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Effectiveness of conventional management in Mediterranean type artisanal fisheries

S. Matić-Skoko*, N. Stagličić, A. Pallaoro, M. Kraljević, J. Dulčić, P. Tutman, B. Dragičević

Institute of Oceanography and Fisheries, Meštrovićevo šetalište 63, P.O. Box. 500, 21000 Split, Croatia

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ABSTRACT

Artisanal fisheries throughout the Mediterranean region are managed mostly by applying gear specific regulations. The data about the extent and dynamics by which littoral fish resources respond to commonly proposed changes of such regulations are lacking. Here the results of a 15 year (1995–2009) monitoring programme of littoral fish resources in a pilot region of island Vis aquatorium, central Adriatic Sea, are reported with the scope of investigating whether a more restrictive fishing regime (encompassing an increase in minimum inner layer mesh size of trammel net from 28 to 40 mm and excluding the trammel net from subsistence artisanal fishing) that has progressively been put in place during the study period has been accompanied by expected positive changes of littoral fish resources' abundance, biomass and structure. Significant increases over time were observed in most of the community indices analyzed (abundance and biomass catch per unit effort, diversity indices) as well as a directional change in abundance and biomass catch composition of littoral fish resources. Positive responses were, however, primarily related with a recovery of *Mullus surmuletus* stock. Additionally, time-series analysis of ABC curves and their corresponding *W* index revealed that fish community in the study area was still moderately disturbed. Limited extent of conventional management restorative potential is further exacerbated by social issues – noncompliant behavior mainly among subsistence artisanal fishers and consequent resentment of commercial artisanal fishers. In order to improve further the state of the resources a more comprehensive set of management measures incorporating closed areas and a new approach actively involving fishers in the management process should be adopted.

1. Introduction

Fisheries management throughout the Mediterranean region is largely based on gear specific management provisions (Papaconstantinou and Farrugio, 2000; Lleonart and Maynou, 2003). In recent years, seasonal closing of fishing grounds or proclamation of marine protected areas are increasingly advocated as a management tool for restoring littoral fish resources and ensuring the sustainability of their exploitation (Francour et al., 2001, Roberts et al., 2005). A large number of studies have focused on evaluating their effectiveness, while the effects of conventional forms of management, although they are still most frequently proposed and implemented, remain poorly investigated (McClanahan et al., 1997; Papaconstantinou and Farrugio, 2000).

Of all the fisheries sectors this is particularly true for artisanal one which is the most challenging and costly to assess, manage and monitor. Artisanal fishery is characterized by a high diversification of fishing gears and techniques, targeting a large variety of species, and by frequent changes in gear and technique use, spatially and seasonally, to optimize the catch and maximize profitability. Moreover, also social and economic context add significantly to the complexity and dynamics of artisanal fisheries (Battaglia et al., 2010).

An artisanal fishery of the eastern Adriatic is no exception to the aforementioned. Rich fishing tradition is fully reflected in this typical multi-species multi-gear fisheries sector employing more than 50 different types of fishing gear to catch about 150 different species of commercial interest (Cetinić et al., 2002). Furthermore, artisanal fisheries holds a high 'cultural' and 'heritage' value among the island and shoreline inhabitants and is consequently the most numerous in terms of number of vessels and fishers involved. Both commercial fishers, excluding larger-scale commercial fleets such as trawlers or purse seiners, and subsistence fishers are regarded as artisanal in Croatian eastern Adriatic Sea based on their use of traditional, relatively small size fishing gear and operating with relatively small fishing vessels not far from the shore. The key distinguishing features between commercial and subsistence artisanal fishers are the purpose of their activity, type and quantity of fishing

* Corresponding author.
E-mail address: sanja@izor.hr (S. Matić-Skoko).

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gear allowed and daily catch limits. Commercial fishing is a profit-making activity, while fish and other marine organisms caught in the course of subsistence fishing are not to be placed on the market and are intended solely for personal use. In the last 10 years type and quantity of fishing gear with which commercial and subsistence artisanal fishing can be undertaken have been the subject of fisheries management changes. Trammel net has traditionally been the favored fishing gear of Croatia's artisanal fishermen as they regard it as the most efficient one providing them with catches as lush as possible (Morović, 1970; Jardas, 1979). On the other hand, numerous studies, besides confirming their great catchability, have pointed out the low selectiveness resulting from their specific construction and operation properties (Jardas et al., 1998 and references therein). Hence, legislative changes of artisanal fishing regulations have mostly been aimed at trammel nets and encompass the increase in minimum inner layer mesh size of trammel net from 28 to 40 mm in 1999 and excluding the trammel net from subsistence artisanal fishing in 2002. Additionally, in 2002 for artisanal subsistence fishing legal provisions proclaimed a daily catch limit of 5 kg and reduced the allowed quantity of most types of gillnets, orienting it thus much more to trap and line fishing.

Studies of eastern Adriatic artisanal fisheries have up to now taken into consideration only the biological aspect. Typically they deal with the state and trends of littoral fish resources in an isolated manner without exploring the extent and nature of actual artisanal fishing activities targeting those resources. At present, the only available characterization of artisanal fisheries per se is the fleet size since data on the type of vessel (total length, capacity, engine power) is recorded when issuing a license at the Directorate of Fisheries. No accurate assessment of fishing effort is possible since reliable data on the type, dimension and quantity of fishing gear is lacking. Socio-economic issues of artisanal fisheries are completely unknown.

This study represents the first integrated approach in the eastern Adriatic to investigate the state of artisanal fisheries in a pilot region of island Vis aquatorium. This region, geographically centrally located in the middle of Adriatic Sea, has historically always been predominantly oriented to fisheries and hence its fishing practices show remarkable diversification. Results of a 15 year (1995–2009) monitoring programme of littoral fish resources are reported with the scope of investigating whether a more restrictive fishing regime that has progressively been put in place during the study period has been accompanied by expected positive changes of littoral fish resources' abundance, biomass and structure in the study region. Furthermore, the study explores the scale of artisanal fishing activities of study region and demonstrates the implications that management changes have had in social terms. Given the aforementioned paucity, this study represents a unique opportunity to follow up the effects of implementing more restrictive conventional management measures regarding artisanal fisheries, both in biological and social terms.

2. Materials and methods

2.1. Study site

Vis aquatorium is located in the open waters of middle Adriatic Sea and encompasses two larger islands Vis and Bisevo and numerous islets and reefs (Fig. 1). The coastline is mainly rocky with minor areas of sandy, gravel and man-made coast. The sea bottom of shelf area is heterogeneous and structurally complex with intermittent *Posidonia oceanica* seagrass beds and rocky bottoms covered by photophilic algae and coralligenous concretions. Sandy to muddy areas become more prevalent deeper than 50 m (Žuljević et al., 2009). Fishing grounds of Vis aquatorium are among the most abundant and diverse on the eastern side of the Adriatic Sea (Matić-Skoko et al., 2009).

2.2. Data collection

Littoral fish resources of Vis aquatorium were monitored from 1995 to 2009 by experimental fishing using sets of trammel net of same construction and technical features which were operated in the same manner. Tied together ten 1.5 m high and 32 m long 'poponica' trammel nets with inner layer mesh size of 28 mm and 150 mm mesh size of outer layers were set in the evening before sunset at a depth range of 10–40 m and retrieved in the morning after sunrise. Each year within the warm period (May–October) 4 sampling stations were surveyed. Sampling stations were randomly placed throughout the E coast of island Vis (Fig. 1) which represents a single biogeographical region (Žuljević et al., 2009). For each of

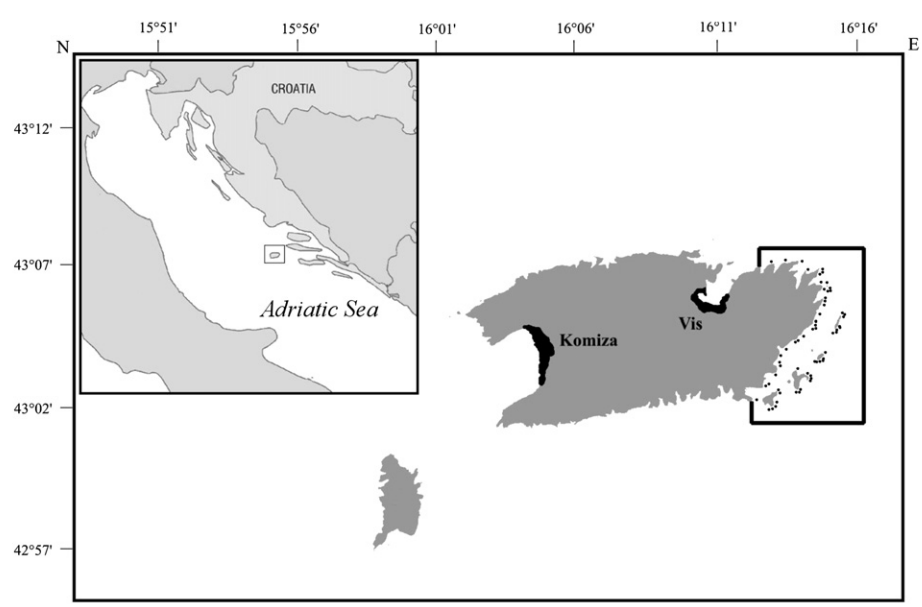

Fig. 1. Location of the study region showing the main fishing ports and the sampling area delimited by a solid line with sampling stations shown as dots.

the trammel net catches all fish individuals were identified to species level, measured (total length, to the nearest 0.1 cm) and weighed (total body weight, to the nearest 0.1 g).

Additionally, during summer 2008 a separate trial of experimental fishing consisting of 10 catches of each 28/150 and 40/150 mm inner/outer layer mesh size combination trammel nets was conducted in the same region and the same manner as described above. The purpose of this trial was twofold: (1) to examine differences in catch rates and catch species composition of trammel nets with these two inner layer mesh sizes; (2) to compare the experimental catches of currently legally allowed 40 mm trammel nets with commercial catch data provided by local fishermen serving thus as means of validation.

Biological and socio-economic implications of current commercial artisanal fisheries were assessed from free interviews followed by structured questionnaires with local fishermen. Questionnaires were designed to elicit the following: characteristics of fishing vessels, type, quantity and technical features of fishing gear used, spatio-temporal fishing activity patters, fish species most commonly caught, market channeling, observed changes of coastal fish resources, possible explanations for observed changes and perceptions on the perspective of artisanal fisheries. Interviews were conducted during spring-summer of 2008 by means of 2 interviewers. Fishermen were usually approached in ports upon returning from their fishing operations. In all cases questionnaires were administered and completed on site.

Number and technical features (length and engine horse power) of vessels registered for commercial artisanal fisheries on Vis Island were obtained through the registries of the Directorate of Fisheries. Direct observation was the method adopted for the estimation of number of people involved in subsistence fishing. All the ports of Vis island were surveyed and vessels were characterized as taking part in subsistence fishing if obvious signs, such as fishing gear on the deck or/and a power block were observed.

2.3. Data analysis

From the number and weight per species caught in each of the trammel net catches we calculated the following set of indices: (1) catch per unit effort (CPUE) for total fish abundance in terms of number of individuals (NCPUE) and for biomass in terms of weight in kilos (BCPUE). CPUE values are expressed per one piece (32 m) of trammel net following the standard notion adopted since 1970s in Croatia's fisheries science. Morović (1970) has established a rating scale assigning 28 mm inner layer mesh size trammel net catches, in terms of weight per one standard net 32 m long, to following categories: >2 kg excellent, 1.5–2 kg very good, 0.8–1.4 kg good, 0.6–0.7 kg poor, <0.5 kg very poor; (2) abundance and biomass CPUE for species groups formed on the basis of their fishing value. All species caught over the course of 15 years studied were characterized as either highly (HC), medium (MC) or low to non-commercial (NC) species depending on their market prices; (3) proportional (%) catch composition in terms of number and weight for individual species and fishing value groups; (4) diversity indices: total number of species (*S*), Margalef's species richness (*d*), Pieolu's evenness (*J*), Shannon–Wiener diversity (SW), average taxonomic distinctness measures in quantitative form (Δ^*) and presence/absence form (Δ^+); (v) *W* index as an indicator of the status of littoral fish resources. *W* index measures the extent to which the biomass k-dominance line lies above the abundance k-dominance line in an ABC plot. The difference between the 2 k-dominance lines may assume 3 possible forms, representing undisturbed, moderately disturbed and heavily disturbed fish communities (Clarke and Gorley, 2006). Biomass line above the abundance line throughout its entire length is expected for undisturbed communities. At moderate disturbance, biomass and abundance line are close and may intersect, while heavy disturbance is characterized by abundance line above biomass line throughout its length. Regarding *W* index, the lower the value, the more heavily disturbed the fish community is (Blanchard et al., 2004). ABC curves were constructed and *W* statistic calculated using PRIMER 6 statistical software.

The existence of temporal trends in all of the above mentioned indices over the course of 15 years studied was tested using linear regression analyses.

The significance of differences in catch rates (mean total abundance and biomass CPUE) between trammel nets of different inner layer mesh sizes (28 mm vs. 40 mm) as well as differences in biomass CPUE of data provided by local fishermen and those obtained by experimental fishing was tested using two sample *t*-test.

Before performing the aforementioned parametric tests the assumptions of normality and homogeneity of variances were tested by the Kolmogorov–Smirnov and Levene's test, respectively. If any of the assumptions was not met, the data were appropriately transformed (Zar, 1999). Univariate data were analyzed using the MINITAB version 15 statistical software with differences considered significant when $p < 0.05$.

Differences in multivariate catch fish species composition over time and between 28 and 40 mm trammel nets were visualized with non-metric multidimensional scaling (nMDS) on the basis of Bray–Curtis similarities between samples of square-root transformed species abundance and biomass data. To test whether pattern of temporal catch composition change conforms to a linear sequence or seriation RELATE procedure was employed. RELATE statistic ρ assesses the extent to which samples follow a linear trend, with adjacent samples being the closest in species composition, samples two steps apart the next closest, and so on. If there is no tendency to seriation then ρ will be close to zero (Clarke and Warwick, 2001). In order to identify the main species driving the temporal change BVSTEP routine was applied. BVSTEP routine uses a 'forward selection backward elimination' algorithm to find the smallest possible subset of species describing the pattern in the full data set at a $\rho > 0.95$ level of Spearman's rank correlation (see Clarke and Warwick, 1998 for a detailed explanation of BVSTEP routine). One-way ANOSIM test was performed to determine the magnitude of differences in catch species composition of 28 and 40 mm trammel nets. Species mainly contributing to the separation between catches of 28 and 40 mm trammel nets were determined using SIMPER procedure. This analysis indicates the average contribution of each species to the dissimilarity between groups of samples. All the multivariate routines were applied using PRIMER 6 statistical software.

Information for characterization of artisanal fisheries that was gathered during the course of free interviews served only for qualitative purposes, while questionnaire answers were analyzed quantitatively by descriptive statistics using MINITAB version 15 statistical software.

3. Results

3.1. Temporal trends of littoral fish resources

A total of 2514 fish belonging to 28 families and 72 species were caught between 1995 and 2009. During the course of the study the most frequently observed species were *Mullus surmuletus*, *Scorpaena porcus*, *Scorpaena scrofa* and *Symhodus tinca* which were present in more than 80% of trammel net catches (Table 1). Most species (91.7%) were present in less than 50% of trammel net catches.

Results of linear regression indicated significant increases over time in most of the analyzed univariate indices of caught littoral fish assemblages (Table 2).

Table 1
List of all fish species recorded in trammel net catches from 1995 to 2009 in decreasing order of their occurrence frequencies (%) and assigned fishing value group (HC high value commercial species; MC medium value commercial species; NC low to no value commercial species).

Species	Occurrence frequency	Fishing value
Mullus surmuletus	88.3	HC
Scorpaena porcus	83.3	MC
Scorpaena scrofa	81.7	HC
Symphodus tinca	80.0	NC
Spicara maena	70.0	MC
Phycis phycis	68.3	MC
Scorpaena notata	46.7	NC
Spondyliosoma cantharus	46.7	HC
Diplodus vulgaris	40.0	HC
Serranus cabrilla	36.7	MC
Zeus faber	36.7	HC
Uranoscopus scaber	35.0	MC
Boops boops	33.3	MC
Serranus scriba	30.0	MC
Diplodus annularis	26.7	MC
Symphodus mediterraneus	25.0	NC
Torpedo marmorata	23.3	NC
Trigloporus lastoviza	20.0	MC
Pagellus erythrinus	18.3	MC
Trachinus radiatus	16.7	HC
Conger conger	13.3	MC
Trachurus mediterraneus	11.7	MC
Labrus merula	11.7	NC
Labrus bimaculatus	10.0	NC
Scyliorhinus stellaris	10.0	MC
Pagellus acarne	10.0	MC
Sarpa salpa	10.0	MC
Trachinus draco	10.0	HC
Merluccius merluccius	8.3	HC
Chromis chromis	8.3	NC
Labrus viridis (turdus)	6.7	NC
Symphodus cinereus	6.7	NC
Raja montagui	6.7	NC
Synodus saurus	6.7	NC
Parablennius gattorugine	5.0	NC
Lophius piscatorius	5.0	HC
Sciaena umbra	5.0	MC
Scomber japonicus	5.0	MC
Scyliorhinus canicula	5.0	MC
Diplodus sargus	5.0	HC
Oblada melanura	5.0	MC
Pagrus pagrus	5.0	HC
Trachinus araneus	5.0	HC
Apogon imberbis	3.3	NC
Trachurus trachurus	3.3	MC
Seriola dumerili	3.3	HC
Trisopterus minutus	3.3	MC
Coris julis	3.3	NC
Symphodus ocellatus	3.3	NC
Talassoma pavo	3.3	NC
Scorpaena maderensis	3.3	NC
Buglossidium luteum	3.3	NC
Monochyrus hispidus	3.3	NC
Atherina hepsetus	1.7	MC
Arnoglossus imperialis	1.7	NC
Arnoglossus thori	1.7	NC
Spicara smaris	1.7	MC
Acantholabrus palloni	1.7	NC
Muraena helena	1.7	MC
Raja miraletus	1.7	MC
Raja polystigma	1.7	NC
Sparisoma cretense	1.7	NC
Scomber scombrus	1.7	HC
Auxis rochei	1.7	MC
Sarda sarda	1.7	HC
Solea nasuta	1.7	NC
Microchirus ocellatus	1.7	NC
Dentex dentex	1.7	HC
Diplodus puntazzo	1.7	HC
Pagellus bogaraveo	1.7	MC
Sphyraena sphyraena	1.7	HC
Mustelus mustelus	1.7	MC

Increase in total abundance and biomass CPUE resulted from proportional increases in abundance and biomass CPUE of all three fishing value groups (Fig. 2). Accordingly, proportional abundances (%NCPUE) and biomass (%BCPUE) of high, medium and low to no value commercial species groups underwent no significant changes throughout the study period (Table 2). On average, high, medium and low to no value commercial species constituted 35.2%, 43.9% and 20.9% of total catch by abundance and 40.7%, 41.6% and 17.7% by biomass, respectively. A continuous increase in total biomass CPUE has also resulted in alterations of trammel net catches categorization. Catches in the period from 1995 to 2000 can be categorized as very poor since yearly biomass CPUE was on average lower than 0.5 kg fish/32 m net. Catches of years 2001–2003 fall into the poor category, improving to good in 2004–2005 and very good in the last four years (2006–2009) of study.

Changes in diversity indices over time showed highly significant ($p < 0.01$) positive trends for total number of species (S), Margalef's species richness (d), Shannon–Wiener diversity (SW) and average taxonomic distinctness measures Δ^* and Δ^+. Such marked increases in species richness and diversity resulted primarily from the occurrence of species *Scyliorhinus canicula*, *Scyliorhinus stellaris*, *Coris julis*, *Symphodus cinereus* and *Scorpaena notata* later on in the study period. Only for Pieolu's evenness (J) there were no significant time trends (Table 2) indicating that the distribution of individuals among different species present in trammel net catches has remained stable during the course of the study.

Time-series analysis for W index shows that index values have remained stable (Table 2) for the entire period studied. Relatively low W index values ($x \pm \text{s.d.} = 0.08 \pm 0.09$) together with yearly ABC plots (not shown) with intersecting abundance and biomass lines

Table 2
Linear regression analyses results of abundance, biomass and diversity indices of fish assemblages in trammel net catches as a function of time (1995–2009).

	Factor	R^2	Slope b	t-Statistic	p Value
Abundance indices	logNCPUE	0.712	0.055	12.12	**<0.001**
	logNCPUE_HC	0.544	0.063	8.44	**<0.001**
	logNCPUE_MC	0.597	0.059	9.40	**<0.001**
	logNCPUE_NC	0.184	0.036	3.78	**<0.001**
	%NCPUE_HC	0.030	0.007	1.68	0.098
	%NCPUE_MC	0.001	0.001	0.20	0.843
	%NCPUE_NC	0.031	−0.003	−1.70	0.094
Biomass indices	logBCPUE	0.685	0.025	11.36	**<0.001**
	logBCPUE_HC	0.559	0.015	8.70	**<0.001**
	logBCPUE_MC	0.596	0.016	9.39	**<0.001**
	logBCPUE_NC	0.097	0.009	2.49	**0.016**
	%BCPUE_HC	0.007	0.003	0.63	0.532
	%BCPUE_MC	0.006	0.006	1.15	0.253
	%BCPUE_NC	0.040	−0.003	−1.86	0.068
Diversity indices	S	0.443	0.656	6.92	**<0.001**
	d	0.196	0.0906	3.92	**<0.001**
	J	0.006	−0.002	−1.18	0.244
	SW	0.319	0.051	5.35	**<0.001**
	Δ^*	0.144	0.406	3.31	**0.002**
	Δ^+	0.126	0.394	3.08	**0.003**
	W	0.001	−0.002	−0.75	0.456

Significant p values are in **bold**.
NCPUE abundance catch per unit effort (N/320 m net); BCPUE biomass catch per unit effort (kg/32 m net); %NCPUE relative abundance catch per unit effort; %BCPUE relative biomass catch per unit effort; HC high value commercial species; MC medium value commercial species; NC low to no value commercial species; S total number of species; d Margalef's species richness; J Pielou's evenness; SW Shannon–Wiener diversity; Δ^* quantitative taxonomic distinctness; Δ^+ presence/absence taxonomic distinctness; W index based on relative positions of abundance and biomass k-dominance lines in ABC plot.
Total abundance and biomass catch per unit effort as well as abundance and biomass catch per unit effort of fishing value groups were $\log_{10}(x+1)$ transformed to satisfy the assumptions of linear regression analysis.

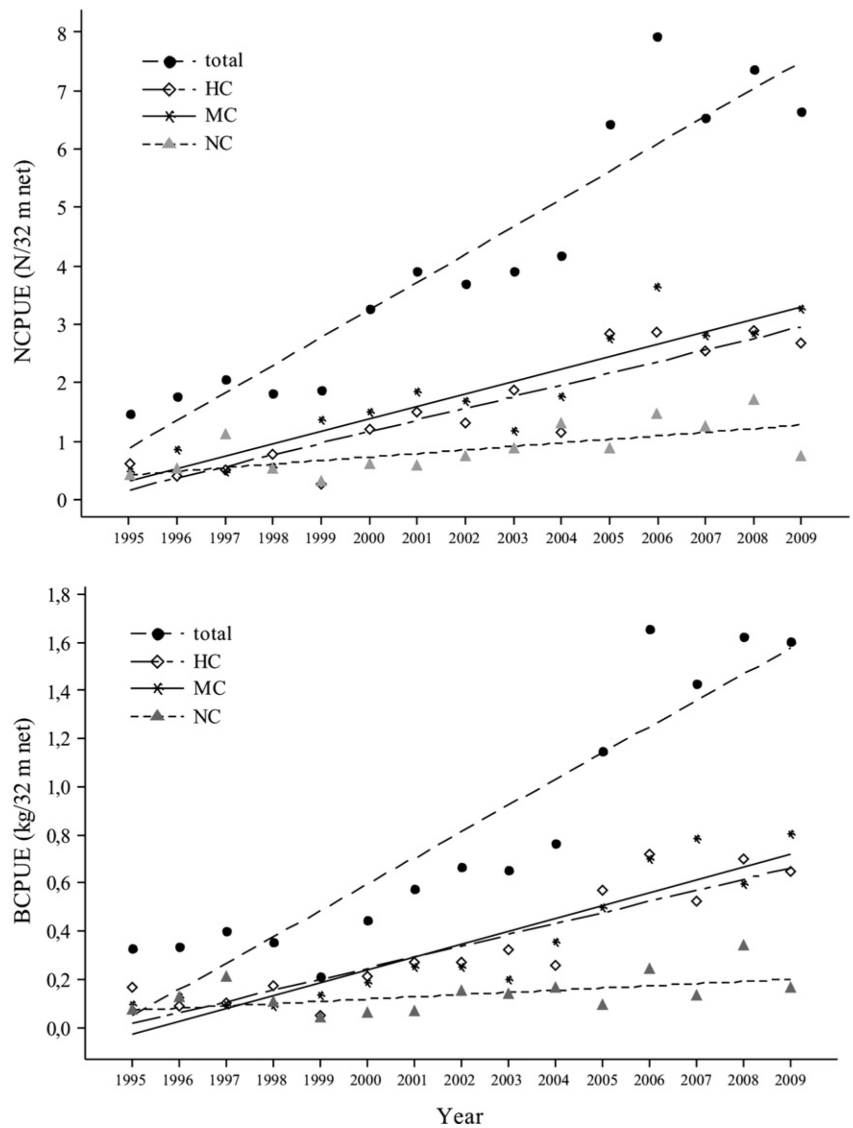

Fig. 2. Annual total, high value (HC), medium value (MC) and low to no value commercial (NC) species group abundance (NCPUE) and biomass (BCPUE) catch per unit effort means of trammel net catches as a function of time.

indicate a moderately disturbed pattern in littoral fish resources throughout the period 1995–2009.

nMDS ordination plots of trammel net catches averaged in each year (Fig. 3) showed similar patterns of interannual change of fish species composition in terms of abundance and biomass. Directional change (seriation) over time seen in nMDS plots proved to be highly significant in both cases (abundance: $\rho = 0.637$, $p < 0.001$; biomass: $\rho = 0.717$, $p < 0.001$). Analysis of caught fish assemblages using BVSTEP revealed that striped red mullet, *Mullus surmuletus*, alone correlates with the full abundance and biomass similarity matrix at about 75% level and is therefore the main species driving the observed temporal change. Additionally, at a 95% level *Phycis phycis*, *Scorpaena scrofa*, *Scorpaena notata*, *Spondyliosoma cantharus*, *Diplodus vulgaris*, *Torpedo marmorata* and *Spicara maena* contributed also to correlation with the directional change of whole fish assemblages caught in trammel nets between 1995 and 2009.

Examined over time, abundance and biomass CPUE of all the aforementioned species increased over the course of 15 years studied ($p = 0.01$ or less in all cases). Analysis on an individual basis for *Mullus surmuletus* showed that increase in abundance and biomass CPUE of this species was accompanied by increase in length ($R^2 = 0.096$, $F_{1.508} = 54.12$, $p < 0.001$) and mass ($R^2 = 0.149$, $F_{1.508} = 88.68$, $p < 0.001$) of *M. surmuletus* specimens caught in trammel nets between 1995 and 2009 (Fig. 4). Catches of two highly represented species *Scorpaena porcus* and *Symhodus tinca* did not demonstrate conspicuous trends between years.

3.2. Catch rates and catch composition of 28 mm vs. 40 mm trammel nets

Catches of 28 mm trammel nets were characterized by on average 4.4 times higher overall CPUE in terms of abundance and 2.7 times higher overall CPUE in terms of biomass than catches of 40 mm trammel nets. In both cases the difference was highly significant (abundance: $t = 5.57$; $p < 0.001$; biomass: $t = 4.04$; $p = 0.001$). Results of one-way ANOSIM analysis show that there are also significant differences in catch composition with respect to inner layer mesh size of trammel nets (abundance: $R = 0.48$; $p = 0.002$; biomass: $R = 0.37$; $p = 0.002$). SIMPER routine revealed that the same 8 species (Table 3), but in different order of %

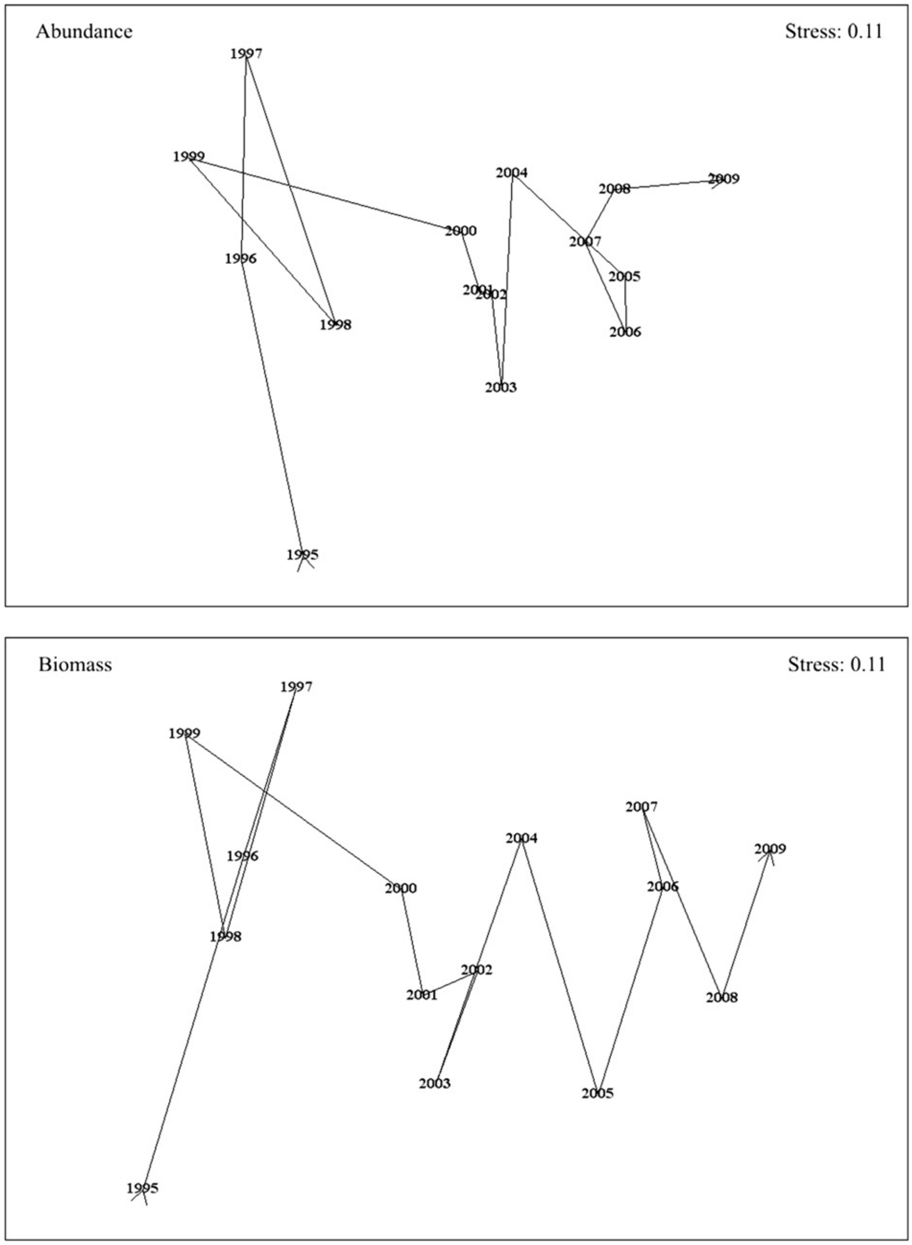

Fig. 3. Non-metric multidimensional scaling (nMDS) ordination plots of annual average abundance and biomass of fish assemblages caught in trammel nets between 1995 and 2009.

contribution for abundance and biomass, are responsible for most (>50%) of dissimilarity between 28 and 40 mm trammel net catches. All of the 8 discriminating species were caught in higher number and weight using 28 mm trammel nets. However, the difference was significant only for *Mullus surmuletus* (abundance: $t = 6.62$; $p < 0.001$; biomass: $t = 6.71$; $p < 0.001$) and *Scorpaena porcus* (abundance: $t = 5.11$; $p < 0.001$; biomass: $t = 4.01$; $p = 0.001$).

3.3. Characteristics of artisanal fisheries

In Vis aquatorium currently about 550 vessels take part in artisanal coastal fisheries operating from two main fishing ports (Fig. 5). Eighty-nine vessels are registered for commercial artisanal fishing, out of which 63 are stationed in fishing port Komiža and 23 in fishing port Vis. Furthermore, in Komiža 116 vessels are actively involved in subsistence artisanal fishing whole year round, while 105 vessels are found on shore for extended periods indicating their seasonal fishing preoccupation, mostly just during the summer months. In fishing port Vis the numbers of continuously and seasonally active subsistence artisanal fishing vessels are 108 and 134, respectively. The structure of commercial artisanal fleet was explored further for each of the fishing ports. Although Komiža hosts a larger commercial artisanal fleet, regarding technical features it is no different from the commercial artisanal fleet of Vis fishing port (vessel length: $t = 0.87$; $p = 0.39$; engine horse power (HP): $t = 1.74$; $p = 0.09$). Vessels are on average (±s.d.) 7.6 (±1.8) m long and have a mean engine power (±s.d.) of 63.7 (±79.3). As can be seen from the Fig. 6, the bulk of the fleet is composed of vessels between 6 and 9 m of length (71.9%) with engines of horse power less than 85 (80.9%).

Interviews and questionnaires were conducted with 37 fishermen encompassing 41.6% of the entire commercial artisanal fleet.

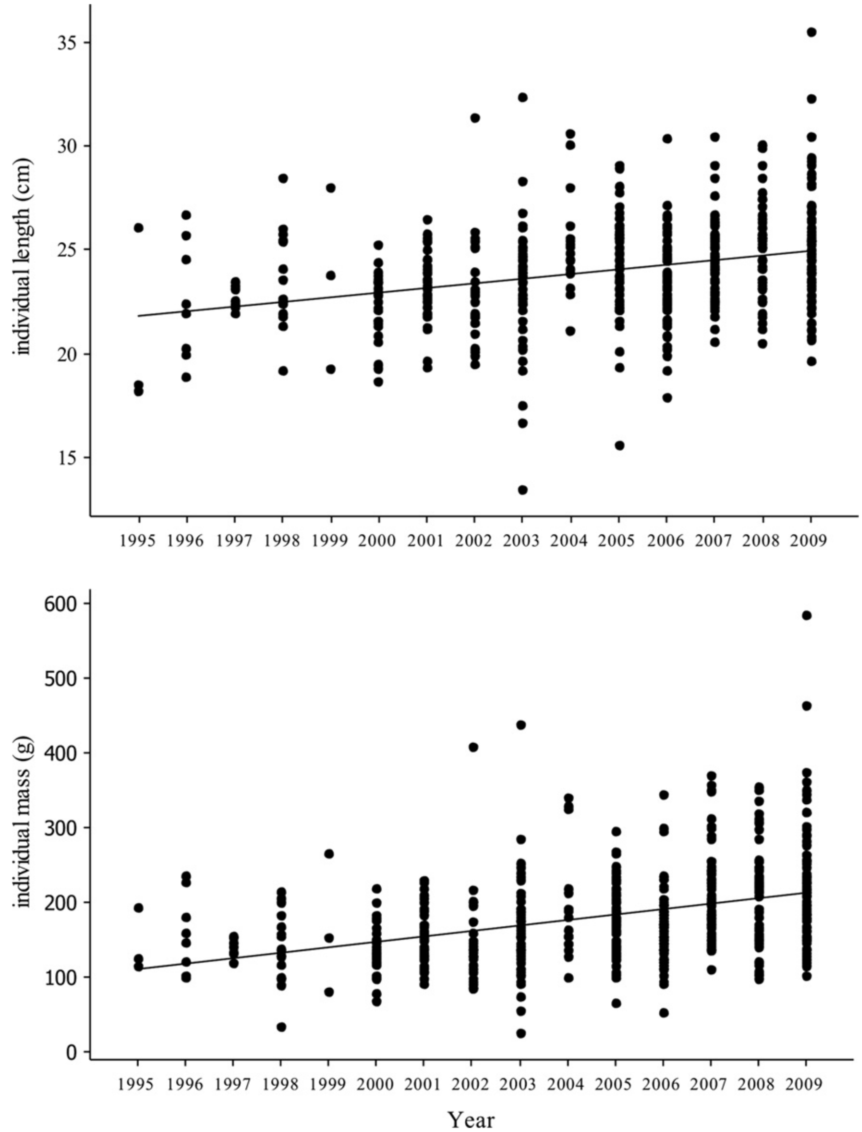

Fig. 4. Length and mass of individual *Mullus surmuletus* specimens caught in trammel nets as a function of time.

All the fishermen are active throughout the year for an estimated average (±s.d.) of 220 (±44) fishing days/year. Most of the remaining days bad weather conditions restrain them from leaving the shore, resulting in fishing activity being more intense between April and October. Fishing respondents varied widely in age and fishing experience, ranging from 21 to 75 years old ($x \pm$ s.d. $= 40 \pm 13$ years) with 3 to 50 years ($x \pm$ s.d. $= 19 \pm 11$ years) being professionally engaged in artisanal fishing. Only 4 fishermen (10.8%) were younger than 30 years indicating a small interest in entering a fishing profession among the younger generation. Search for more profitable employment opportunities in urban surroundings is perceived as the main reason for the lack of interest by all the respondents.

Table 3
SIMPER: species contributing most to the dissimilarity, in terms of abundance and biomass, of 28 and 40 mm inner layer mesh size trammel net catches.

Abundance			Biomass		
Species	Contribution (%)	Cumulative (%)	Species	Contribution (%)	Cumulative (%)
Mullus surmuletus	13.55	13.55	*M. surmuletus*	14.28	14.28
Scorpaena porcus	9.37	22.92	*S. porcus*	7.80	22.08
Scorpaena scrofa	6.03	28.95	*P. phycis*	6.50	28.58
Symhodus tinca	5.85	34.79	*S. tinca*	5.65	34.23
Spondyliosoma cantharus	4.62	39.42	*O. melanura*	4.64	38.87
Spicara maena	4.36	43.78	*S. maena*	4.52	43.39
Phycis phycis	4.16	47.94	*S. scrofa*	3.94	47.34
Oblada melanura	4.11	52.04	*S. cantharus*	3.72	51.06

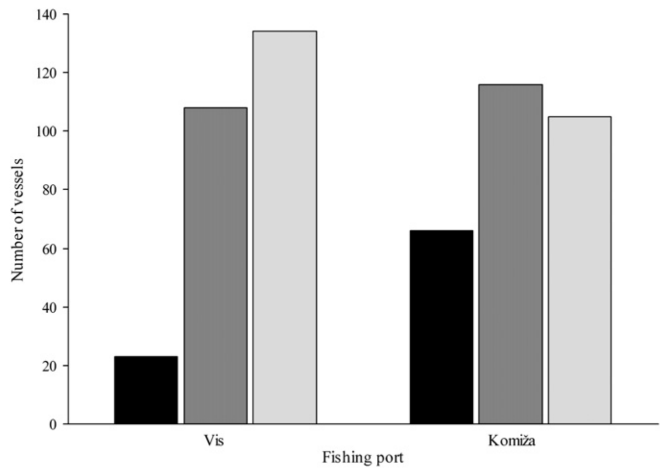

Fig. 5. Artisanal fisheries fleet of Vis island (■ commercial fishers, ▩ continuously active subsistence fishers, □ seasonally active subsistence fishers).

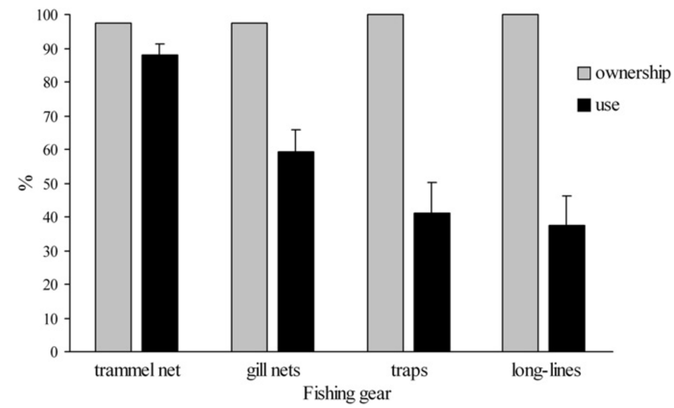

Fig. 7. Frequency of ownership and use* of fishing gear by commercial artisanal fishermen (*fishing gear use values are reported as averages of estimated percent of fishing trips when particular fishing gear owned by the fishermen was used).

Questionnaire returns indicated that there are 4 main types of fishing gear characteristic for the artisanal fisheries of the surveyed region – trammel net, gillnets (of larger mesh sizes), traps and bottom long-lines. 36 fishermen (97.3%) reported owning all of the 4 main types of fishing gear, while only 1 fishermen is exclusively oriented to fishing with traps and long-lines (Fig. 7) without ever using fishing nets (in his words 'nets are simply to much of a hassle').

Although net fishing, especially by trammel net, provides highly varied catches, fishery is mostly sustained by few highly commercial species. In the study region trammel net is primarily used to target *Mullus surmuletus* and *Scorpaena scrofa*, while gillnets, depending on the type, can target also *S. scrofa* and to a lesser extent *Palinurus elephas* or members of Scombridae family. Traps are generally employed to catch *P. elephas* and occasionally *Spondyliosoma cantharus*. Bottom long-line catches are highly dominated by two species – tub gurnard, *Trigla lucerna*, and european hake *Merluccius merluccius*. However, it should be noted that trap and long-line catches are mostly realized on offshore fishing grounds further away from Vis aquatorium. On the other hand, the preferred fishing grounds for net fishing were at the E coast of island Vis, mainly at depths <50 m where the seabed is highly heterogeneous with coralligenous, rocky substrata and seagrass beds interspersed in different proportions, which is concomitant with the sampling area covered by the study.

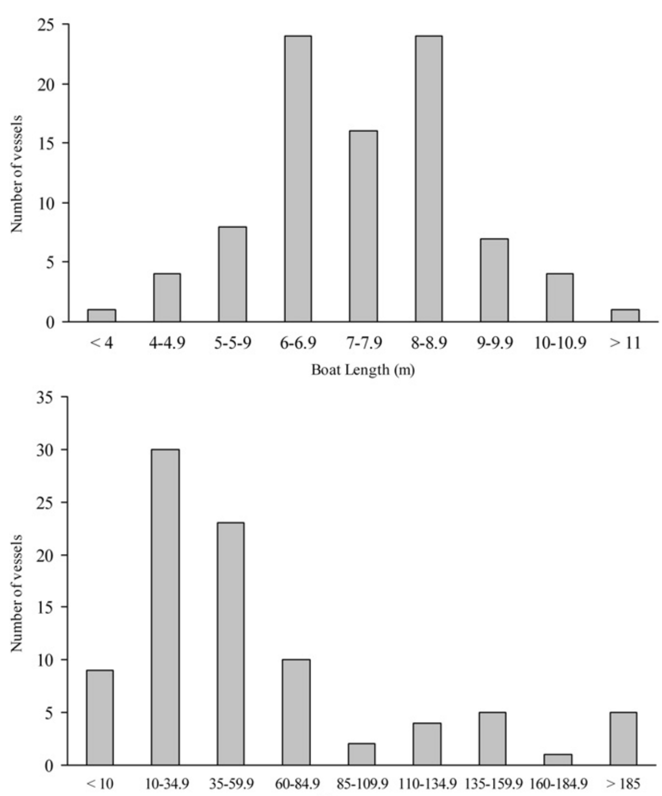

Fig. 6. Structure of commercial artisanal fisheries fleet by vessel length and engine horse power.

Fishermen responses revealed that they are primarily involved in trammel net fisheries using the trammel nets on average in 88.1% of their fishing operations during the time when they're allowed (Fig. 7) and alternating to other gear types mostly just when trammel net is prohibited (June–September). In most cases one type of fishing gear is used per fishing trip. Characterization of fishing gear used per fishing trip is summarized in Table 4. The average (±s.d.) CPUE of 0.78 (±0.24) kg of fish/32 m net reported by fishermen for 40 mm trammel net is on the verge of being significantly higher than the average (±s.d.) CPUE of 0.56 (±0.25) kg of fish/32 m net realized by experimental fishing ($t = -2.10$; $p = 0.05$). Fishermen's higher catches are attributable to their extensive knowledge and experience of local fishing grounds. Comparison of reported CPUE for trammel net and gillnets (Table 4) reveals that trammel net catches are significantly ($t = -2.94$; $p < 0.01$) and on average 50% higher than those realized with gillnets explaining thus fishermen's preference for using trammel nets.

The majority of catch is commercialized, with species of low fishing values usually retained for personal consumption. Discards are practically irrelevant, represented mainly by species as *Torpedo marmorata* or smaller representatives of genus *Symphodus*.

Regarding the trends in total catches fishermen reported not perceiving any changes, except for the fishermen with more than 15 years of professional engagement in fishing who experienced a substantial decline in trammel net catches following the legislative increase of trammel net inner layer mesh size from 28 to 40 mm. Nevertheless, economic viability of their fisheries did not wane since the drop in the overall fish catches was compensated by catching on average larger sized, commercially more valuable specimens and by continuous increase of fish prices in general. Additionally, the oldest fishermen recalled the catches going considerably downwards throughout the late 1960s and 1970s. All

Table 4
Characterization of fishing gear used per fishing trip by commercial artisanal fishermen with their catch per unit effort (CPUE).

Fishing gear	CPUE (kg/32 m net; kg/trap; kg/100 hooks)		Length of fishing sets (m)		Number of fishing sets; traps; hooks	
	Range	Mean ± s.d.	Range	Mean ± s.d.	Range	Mean ± s.d.
Trammel net	0.53–1.33	0.78 ± 0.24	250–600	440.91 ± 128.10	1–3	2.45 ± 0.69
Gill nets	0.33–0.80	0.52 ± 0.17	300–800	527.27 ± 134.84	1–4	2.18 ± 1.08
Traps	0.20–1.50	0.54 ± 0.41	–	–	50–150	87.50 ± 37.69
Long-lines	1.15–2.50	1.79 ± 0.45	–	–	500–1500	808.33 ± 305.88

the respondents felt that artisanal fishing, as it is currently prescribed, is to a large extent compatible with the sustainability of littoral fish resources. However, as major threat they perceived the widespread misuse of fishing regulations by subsistence artisanal fishermen. Resentment towards subsistence fishermen is provoked by their excessive fishing effort – employing quantities of fishing gear, mostly relating to gill nets, far surpassing what is prescribed to catch more than allowed 5 kg/day – as well as putting the fish on the market. By fishing not only for their own consumption, but also for sale subsistence fishermen represent unfair market competitors of commercial fishermen.

4. Discussion and conclusion

Mediterranean fisheries are to a large extent artisanal in nature. Given the diversity and complexity of these fisheries, quota systems and many means of fishing effort control are generally not applied (Papaconstantinou and Farrugio, 2000). On the other hand, commonly utilized management provisions concerning gear specification, gear deployment, fishing practices and techniques have rarely been accompanied by long-term studies of fisheries resources although they are essential in providing information on the effects of fisheries management measures (Lleonart and Maynou, 2003; Battaglia et al., 2010). Although legislative changes of gear specific regulations are relatively common and surely advised by fisheries experts, curiously the reasons for ordaining them and the effects they have remain outside the domain of scientific literature. Hence, the data about the extent and dynamics by which fish assemblages respond to conventional methods of fisheries regulation are lacking throughout the Mediterranean region. To our best knowledge, there is no study putting in relation the legislative changes with the consequent changes of exploited resources. Despite a history of ichthyological research of littoral fish resources in the eastern Adriatic, still the relationships between fisheries management and changes in fish assemblages are unknown since trends in experimental trammel net catches have always been discussed in isolation of the current management situation.

Our results clearly indicate that recent conventional approaches to fisheries management have played a positive role in promoting the sustainability of artisanal fisheries in the study region. Temporal change was patent in most community indices analyzed. Increases of diversity indices during the study period could be explained by the fact that common bycatch species such as *Scyliorhinus canicula*, *Scyliorhinus stellaris* and *Scorpaena notata* directly benefited from a more restrictive fishing regime, while more frequent occurrence of species such as *Coris julis* and *Symphodus cinereus* may be related to the recovery of *Mullus surmuletus* stock. Namely, species of Mullidae family may act as nuclear species forming multi-species foraging associations. The interaction is based on their vigorous stirring up of sediments by barbels (Uiblein, 2007). A continued decline in biomass CPUE observed throughout the eastern Adriatic from the 1970s onwards (Jardas, 1999 and references therein) seems to be reversed in the study region as indicated by the alterations in the presence of different biomass CPUE categories of trammel net catches. The prevalence of very poor category, characterizing the eastern Adriatic trammel net catches in the first half of 1990s, continued to be present in the study region also in the second half of 1990s. Following the first legislative change in 1999, the catches progressed to poor category in 2001 and remained so until 2003. Additional restrictions in 2002, have led to further improvements with average biomass CPUE of 2004 and 2005 catches falling into good category. In the last four years of study (2006–2009) the catches were consistently categorized as very good. The reappearance of catches exceeding 1.5 kg is promising since the last time the presence of such high CPUE classes was observed was in the 1960s when the analysis of experimental trammel net catches first started. Moreover, average yearly biomass CPUE obtained in this study is exceptionally higher than values reported from other Mediterranean regions, where average catch rarely exceeds 0.64 kg/32 m net (Guidetti et al., 2010 and references therein). It is worth noting that same authors reported comparable CPUE of 1.6 kg/32 m net only in the first year of opening a formerly fully protected Torre Guaceto marine reserve to a co-management protocol authorizing local fishermen to fish inside it once a week. The aforementioned comparisons, although approximative due to employment of different 'métier' (Tzantos et al., 2006), are indicative since catches in our study region are considerably in excess of other reported Mediterranean regions. Plausible causative factors that may have contributed to lush catches realized in Vis aquatorium are the remoteness from coastal areas and highly structured habitats capable of supporting diverse and abundant ichthyofauna.

Furthermore, increases in abundance and biomass CPUE involved species of all three fishing values groups. Therefore, the catches were characterized by stability in the proportion of high, medium and low to no value commercial species. Finally, a directional change in abundance and biomass catch composition of littoral fish resources was also detected over the time course studied. However, *Mullus surmuletus* was consistently a major contributor to the observed positive responses. Why a more restrictive artisanal fishing regime has primarily benefited *M. surmuletus* is elucidated by the comparison of formerly and currently allowed trammel nets. *M. surmuletus* is by far the most dominant species in 28 mm trammel net catches, while in 40 mm trammel nets it is much less represented. Additionally, in their studies assessing the biological harmfulness of trammel nets Jardas and Pallaoro (1991a,b) ascertained that, of the 23 commercially important species analyzed, fishing with 28 mm trammel nets produces catches with unacceptable levels of immature specimens for most of them, including *M. surmuletus*. However, increasing the mesh size to 36 mm did not significantly lessen the impact, except for *M. surmuletus*, which was attributed to specific construction and operation properties of trammel nets. Uiblein (2007) gives an opinion that Mullidae could be considered as indicator species owing to their strong response to human-induced factors such as fisheries and habitat modification induced e.g. by water warming. Both, released fishing pressure and temperature increase may lead to increased abundance and reproductive or growth rates and longer warming periods may induce Mullidae to migrate to higher latitudes. In the Adriatic northernward spreading of *M. surmuletus* was not yet noticed. Therefore, we believe that its stock recovery in the study region is primarily related with a more restrictive fishing regime.

Fishers' perceptions on trends in littoral resources are not entirely in line with what has been observed by assessments of long-term experimental fishing. The decline in catches occurring in 1960–1970s as recalled by the oldest fishermen is consistent with the findings of Jardas (1999) and references therein, while recent increases in CPUE have not been perceived by any of the respondents. Recent improvements went unnoticed to fishers since they are to a large extent involving only *Mullus surmuletus* – species which due to management changes of gear specific regulations is rarely present in their catches for the last 15 years. Other species which are more regularly caught in currently allowed fishing gear, e.g. *Scorpaena scrofa*, have experienced too little of an increase over a relatively long period to be readily observable to fishers. With lack of long-term data sets being the common situation, fishers' statements are often the only source of information on the status and historical changes of exploited resources (Battaglia et al., 2010). Fortunately, for eastern Adriatic artisanal fisheries such long data series exist (Jardas et al., 1998) pointing that fishers' perception can be different from the real state due to different valorization of catches. Moreover, as our study shows, management changes of what fishers' are allowed to fish with, inevitably influence their perception of trends in the catches. Also fishers may in general be more sensitive to decreases than increases and more likely to be more pessimistic than formal fisheries resource assessments. These findings suggest that consistent, standardized fisheries data collection are likely the better approach for documenting the trends of exploited resources. The importance of interviewing should in no way be discounted, as the information provided through this approach yields an important overview of the fisheries and provides an opportunity to build relationships with local fishers (Lunn and Dearden, 2006). Additionally, Rochet et al., 2008, point out that on shorter time-scales, not encompassing management changes, fishers' perceptions can be accurate and do have potential as early warning signals.

In Vis area most genuine fishing vessels are polyvalent meaning they fish throughout the year with different, seasonally-allowed fishing gear, e.g. with lobster traps from May to September switching to demersal long-lines and fishing nets in the cold period of the year. The same has been observed for the whole Mediterranean region confirming polyvalence as an important feature of artisanal fisheries (COM, 2002, Battaglia et al., 2010). Fishing intensity is highest in warm period (April–October), owing to suitable weather conditions, and is mostly oriented at E coast of island where preferred fishing grounds are located. In fact, artisanal fishing effort strongly depends on proximity to home harbor and habitat heterogeneity as was previously stated by Forcada et al. (2010). Fishers rotate fishing gears throughout the year not only in accordance with legislative regulations, but also to optimize yields, based on their knowledge of the behavior and catchability of target species. Although artisanal fisheries involves a variety of fishing gears, throughout the Mediterranean region trammel net is the most widely used assuring the capture of many valuable and appreciated species (i.e.: scorpion fishes, striped red mullets, cuttlefish, common spiny lobster) (Battaglia et al., 2010). Legislative changes, increasing the minimum inner layer mesh size of trammel net from 28 to 40 mm, have not led to a shift in the preference of fishing gear in the study region. Trammel net is still the favored fishing gear enabling higher catches in comparison with gillnets.

The fact that observed positive responses are largely a reflection of a recovery of single species together with the results of the ABC curves and their corresponding *W* index revealing the moderately disturbed nature of fish community, indicate that applying conventional management measures on their own is beneficial only to a limited extent.

Improving further the state of resources requires a more comprehensive set of measures to be considered. The use of ecosystem-based approach to fisheries management incorporating spatially-explicit measures, such as closures in reproductive or recruitment areas, rotation of fishing areas or permanently closed areas (marine protected areas), is considered as the most relevant mean of rehabilitating exploited populations and sustaining fisheries (Dugan and Davis, 1993; Olver et al., 1995; Sumaila, 1998; Jennings, 2001; Gell and Roberts, 2003), especially in the case of artisanal one.

Different approach to management is needed also from a social perspective. Current fisheries management provokes resentment between commercial and subsistence artisanal fishers. Limited institutional capability to effectively conduct surveillance and monitoring of fishing activities is exploited by subsistence fishers who don't comply mainly with regulations regarding restrictions on quantities of allowed fishing gear, leading thus also to violation of daily catch limit of 5 kg. On the other hand, commercial artisanal fishers with what and how they're allowed to fish are in no need to violate the regulations. They argue that the catches of subsistence fishers, who greatly outnumber them, are in no way negligible and are often sold in unofficial market hindering the sale by commercial fishers. Future management approaches aiming to alleviate the existing conflicts should increase the involvement of fishers in the management process (Salas et al., 2007). Actively involving fishermen can not only bring otherwise unavailable traditional and local knowledge to the decision making process, it also gives legitimacy to rules governing the fisheries in question and is more likely to result in management strategies that are respected and complied with willingly (Dimech et al., 2009). Synthesizing conservation and social considerations should become essential in guiding future legislative decisions related to artisanal fisheries (Gómez et al., 2006). Better knowledge of recent changes in littoral fish communities, accompanied with better flow of communication and a sense of trust between scientists, fishermen and fisheries managers should significantly facilitate the desired outcome for the fisheries – fisheries managed in a sustainable way.

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