ; 8. ; 9. ; 15.*
Dicentrarchus labrax	71.4	4.9	38.5	2.3	12	Froese & Pauly. FishBase (2014) [5]
Diplodus annularis	22.4	1.7	13.9	0.8	3	Stergiou et al. (2009) [14]
Diplodus puntazzo	35.2	5.9	20.9	2.0	6	*4 ; 5 ; 7 ; 8 ; 15*
Diplodus sargus	47.9	4.0	27.5	2.1	3	Stergiou et al. (2009) [14]
Diplodus vulgaris	29.1	2.6	17.2	1.4	5	*4. ; 5. ; 7. ; 9. ; 10.*
Epinephelus costae	72.5	-	39.1	-	1	Froese & Pauly. FishBase (2014) [5]
Epinephelus marginatus	135.0	19.7	68.1	9.0	5	Froese & Pauly. FishBase (2014) [5]
Euthynnus alletteratus	133.3	5.6	67.5	2.5	4	Froese & Pauly. FishBase (2014) [5]
Labrus merula	37.8	3.1	21.8	1.6	3	Froese & Pauly. FishBase (2014) [5]
Labrus mixtus	38.5	4.4	22.1	2.3	2	Froese & Pauly. FishBase (2014) [5]
Labrus viridis	42.9	3.5	24.3	1.8	3	*3. ; 8. ; 9.*
Lithognathus mormyrus	33.6	2.7	19.1	1.4	6	*4. ; 5. ; 10. ; 15.*
Merluccius merluccius	73.4	5.2	40.3	2.6	11	Stergiou et al. (2009) [14]
Mugil cephalus	52.6	3.1	31.1	1.6	10	Froese & Pauly. FishBase (2014) [5]
Mullus barbatus	26.2	0.9	16.0	0.5	11	Stergiou et al. (2009) [14]
Mullus surmuletus	33.9	4.4	20.1	2.3	4	Stergiou et al. (2009) [14]
Muraena helena	75.6		40.6		(1)	Dimitriadis et al. (2013) [3]
Oblada melanura	33.6	-	20.0	-	1	Stergiou et al. (2009) [14]
Pagellus bogaraveo	48.4	5.5	27.2	1.0	5	Froese & Pauly. FishBase (2014) [5]
Pagellus erythrinus	36.4	3.1	21.5	1.7	6	Stergiou et al. (2009) [14]
Pagrus pagrus	51.1	0.4	29.1	0.2	2	Stergiou et al. (2009) [14]
Phycis phycis	52.1	3.4	29.0	1.7	4 (307)	*3. ; 4. ; 7. ; 8.*
Raja asterias	50.2		28.1		(2)	Dimitriadis et al. (2013) [3]
Raja miraletus	89.9	2.0	47.4	0.9	2	Froese & Pauly. FishBase (2014) [5]
Sarpa salpa	37.3	-	21.5	-	1	Froese & Pauly. FishBase (2014) [5]
Sciaena umbra	54.0	5.4	30.0	2.7	4	Froese & Pauly. FishBase (2014) [5]
Scorpaena notata	17.9	0.0	11.1	0.0	2	Froese & Pauly. FishBase (2014) [5]
Scorpaena porcus	25.1	1.5	15.1	0.8	10	Froese & Pauly. FishBase (2014) [5]
Scorpaena scrofa	47.2	3.9	26.6	2.0	5	*3. ; 4. ; 5. ; 8. ; 10.*
Seriola dumerili	91.2	41.7	47.2	5.2	3	*3. ; 5. ; 8.*
Serranus cabrilla	23.3	0.7	14.4	0.4	4	Stergiou et al. (2009) [14]
Serranus hepatus	15.6	0.4	9.8	0.2	5 (19'993)	Stergiou & Karachle (2006) [13]
Serranus scriba	30.3	1.3	17.9	0.7	5	Froese & Pauly. FishBase (2014) [5]
Siganus luridus	25.9	1.6	15.3	0.9	6 (2'747)	*1. ; 2. ; 3. ; 6. ; 12.*
Solea solea	38.3	2.2	22.0	1.1	15	Froese & Pauly. FishBase (2014) [5]
Sparisoma cretense	35.8	1.1	20.7	0.6	4	*3. ; 5. ; 9. ; 11.*
Sparus aurata	49.6	-	29.1	-	1	Tsikliras & Stergiou (2013) [15]
Sphyraena sphyraena	55.3	-	30.7	-	1	Froese & Pauly. FishBase (2014) [5]
Spicara maena	24.0	1.1	14.5	0.6	6 (99'959)	Stergiou & Karachle (2006) [13]
Spicara smaris	19.2	1.7	11.9	1.0	6 (22'554)	Stergiou & Karachle (2006) [13]
Spondyliosoma cantharus	56.1	-	31.6	-	1	Stergiou et al. (2009) [14]
Symphodus mediterraneus	16.4	0.6	10.3	0.4	2	Froese & Pauly. FishBase (2014) [5]
Symphodus ocellatus	10.6	0.3	6.9	0.1	2	Froese & Pauly. FishBase (2014) [5]
Symphodus tinca	28.8	2.8	16.8	1.6	7	*3. ; 5. ; 15.*
Synodus saurus	36.7	-	21.2	-	1 (320)	Stergiou & Karachle (2006) [13]
Trachinus draco	41.8		23.8		(3)	Dimitriadis et al. (2013) [3]
Trachinus radiatus	23.8		14.4		(3)	Dimitriadis et al. (2013) [3]
Trigloporus lastoviza	33.5	-	19.5	-	1 (3542)	Stergiou & Karachle (2006) [13]
Uranoscopus scaber	31.9	4.5	18.7	2.4	2	Froese & Pauly. FishBase (2014) [5]
Zeus faber	61.5	4.3	35.5	2.1	2	Froese & Pauly. FishBase (2014) [5]

Note: N = numbers of records ; (N) = total number of individuals

References :

1. Abdallah, M., 2002. *Length-weight relationship of fishes caught by trawl off Alexandria, Egypt.* Naga, The ICLARM Quarterly 25, 19–20.
2. Bariche, M., 2005. *Age and growth of Lessepsian rabbitfish from the eastern Mediterranean.* Journal of Applied Ichthyology 21, 141–145.
3. Dimitriadis, C., Sini, M., Gerovasileiou, V., Poursanidis, D., Evagelopoulos, A., Fournari-Konstantinidou, I., Badouvas, N., Lekkas, V., Giourgis, E., Akritopoulou, E., Bakopoulos, V., Koutsoubas, D., 2013. *Management Measures for Fisheries in the Marine Protected Area of the National Marine Park of Zakynthos (Final report).* MedPAN North Project, Mytilini.
4. Dulčić, J., Kraljević, M., 1996. *Weight-length relationships for 40 fish species in the eastern Adriatic (Croatian waters).* Fisheries Research 28, 243–251.
5. Froese, R., Pauly, D., 2014. FishBase. World Wide Web electronic publication [WWW Document]. URL *http://www.fishbase.org/*
6. Kara, A., Akyol, O., 2011. *Record of Lessepsian rabbitfish Siganus luridus from northern Aegean Sea (Izmir Bay, Turkey).* Journal of Applied Ichthyology 27, 1381–1382.
7. Karakulak, F., Erk, H., Bilgin, B., 2006. *Length–weight relationships for 47 coastal fish species from the northern Aegean Sea, Turkey.* Journal of Applied Ichthyology 22, 274–278.
8. Morey, G., Moranta, J., Massutı, E., Grau, A., Linde, M., Riera, F., Morales-Nin, B., 2003. *Weight–length relationships of littoral to lower slope fishes from the western Mediterranean.* Fisheries Research 62, 89–96.
9. Moutopoulos, D., Stergiou, K., 2002. *Length–weight and length–length relationships of fish species from the Aegean Sea (Greece).* Journal of Applied Ichthyology 18, 200–203.
10. Ozaydin, O., Taskavak, E., 2006. *Length-weight relationships for 47 fish species from Izmir Bay (eastern Aegean Sea, Turkey). Acta Adriatica 47, 211.*
11. Petrakis, G., Papaconstantinou, C., 1990. Biology of Sparisoma cretense in the Dodecanese (Greece). Journal of Applied Ichthyology 6, 14–23.
12. Shakman, E., Winkler, H., Oeberst, R., Kinzelbach, R., 2008. *Morphometry, age and growth of Siganus luridus Rüppell, 1828 and Siganus rivulatus Forsskål, 1775 (Siganidae) in the central Mediterranean (Libyan coast).* Revista de biología marina y oceanografía 43, 521–529.
13. Stergiou, K.I., Karachle, P.K., 2006. *A review of various biological parameters for fish from the Greek Seas.* Journal of Biological Research 199–211.
14. Stergiou, K.I., Moutopoulos, D.K., Armenis, G., 2009. *Perish legally and ecologically: the ineffectiveness of the minimum landing sizes in the Mediterranean Sea.* Fisheries Management and Ecology 16, 368–375.
15. Tsikliras, A.C., Stergiou, K.I., 2013. *Size at maturity of Mediterranean marine fishes.* Reviews in Fish Biology and Fisheries 1–50.
16. Collette, B.B., Nauen, C.E., 1983. FAO species catalogue. Volume 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date.

Table 3. Results of the PERMANOVA analysis on 6 different cases, with “Mesh size” as fixed factor

		Species Number			Mean CPUE			Mean IPUE		
Source of Variation	*df*	*MS*	*Pseudo - F*	*P*	*MS*	*Pseudo - F*	*P*	*MS*	*Pseudo - F*	*P*
Mesh size	3	115.23	2.8829	0.056	0.16816	4.4933	**0.011**	21.02	2.6325	0.063
Res	26	39.972			3.74E-002			7.9847		
Total	29									
		Mean %<Lm			**Mean %<MCRS**			**Species Composition**		
Source of Variation	*df*	*MS*	*Pseudo - F*	*P*	*MS*	*Pseudo - F*	*P*	*MS*	*Pseudo - F*	*P*
Mesh size	3	7441.3	7.3672	**0.001**	2558.1	4.3103	**0.035**	6948.5	2.4387	**0.001**
Res	26	1010.1			593.48			2849.3		
Total	29									

Table 4. Percentage of the number of individuals with total length smaller than the length at maturity (Lm), +/- its standard error (SE), and the minimum conservation reference size (MCRS) per mesh sizes, for 8 species caught in Zakynthos Island 2012-2014

	21 mm				**26 mm**				**28 mm**				**36 mm**				**TOTAL**			
Species	% < Lm	-SE	+SE	% < MCRS	% < Lm	-SE	+SE	% < MCRS	% < Lm	-SE	+SE	% < MCRS	% < Lm	-SE	+SE	% < MCRS	% < Lm	-SE	+SE	% < MCRS
Diplodus sargus	66.7	66.7	68.8	66.7	22.9	20.8	22.9	14.6	0.0	0.0	0.0	0.0	2.1	2.1	2.1	2.1	91.7	89.6	93.8	83.3
Mullus surmuletus	82.1	60.0	84.8	0.0	2.1	1.4	2.1	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.7	0.0	84.1	61.4	91.0	0.0
Pagrus pagrus	21.4	21.4	21.4	17.9	42.9	42.9	42.9	10.7	14.3	14.3	14.3	10.7	17.9	17.9	17.9	0.0	96.4	96.4	96.4	39.3
Phycis phycis	26.3	23.7	26.3	0.0	21.1	18.4	21.1	0.0	26.3	26.3	26.3	0.0	5.3	2.6	5.3	0.0	78.9	71.1	78.9	0.0
Scorpaena porcus	79.6	73.7	79.6	0.0	0.7	0.7	0.7	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	80.3	74.5	81.0	0.0
Scorpaena scrofa	23.5	22.6	23.5	0.0	20.9	16.5	24.3	0.0	24.3	20.0	26.1	0.0	17.4	9.6	19.1	0.0	86.1	68.7	93.0	0.0
Sparisoma cretense	24.8	23.8	25.7	0.0	11.9	8.9	12.9	0.0	6.9	6.9	10.9	0.0	4.0	2.0	6.9	0.0	47.5	41.6	56.4	0.0
Spondyliosoma cantharus	28.6			0.0	20.0			0.0	17.1			0.0	25.7			0.0	91.4			0.0
Mean % < Lm, MCRS	44.1	41.7	47.2	10.6	17.8	15.7	18.1	3.2	11.1	9.6	11.7	1.3	9.1	4.9	7.4	0.3	82.1	71.9	84.4	15.3

Table 5. Results of the Wilcoxon signed-rank test for 8 species showing the significances of the departing values of the median size of the individuals caught in different mesh sizes from their length at maturity (Lm), Lm-SE and Lm+SE.

Species	Mesh Size	L_m	-SE	+SE
Diplodus sargus	21mm	(-) p<0.0001*	(-) p<0.0001*	(-) p<0.0001*
	26mm	(-) p<0.027*	(ns)	(-) p<0.009*
	28mm			
	36mm			
Mullus surmuletus	21mm	(-) p<0.0001*	(-) p<0.0001*	(-) p<0.0001*
	26mm	(ns)	(ns)	(ns)
	28mm	(+) p<0.016*	(+) p<0.016*	(ns)
	36mm	(+) p<0.020*	(+) p<0.012*	(+) p<0.017*
Pagrus pagrus	21mm	(-) p<0.028*	(-) p<0.028*	(-) p<0.028*
	26mm	(-) p<0.023*	(-) p<0.023*	(-) p<0.023*
	28mm	(ns)	(ns)	(ns)
	36mm	(-) p<0.042*	(-) p<0.042*	(-) p<0.042*
Phycis phycis	21mm	(-) p<0.005*	(-) p<0.007*	(-) p<0.005*
	26mm	(-) p<0.012*	(-) p<0.017*	(-) p<0.012*
	28mm	(ns)	(ns)	(-) p<0.035*
	36mm	(ns)	(ns)	(ns)
Scorpaena porcus	21mm	(-) p<0.0001*	(-) p<0.0001*	(-) p<0.0001*
	26mm	(+) p<0.011*	(+) p<0.011*	(+) p<0.038*
	28mm	(+) p<0.005*	(+) p<0.005*	(+) p<0.007*
	36mm	(ns)	(ns)	(ns)
Scorpaena scrofa	21mm	(-) p<0.0001*	(-) p<0.0001*	(-) p<0.0001*
	26mm	(-) p<0.001*	ns	(-) p<0.0001*
	28mm	(-) p<0.0001*	(-) p<0.0001*	(-) p<0.0001*
	36mm	(-) p<0.015*	(ns)	(-) p<0.001*
Sparisoma cretense	21mm	(-) p<0.0001*	(-) p<0.0001*	(-) p<0.0001*
	26mm	(+) p<0.039*	(+) p<0.003*	(ns)
	28mm	(+) p<0.0001*	(+) p<0.0001*	(+) p<0.003*
	36mm	(ns)	(ns)	(ns)
Spondyliosoma cantharus	21mm	(-) p<0.005*		
	26mm	(-) p<0.017*		
	28mm	(-) p<0.050*		
	36mm	(-) p<0.008*		

(-) indicates that the median size of individuals were significantly smaller than Lm, +/-SE.
(+) indicates that median size of individuals was significantly bigger than Lm, +/-SE.
(ns) indicates non-significant values.

Figure 1.

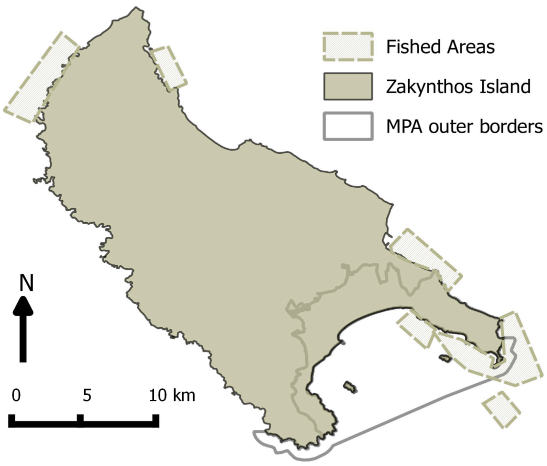


Figure 2.

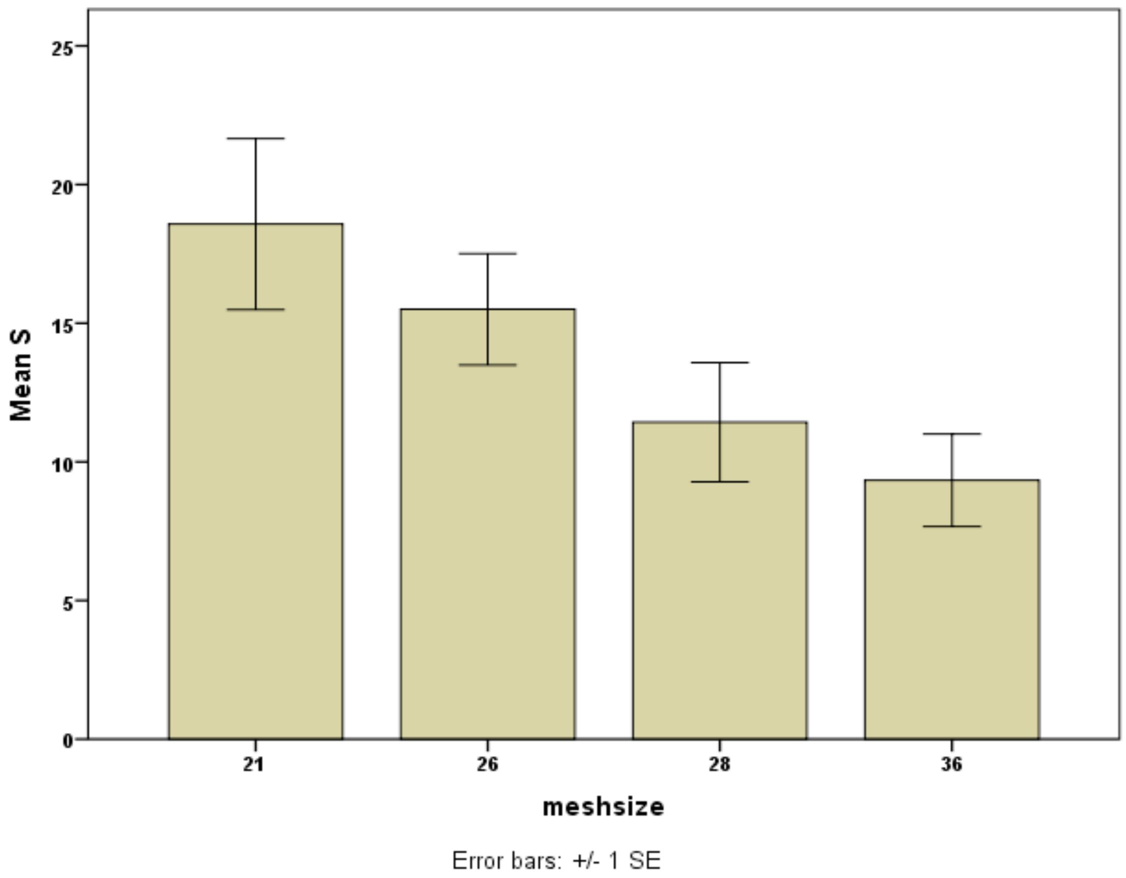


Figure 3.

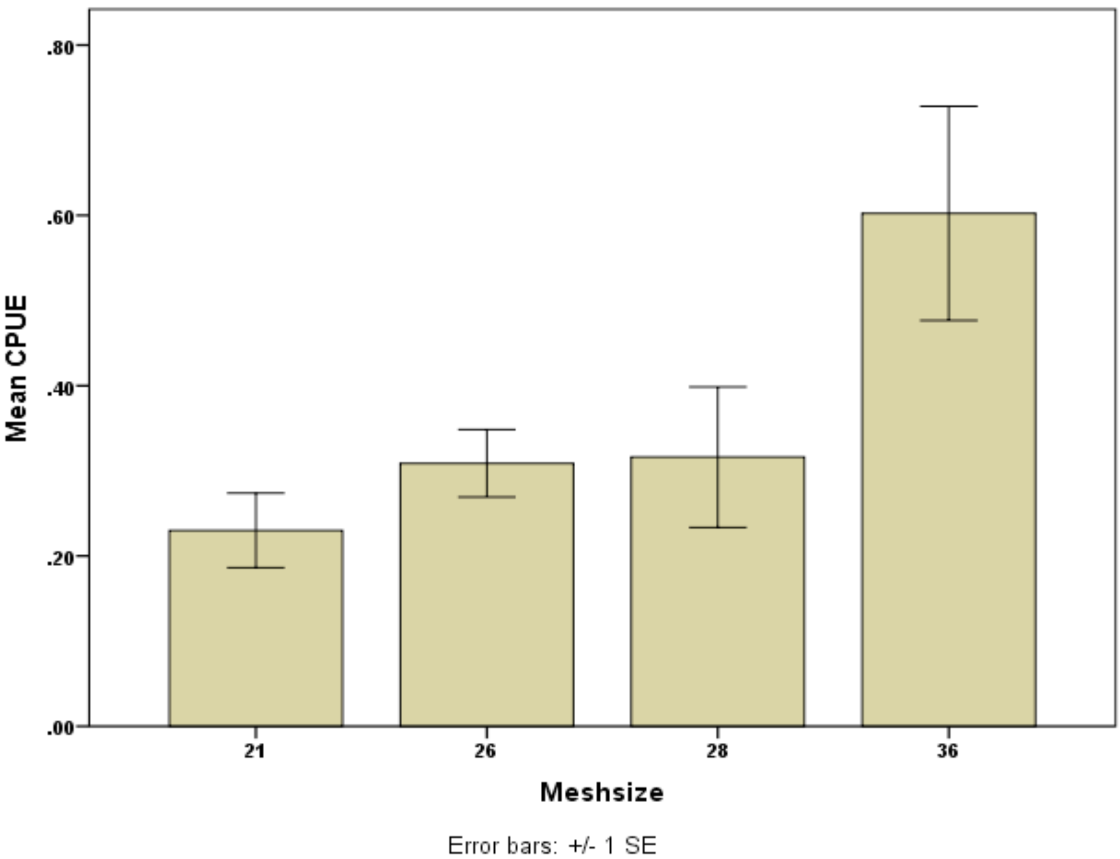


Figure 4.

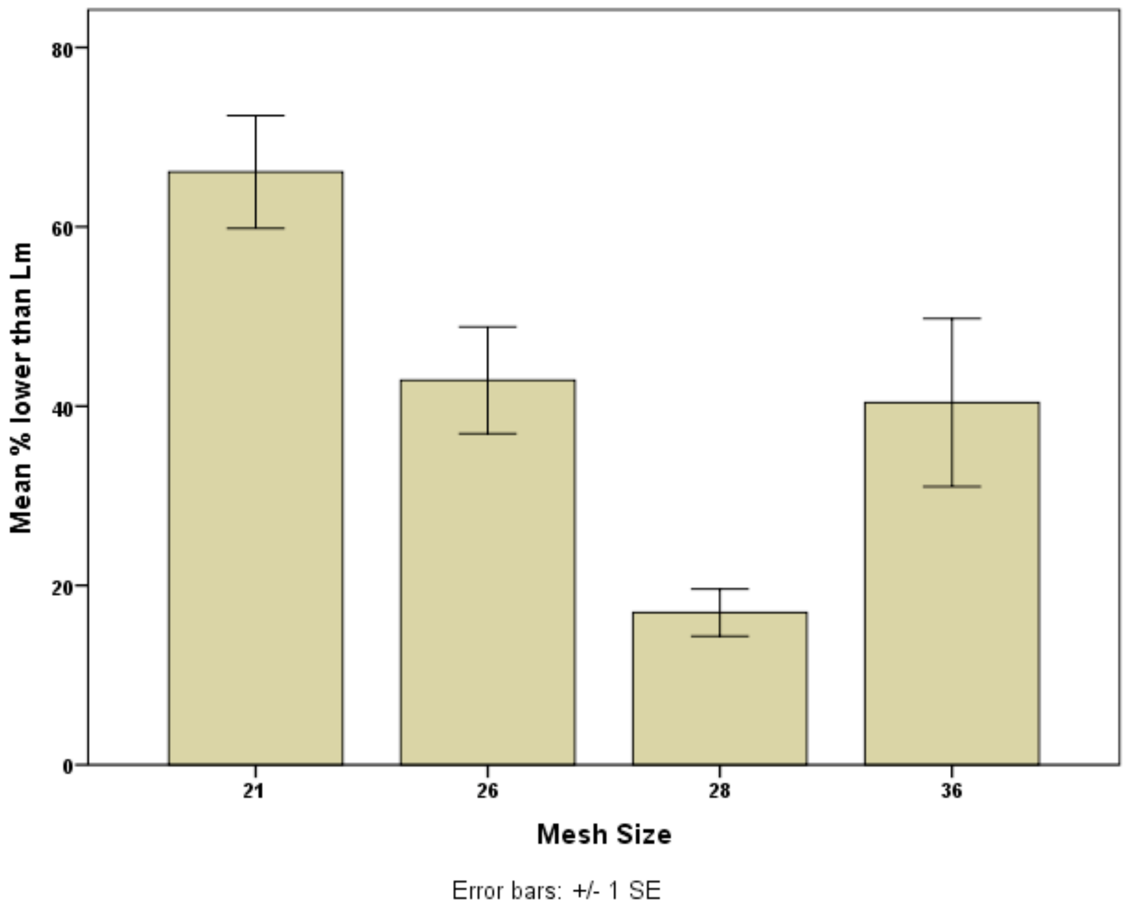
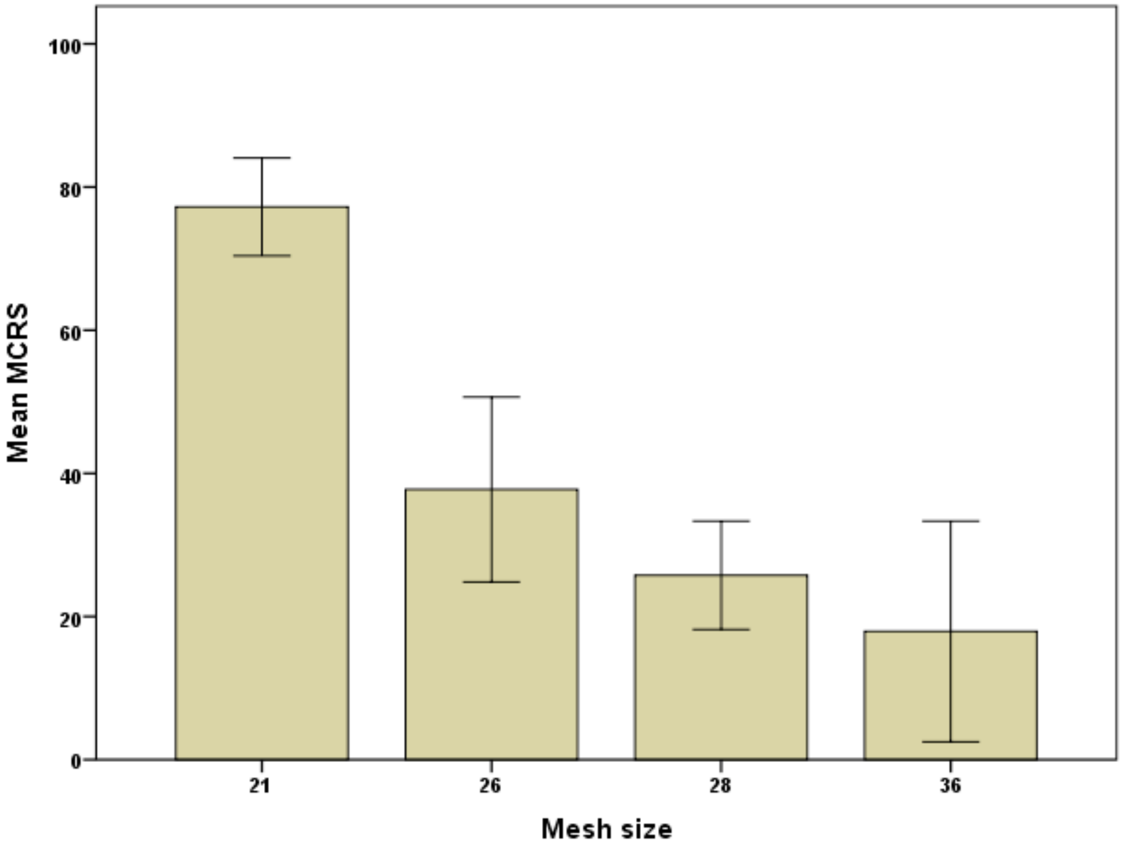

80
60
40
20
0
Mean % lower than Lm
21
26
28
36
Mesh Size
Error bars: +/- 1 SE

Figure 5.



Error bars: +/- 1 SE

Figure 6.

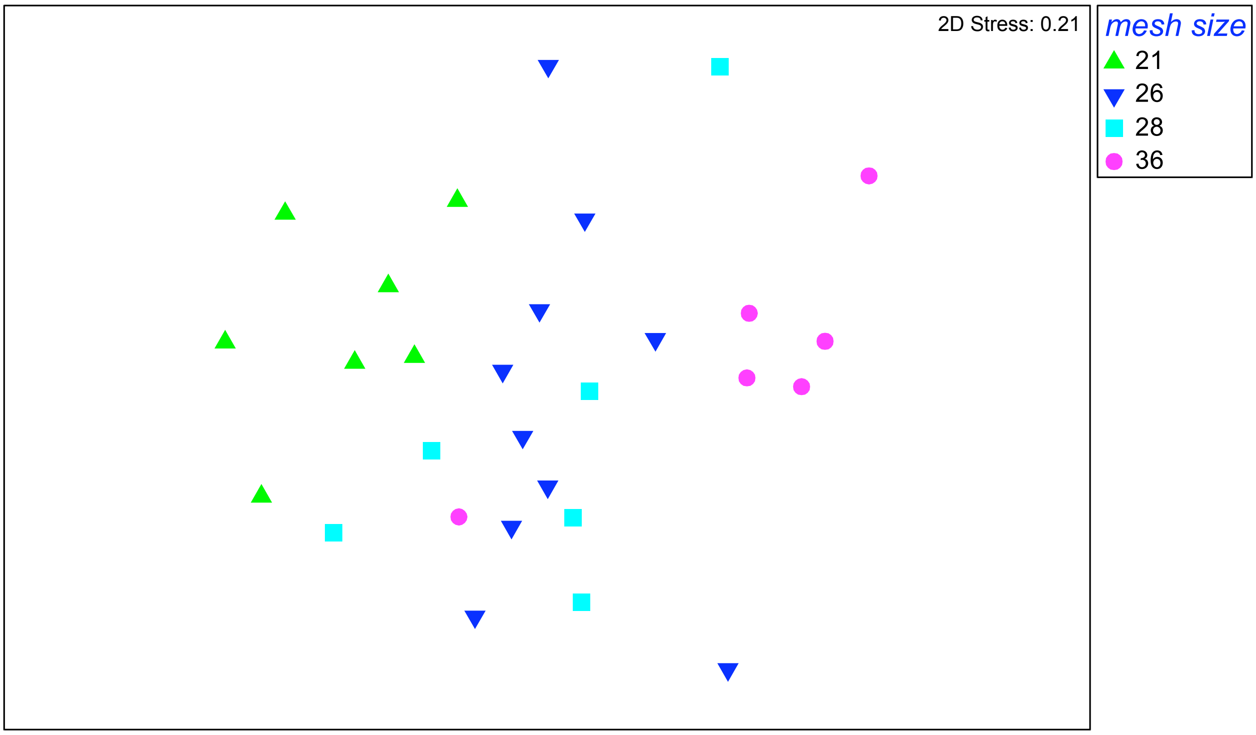
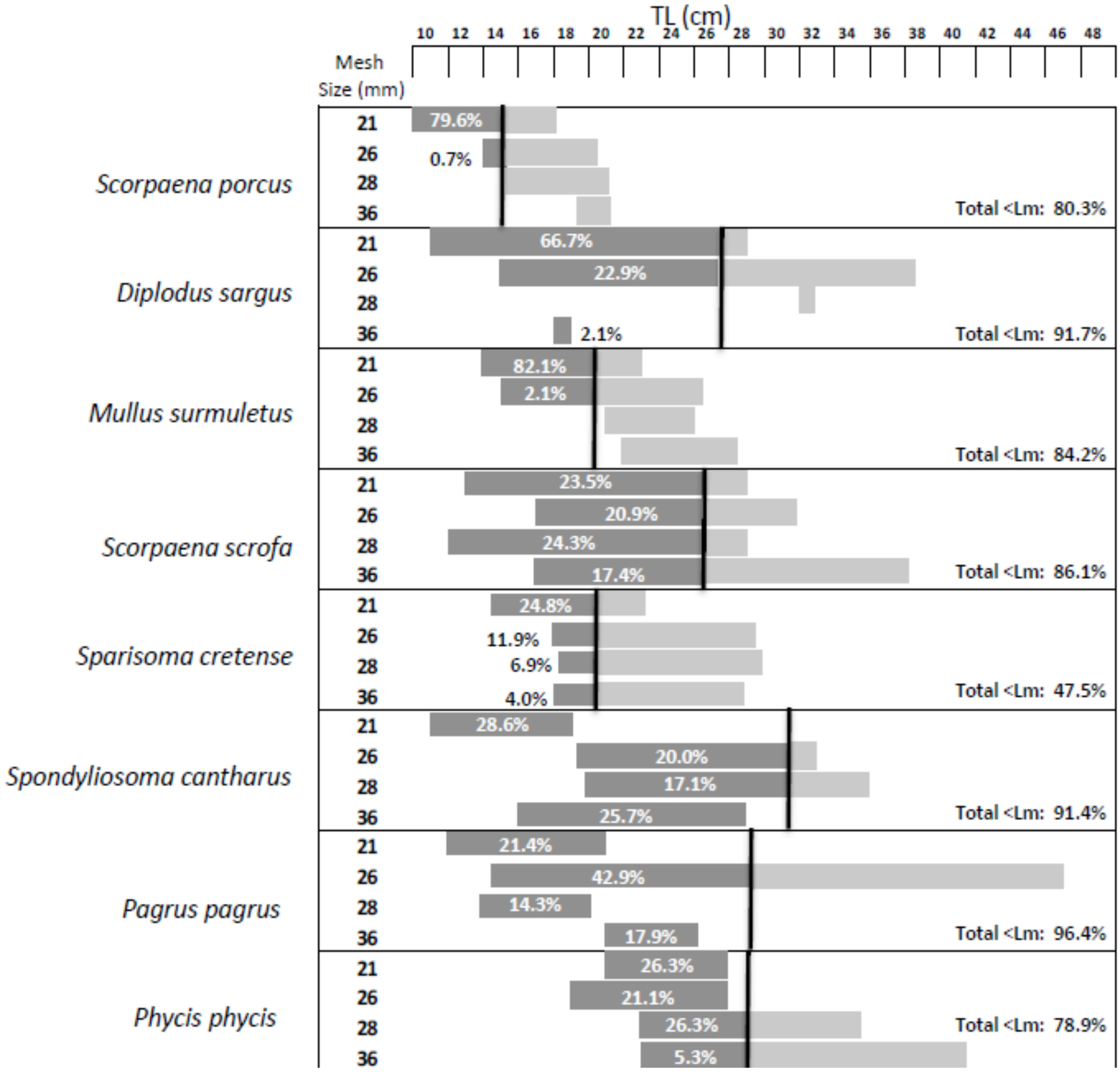


Figure 7.


TL (cm)
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Mesh Size (mm)
Scorpaena porcus
21 79.6%
26 0.7%
28
36
Total <Lm: 80.3%
Diplodus sargus
21 66.7%
26 22.9%
28
36 2.1%
Total <Lm: 91.7%
Mullus surmuletus
21 82.1%
26 2.1%
28
36
Total <Lm: 84.2%
Scorpaena scrofa
21 23.5%
26 20.9%
28 24.3%
36 17.4%
Total <Lm: 86.1%
Sparisoma cretense
21 24.8%
26 11.9%
28 6.9%
36 4.0%
Total <Lm: 47.5%
Spondyliosoma cantharus
21 28.6%
26 20.0%
28 17.1%
36 25.7%
Total <Lm: 91.4%
Pagrus pagrus
21 21.4%
26 42.9%
28 14.3%
36 17.9%
Total <Lm: 96.4%
Phycis phycis
21 26.3%
26 21.1%
28 26.3%
36 5.3%
Total <Lm: 78.9%

Appendix

Appendix 1. Species list of 35 fishing sets in Zakynthos Island, 2012-2014

Species name	Common name
Auxis rochei	Bullet tuna
Boops boops	Bogue
Bothus podas	Wide-eyed flounder
Chelidonichthys lucerna	Tub gurnard
Coris julis	Mediterranean rainbow wrasse
Dactylopterus volitans	Flying gurnard
Dasyatis pastinaca	Common stingray
Dentex dentex	Common dentex
Dicentrarchus labrax	Sea bass
Diplodus annularis	Annular seabream
Diplodus puntazzo	White seabream
Diplodus sargus	Sharpsnout seabream
Diplodus vulgaris	Two-banded seabream
Epinephelus costae	Gold-blotched grouper
Epinephelus marginatus	Dusky grouper
Euthynnus alletteratus	Little tunny
Labrus merula	Brown wrasse
Labrus mixtus	Cuckoo wrasse
Labrus viridis	Green wrasse
Lithognathus mormyrus	Sand steenbras
Loligo vulgaris	European squid
Merluccius merluccius	Hake
Mugil cephalus	Common grey mullet
Mullus barbatus	Striped mullet
Mullus surmuletus	Red mullet
Muraena helena	Mediterranean moray
Oblada melanura	Saddled seabream
Octopus vulgaris	Common octopus
Pagellus bogaraveo	Blackspot seabream
Pagellus erythrinus	Common pandora
Pagrus pagrus	Red porgy
Palinurus elephas	European spiny lobster
Phycis phycis	Forkbeard
Raja asterias	Mediterranean starry ray
Raja miraletus	Brown ray
Sarpa salpa	Salema
Sciaena umbra	Brown meagre
Scorpaena notata	Small red scorpionfish
Scorpaena porcus	Black scorpionfish
Scorpaena scrofa	Red scorpionfish
Scyllarides latus	Mediterranean slipper lobster
Sepia officinalis	Common cuttlefish
Seriola dumerili	Greater amberjack
Serranus cabrilla	Comber
Serranus hepatus	Brown comber
Serranus scriba	Painted comber
Siganus luridus	Dusky spinefoot
Solea solea	Common sole
Sparisoma cretense	Parrotfish
Sparus aurata	Gilthead seabream
Sphyraena sphyraena	European barracuda
Spicara maena	Blotched picarel
Spicara smaris	Picarel
Spondyliosoma cantharus	Black seabream
Symphodus mediterraneus	Axillary wrasse
Symphodus ocellatus	Ocellated wrasse
Symphodus tinca	Peacock wrasse
Synodus saurus	Atlantic lizardfish
Trachinus draco	Greater weever
Trachinus radiatus	Starry weever
Trigloporus lastoviza	Streaked gurnard
Uranoscopus scaber	Stargazer
Zeus faber	John dory