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Fish population changes following the invasion of the allochthonous alga *Caulerpa taxifolia* in the Ligurian Sea (N-W Mediterranean)

by

Giulio Relini, M. Relini, G. Torchia

Laboratori di Biologia Marina ed Ecologia Animale – DIP.TE.RIS. Università di Genova, via Balbi 5, 16126 Genova, Italia. Tel/Fax +39-010- 2477537, biolmar@unige.it

Abstract

Using visual census by scientific SCUBA divers and trammel net catches the fish population of a flat area at Imperia (Ligurian Sea), where the allochthonous alga *Caulerpa taxifolia* is colonizing the seabed, was studied from October 1994 to November 1999. An area with a coverage of about 100% *C. taxifolia* (CSL) which had previously been colonized by *Cymodocea nodosa* is compared to areas colonized respectively by *C. nodosa* (CY), 25% coverage by *C. taxifolia* (CMA) and *Posidonia oceanica* (P). The main consequences of the growth of this green alga are changes in fish community from both a qualitative and quantitative point of view.

The comparison between CSL and CY showed, during fish censuses, higher values for number of species and individuals on *C. taxifolia*. The fish population of the *C. taxifolia* was dominated quantitatively by 5 species (*Symphodus tinca, Coris julis, Diplodus annularis, Scorpaena porcus, Mullus surmuletus*). In particular, the abundance of Labridae, mainly the species *S. tinca*, and Scorpaenidae (*S. porcus*), seemed to be a characteristic of this community.

Fish catches (trammel net) at the *C. taxifolia* site were almost double those at *C. nodosa* site and the species richness of the catches was on average higher on *C. taxifolia* (10.7 against 8.4 species per 200 m net) than elsewhere.

Besides the appearance of new species (mainly Labridae) and an increase in others, the reduction in sandy seabed caused by the arrival of the *C. taxifolia* led to a reduction in the species typical of sand-mud bottoms, such as *Trachinus traco, Trigla lucerna, Uranoscopus scaber, Solea impar, Scophthalmus rhombus* – all of which are important species for the commercial fishery.

Where the *C. taxifolia* cover was thin (>25%, CMA station), the fish population still maintained the characteristics found on *C. nodosa* meadows and on sandy bottoms, characterised by the presence of flat fish (Soleidae and Bothidae).

Marked similarities emerged between the fish fauna of the *C. taxifolia* and the *P. oceanica* meadow. The fishing catches (trammel) were higher in the two stations with *C. taxifolia* (CSL and CMA) than in CY and P stations.

Introduction

The main problems rising with the introduction of non-native marine species have been outlined by many papers (for example Boudouresque *et al*., 1994; Cohen and Carlton 1995; Eno *et al*., 1997).
The Mediterranean Sea is being colonised by a variety of 'alien' species; some entering via the Straits of Gibraltar or Suez Canal, others being introduced deliberately or accidently by man. Among the recent invaders the green alga *Caulerpa taxifolia* (Vahl) C. Agadh has caused considerable concern (UNEP, 1998) and the mass media have called it *"alga killer"* because of the presence in its tissues of some terpenoid compounds as caulerpyna and caulerpynina, probably natural allelopathic substances and antigrazing products. Some authors suggest that there has been a progressive decline in the biodiversity of areas colonized by this allochthonous alga (Boudouresque *et al*., 1996). Benthic invertebrate distribution was studied by Bellan-Santini *et al.,* (1995, 1996), Relini *et al*., (1996, 1998a), while fish were examined by Francour *et al*., (1995), Gelin *et al*., (1998), Harmelin-Vivien *et al*., (1994, 1996, 1999) and Relini *et al*., (1996, 1998 b, c).
The alga was recorded for the first time in the Mediterranean Sea near Monaco in 1984 (Meinesz and Hesse, 1991) and in Italian waters near Imperia in 1992 (Relini and Torchia, 1992). At present (summer 2000) the alga is found from the French border to Varazze (Savona), mainly in harbours and coastal seabed with a patchy and irregular distribution along about 150 km of the western Ligurian Riviera. The alga spreads through yachting (chain, anchor) and (mainly) fishing activity (trammel net, otter-trawl) and the first colonization occurs generally where fishing boats are moored in a port (Relini *et al*., 2000).
The aim of this paper is to summarize data collected in the Imperia area (Western Liguria Riviera, NW Mediterranean Sea) on fish fauna present in a coastal environment which has been recently colonized (since 1992) by the green allochthonous alga *C. taxifolia* and to describe change in the fish community when a flat, sandy mud seabed is invaded by *C. taxifolia*.

Methods

Three sets of data were collected between 1994 and 1999 in the coastal water at Imperia, comparing fish present in habitats differently affected by the new invader, the alga *C. taxifolia*.
In the first period of study (1994 – 1996), two stations were chosen: one in the San Lazzaro Basin (CSL), between the two harbours of Imperia, 4-8 meters deep; here the seabed was covered by an almost continuous meadow of *C. taxifolia* while previously only parts of it had, in the past, been colonized by the sea grass *Cymodocea nodosa* (Ucria) Ascherson. The area was eutrophic, degraded because of antropic works and had a muddy seafloor. The second station (CY) was the control area with *C. nodosa* (4-10 m deep) and was established 1 km away from the S. Lazzaro Basin on the west side. This site was exposed to the open sea and the bottom was mainly sandy (see fig. 1 in Relini *et al*., 1998).
Between October 1994 and October 1996, with the help of a professional fisherman, twenty-four trammel net, 200 m long and 3 m high, sets were made, twelve on *C. taxifolia* (CSL) and twelve on *C. nodosa* (CY). The nets were set and anchored to the bottom in the evening and hauled early in the morning (after about 12 h). Each fish caught was identified at species level, weighed (g) and measured (t.l.) in the laboratory. During this period (Oct. 94 – Oct. 96), twelve separate diver visual censuses were undertaken, each 100 m long and 4 m wide (400 m²), at San Lazzaro Basin

(CSL) and one on the *C. nodosa* meadow control (CY). Each transect censuses lasted approximately 15 min. during the morning. Fish counts were made using abundance clusters (1, 2, 3-5, 6-10, 11-30, 31-50), and distinguishing between young, pre-adults, and adults for every fish species counted (Harmelin-Vivien *et al.*, 1985). Few cephalopods and crustaceans were caught or observed are not considered in this paper.
During the second (1998) and third (1999) periods of study two additional stations were considered:
(1) station CMA; an area of open sea between Oneglia and Porto Maurizio, characterized by a sandy seabed (9 – 12 m) with less than 25% total cover of both *C. taxifolia* and the phanerogam *C. nodosa*.
(2) The *Posidonia* station (P): this station was to the west of Porto Maurizio, and colonised almost entirely by *Posidonia oceanica*. Depths varied between 9 and 12 m.
A total of four fishing campaigns were carried out between January and August 1998. In each campaign a total of 800 m of trammel nets were deployed, 200 m at each station. At the same four sites three underwater transect censuses 50 m long and 4 m wide (200 m^2) were carried out during the fishing campaign. Each transect census took place during the morning and lasted approximately 8 minutes.
During 1999 the fishing effort by trammel nets was doubled: eight catches, two per season were carried out following the same methodology used during the previous years. In the four stations three visual censuses per season as during 1998 were performed.
In order to make a comparison between the station CSL and CY data from October 1994 to November 1999 were used. The additional comparisons between CSL and P as well as between CSL and CMA were made using data collected only during the campaigns carried out in 1998 and 1999.
The Wilcoxon test (as reported in Siegel, 1956) was used to evaluate differences between the stations.

Results

Comparison between CSL and CY

- From October 1994 to November 1999, a total of 50 different species of fish were caught in the two stations, 41 at CSL and 31 at CY (table 1). Thirty-five species were observed by visual census, 32 at CSL and 8 at CY (table 2).
- On the basis of the catches *Symphodus tinca, Scorpaena porcus, Mullus surmuletus* and *Diplodus annularis* were the four species dominant in both weight and number of individuals from the *C. taxifolia* meadow. Data obtained during the censuses confirm the importance of *S. tinca* and add *Coris julis* to the main species list. Species that are thought to need sheltered environments (*Sciaena umbra, Apogon imberbis, Gaidropsarus mediterraneus, Serranus scriba*) were also present in *C. taxifolia* meadow.

Flatfish (*Bothus podas, Solea impar, S. lascaris*) and species typical of sandy environments (*Mullus barbatus*) as well as *Spicara maena* and *D. annularis* were dominant around *C. nodosa*.

- Using the Wilcoxon test, a comparison of the fish caught was carried out only for the 23 main species, for which samples were frequent enough (table 3). For 8 of the 23 species tested, significantly differences were not found. Eight species were significantly more abundant, in terms of numbers of individuals, on *C. taxifolia*, 7 species more numerically abundant on *C. nodosa*.

- It was possible to test 13 of the 35 species censused at the two different stations (table 4). Eleven species were significantly more abundant on *C. taxifolia* (CSL) than on *C. nodosa* (CY).
- The two different complementary methods used (visual census and trammel net) provided a complete overall picture of the differences between the two stations. Three species (*D. annularis, S. scriba, S. tinca*) were shown to be significantly more abundant on *C. taxifolia* using both methods. Eight of the 10 species significantly more abundant on *C. taxifolia*, using visual census, were mostly juveniles *(Labrus viridis, Diplodus sargus, D. vulgaris*) or small-sized fish (*C. julis, Symphodus cinereus, Chromis chromis, Symphodus ocellatus, S. roissali*) uncatchable in the trammel net. Of eight species found to be more abundant on *C. taxifolia* when sampling with the trammel net, two (*M. surmuletus* and *S. porcus*) are well camoflaged when in *C. taxifolia* meadows, consequently being difficult for SCUBA divers to see, and two (*Trachurus Mediterraneus* and *Oblada melanura*) are thought to be active in the *C. taxifolia* meadow principally during the night or are transit species.
- Trammel net catches at station CSL yielded fish weighting 2982±299 g/200m of net, in number 38±4.3 ind/200 m and in species richness 10.7±1.4 species/200 m net, while at station CY the values were respectively 1214±154 g/200 m, 19±2.7 ind/200 m and 8.4±1.1 species/200 m net. The Wilcoxon test showed that there were significant differences ($\alpha<0.005$) between the two sites in terms of numbers of individuals, in terms of weight and in terms of species richness.

Comparison between stations CSL and P
- In 1998 and 1999 thirty six species of fish were caught, 29 on CSL and 22 on P (tab 1). In total 30 species were observed using visual census, 23 on CSL and 25 on P (table 2).
- The same species (*D. annularis*, *S. porcus, S. tinca* and *M. surmuletus*) were numerically dominant in both *Posidonia* (P) and C*aulerpa* (CSL) meadows. *S. maena, C. chromis* and *B. boops* were numerically dominant among the species censused at station P, while *S. tinca* and *C. julis* were dominant among the species censused at station CSL. Species that need sheltered environments (*S. umbra, G. mediterraneus, Symphodus mediterraneus, S. scriba*) were present in both *Posidonia* and *Caulerpa* meadows.
- The abundance of the 8 main species caught in trammel nets were compared using Wilcoxon test (table 5). Two species, *M. surmuletus* ($\alpha<0.005$) and *B. podas* ($\alpha<0.05$), were significantly more abundant on *C. taxifolia*.
- Abundance of the seven numerically dominant species recorded by the census was compared using the Wilcoxon test (table 6). Two labrids, *S. tinca* and *C. julis,* were found to be significantly more abundant (respectively $\alpha<0.005$, and $\alpha<0.025$) on *Caulerpa* meadow whilst *C. chromis* ($\alpha<0.005$), *B. Boops* ($\alpha<0.01$) and *S. maena* ($\alpha<0.05$) were more abundant on *Posidonia*. Because *S. tinca* censused on *C. taxifolia* meadow were mostly young fish not caught by trammel nets, there is a discrepancy between data collected by the two methods.
- Trammel nets gave the following information: at station CSL catch weight 2574±376 g/200m of net, 30±3.9 individuals/200 m of net and 8.3±0.9 species/200 m net, while at station P the values were respectively 1792±300 g/200 m, 19±2.6 ind/200 m and 6.6±0.6 species/200 m net. There were significant differences between the two sites in terms of numbers of individuals, weight of catch and species richness ($\alpha<0.025$).

Comparison between CSL and CMA

- During 12 hauls carried out between January 1998 and November 1999, 40 different species were caught, 29 on CSL and 31 on CMA (tab 1). In the same period 28 species of fish were censused, 23 on CSL and 13 on CMA (table 2).
- On the basis of the trammel net catches flat fish (*B. podas, S. impar*) and the sparids *D. annularis* and *Pagellus erythrinus* were numerically dominant on CMA. On basis of the census data *S. maena* and *M. barbatus* were the more abundant species on CMA. The fish population caught at station CMA showed similar characteristics to that found at station CY, but at station CMA some labridae and a fairly good number of *S. porcus* (table 1) were present as well as species typical of such a sandy environment.
- The abundance of the 12 main species caught by trammel nets were compared using Wilcoxon test (table 7). Three species, typical of *C. taxifolia* meadow (*M. surmuletus, S. porcus, S. tinca*), were significantly more abundant at station CSL ($\alpha<0.005$). Six species typical of a sandy seabed were found to be more abundant at station CMA. These 6 species are the same that, in the comparison between stations CSL and CY, were more abundant at station CY.
- Abundance of the main 5 species censused was compared using the Wilcoxon test (tab 8). Four species were significantly more abundant at station CSL.
- At station CMA the net catches provided mean biomass values of 2534±494 g/200 m net, corresponding to 35±8 ind/200 m net and 8.3±1.1 species/200 m net. These values are comparable with these obtained at station CSL. The differences between the 12 hauls carried out in the two station proved to be not significantly different according to the Wilcoxon test.

Conclusions

- The main consequence of *C. taxifolia* colonization on a flat seabed is not a decrease in fish biodiversity compared to *C. nodosa* environment, but a change in the type and structure of the community. However, since the invasion of *C. taxifolia* homogenizes different environments and biocoenosis (rocky, sandy and muddy bottoms) there may be a considerable reduction in the overall diversity of a large area of some km^2 where different communities are living.

The two different methods used (visual census and trammel net) provided a complete overall picture of the fish population. During fish censuses higher numbers of species and individuals were always found at the station dominated by *C. taxifolia*. The fish population of the *C. taxifolia* meadow at Imperia was dominated quantitatively by 5 species (*S. tinca, C. julis, D. annularis, S. porcus, M. surmuletus*). In particular, the abundance of Labridae, especially the species *S. tinca*, and of Scorpaenidae (*S. porcus*), seems to be a characteristic of this community.

Fish yields (trammel net) were about double at the *C. taxifolia* site in comparison with the *C. nodosa* site, and the species richness of the catches was, on average, higher (10.7 against 8.4 species per 200 m net).

Besides the appearance of new species (mainly Labridae) and an increase in others, the reduction in the area of sandy seabed caused by the arrival of the *C. taxifolia* did however lead to a reduction in the species typical of sandy areas, such as *Trachinus traco, Trigla lucerna, Uranoscopus scaber, S. impar, Scophthalmus rhombus* – all of which are important species for the commercial fishery.

Initial studies conducted on fish populations on rocky sites colonized by *C. taxifolia* in France have mainly demonstrated a reduction in fish density (Harmelin-Vivien *et al.*, 1996; Francour *et al.*,

1995). Further observations (Harmelin-Vivien *et al*., 1999) have demonstrated that there is a significant decrease in mean species richness, mean density and mean biomass of fish in the sites colonised by *C. taxifolia***.**
In rocky habitats which are structurally complex by nature (full of lairs, shelters and shadow zones), the arrival of *C. taxifolia* cannot lead to any increase in “rugosity”, but may sometimes decrease this important character .
On flat seabeds which, unlike rocky bottoms, do not possess a high “complexity” or “rugosity”, the structural complexity attendant on the colonization of *C. taxifolia* is probably at the root of the consequent changes occured in the fish population observed at Imperia. The “architecture” of the sea bed takes on a crucial role in influencing the fish population (Gorham *et al*., 1989; Harmelin-Viven *et al*., 1994; Harmelin *et al*., 1994; Ody and Harmelin, 1994)
- Where the *C. taxifolia* cover is thin (>25%, CMA station), the fish population maintained the characteristics to be found at *C. nodosa* meadows and on a sandy bottom, characterised by the presence of flat fish (Soleidae and Bothidae). Besides the species typical of sandy environments, there were however already present - in small quantities - some species of the Labridae family, and the *S. porcus* species, which was dominant on the *C. taxifolia* meadow (CSL). This intermediary or transitional situation makes it possible for there to be a fairly high level of specific richness on flat bottoms with a thin covering of *C. taxifolia*.
- Marked similarities have emerged between the fish fauna of the *C. taxifolia* and the *P. oceanica* meadow. This comparison also shows the higher densities of *S. tinca* and *C. julis* on *C. taxifolia* meadows and the significant lower densities of the species *C. chromis, B. boops* and *S. maena* in *C. taxifolia* meadows. These three species belong to the first two spatial categories suggested by Harmelin (1987) (cat. 1 - hightly mobile and gregarius, pelagic erratic species; cat. 2 – planktophagous and relatively sedentary species, living throughout the water column).
- The fishing yields (trammel) were higher in the two stations with *C. taxifolia* (CSL and CMA). However these data need to be interpreted also in the light of a possible greater impact of professional fishing on the CY and P stations compared to CSL and CMA, since fishermen choose areas where their nets do not get heavily fouled by algae, a consequence of fishing in the meadows of the allochthonous alga.

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Table 1 - Average number of individuals caught by 200 m of trammel net in different years and stations.

TRAMMEL NET	series 1				Series 2				series 3			
Years	('94-'95)		('95-'96)		(1998)				(1999)			
Stations	CSL	CY	CSL	CY	CSL	CY	CMA	P	CSL	CY	CMA	P
No. hauls	**6**	**6**	**6**	**6**	**4**	**4**	**4**	**4**	**8**	**8**	**8**	**8**
ANGUILLIDAE												
Anguilla anguilla			0.2									
CONGRIDAE												
Conger conger	0.5	0.5										
MURAENIDAE												
Muraena helena								0.8				0.3
CLUPEIDAE												
Alosa fallax	0.2	0.7										
Sardinella aurita			0.2									
GADIDAE												
Gaidropsarus mediterraneus	0.3		0.3		0.5							0.1
SCORPENIDAE												
Scorpaena porcus	8.2	0.3	8.2	1.3	9.8	1.5	4.3	4.8	6.9	0.9	1.3	3.9
Scorpaena scrofa		0.2										
TRIGLIDAE												
Trigla lucerna		0.3		0.7		0.3	2.5		0.1	0.4	0.5	
Trigloporus lastovizia											0.1	
SERRANIDAE												
Serranus cabrilla					0.3							
Serranus scriba			0.8		0.5			1	0.1			0.5
APOGONIDAE												
Apogon imberbis					0.5				0.3			
CARANGIDAE												
Seriola dumerili				0.2					0.1	0.1	0.3	
Trachurus mediterraneus			1		0.3						0.1	
Trachurus trachurus		0.2					0.3					
SPARIDAE												
Boops boops			1.5	0.5	0.3	0.3		0.3	0.3	0.1	0.1	0.4
Dentex dentex	0.2	0.2	0.5	0.2	0.5		0.3		0.6	1	1.4	0.4
Diplodus annularis	2.5	0.7	8	5.3	6	1.3	14.5	8.8	4.4	1	5.6	5.3
Diplodus puntazzo												0.4
Diplodus sargus				0.7	0.3			0.3	0.6	0.1	0.1	0.3
Diplodus vulgaris					1			1	0.6	0.4	0.3	0.5
Lithognatus mormyrus	0.3	0.2	0.8	0.3	0.3				0.5	0.3	0.5	
Oblada melanura	0.3	0.2	1.2	0.2	0.3				0.3	0.1		
Pagellus acarne		0.8	0.8	0.5	0.3	0.5	0.3		0.1	1.1	1	0.1
Pagellus erythrinus	0.5	0.7	2	3.7	0.5	1.3	2.8		0.5	1	3.4	
Pagrus pagrus		1.2		0.7						0.8		0.1
Sarpa salpa			0.7	0.3	0.3		0.3	1	0.4			0.8
Spondyliosoma cantharus	0.5	0.5	0.3	0.3		0.3		0.5	0.3	0.1		0.1
CENTRACANTHIDAE												
Spicara maena	4.5	3.8	6.3	8.7	5.5		0.5					
Spicara smaris			0.8				0.3					
SCIAENIDAE												
Sciaena umbra			0.2					0.3				0.1

Table 1 - continued

TRAMMEL NET	series 1				Series 2				series 3			
Yeras	('94-'95)		('95-'96)		(1998)				(1999)			
Stations	CSL	CY	CSL	CY	CSL	CY	CMA	P	CSL	CY	CMA	P
No. hauls	**6**	**6**	**6**	**6**	**4**	**4**	**4**	**4**	**8**	**8**	**8**	**8**
MULLIDAE												
Mullus barbatus	1.5	3.5	0.5	1.5	0.3	0.8	2			0.5	0.6	
Mullus surmuletus	3.3	1.5	6.3	1.3	2.3	0.5	1.5	0.5	5.9	1.3	0.6	1.1
MUGILIDAE												
Liza aurata			0.3		0.3		0.3		0.4		0.3	
Liza saliens		0.2										
SPHYRAENIDAE												
Sphyraena sphyraena			0.5				0.8			0.1		
LABRIDAE												
Labrus merula	1.3		0.2					0.3				
Labrus viridis	0.3								0.3			0.4
Symphodus cinereus	0.2						0.3					
Symphodus mediterranus					0.3			0.3				
Symphodus melops	0.7		0.2									
Symphodus roissali	0.8											
Symphodus rostratus												0.1
Symphodus tinca	12.3		6.3		6.8			2.8	1.6		0.4	2.6
CALLYONIMIDAE												
Callionimus sp.												
SYNODONTIDAE												
Synodus saurus				0.2		0.3		0.5		0.1		
TRACHINIDAE												
Trachinus draco		0.2		0.5						0.3	0.1	
URANOSCOPIDAE												
Uranoscopus scaber		0.2		0.7		0.5	2.3			0.4	0.5	
BOTHIDAE												
Bothus podas	0.3	1.3	1	1.5		2.8	13.8		1.9	4.9	5.6	
Psetta maxima					0.3							
Scophthalmus rhombus		0.2					0.3				0.1	
SOLEIDAE												
Solea impar		0.7	0.2	1.5								
Solea lascaris				1.2		1.3	8.3			1.1	1.3	
Solea kleini							0.5				0.9	
Solea vulgaris							0.3					
Solea sp.			0.2			0.3			0.3		0.1	

Table 2 - Average number of individuals (No./200 m^2) censused by SCUBA divers in different years and stations.

VISUAL CENSUS	**series 1**				**series 2**				**series 3**			
Period of study	'94-'95		'95-'96		1998				1999			
Stations	SL	CY	SL	CY	CSL	CY	MA	P	CSL	CY	MA	P
No. of transects	6	6	6	6	12	12	12	12	12	12	12	12
ATHERINIDAE												
Atherina sp.			1.67								4.17	
SCORPENIDAE												
Scorpaena porcus								0.08				
SERRANIDAE												
Serranus cabrilla					0.04							
Serranus hepatus							0.08					
Serranus scriba	0.08		0.21		0.38			0.13	0.13			0.46
SPARIDAE												
Boops boops		0.83	0.08	0.67	0.16			3.42		0.17		2.63
Dentex dentex								0.04				
Diplodus annularis	1.83		1.04		0.21	0.38		1.21	2.71	0.25	0.04	1.08
Diplodus puntazzo								0.04				
Diplodus sargus	0.42		0.21		0.05							0.04
Diplodus vulgaris			0.13		0.29			0.08	0.08			0.08
Oblada melanura	0.63		0.50					0.04	2			0.08
Pagellus acarne							0.83			0.21		
Pagellus erythrinus (Linnaeus,		0.08										
Sarpa salpa			0.83									0.88
Sparus aurata	0.08											
Spondyliosoma cantharus	0.13											
CENTRACANTHIDAE												
Spicara maena	0.33	1.33	0.67	1.33	1.5	1.13	2.92	7.71	2	0.92	2	14
MULLIDAE												
Mullus barbatus		0.08				0.92	0.46					
Mullus surmuletus	0.08	0.08		0.13	0.04		0.08	0.04	0.08			
POMACENTRIDAE												
Chromis chromis	0.33		1.04		0.54			10.5	0.58		0.21	10.0
MUGILIDAE												
Mugilidae nc.			0.04									
LABRIDAE												
Coris julis	1.75		3.08	0.04	6.25		0.33	1.33	2.42			0.50
Labrus merula	0.13		0.08						0.13			0.04
Labrus viridis	0.38		0.21		0.08			0.17	0.63			0.04
Symphodus cinereus	0.50		0.50		0.38		0.13		0.38			0.04
Symphodus doderleini			0.04		0.04							0.04
Symphodus mediterraneus								0.04	0.21			0.04
Symphodus melops												0.04
Symphodus melanocercus								0.63				0.13
Symphodus ocellatus	1.38		0.13		0.21			0.04				
Symphodus roissali	0.21		0.08		0.08							
Symphodus rostratus	0.08				0.04			0.08	0.04			0.04
Symphodus tinca	4.29		1.54		6.92		0.08	0.25	3.92			0.08
Sympodus sp.	1.67		0.79									
Thalassoma pavo								0.04				0.08
CALLYONIMIDAE												
Callionimus sp.							0.04					
BLENNIIDAE												
Parablennius gattorugine					0.04							
Parablennius sp.					0.04							
OPHICHTHYDAE												
Ophiusurus serpens							0.04					
GOBIIDAE												
Gobius cruentatus			0.04									
Gobius geniporus	0.13											
Gobius niger			0.04									
Gobius sp.			0.04		0.04						0.08	

Table 3 – Results of the Wilcoxon test for species caught using trammel net in CSL and in CY.

Trammel net							
Significantly more abundant on CSL			**Differences not significant**		**Significantly more abundant on CY**		
Species	n	α	Species	n	**Species**	n	α
Diplodus annularis	21	<0.005	*Boops boops*	6	*Bothus podas*	15	<0.005
Mullus surmuletus	20	<0.005	*Dentex dentex*	9	*Pagellus erythrinus*	16	<0.005
Scorpaena porcus	23	<0.005	*Diplodus sargus*	8	*Pagrus pagrus*	9	<0.005
Serranus scriba	6	<0.005	*Lithognatus mormyrus*	9	*Solea lascaris*	8	<0.005
Symphodus tinca	19	<0.005	*Pagellus acarne*	10	*Uranoscopus scaber*	8	<0.005
Trac. mediterraneus	5	<0.005	*Sarpa salpa*	7	*Mullus barbatus*	12	<0.01
Oblada melanura	10	<0.025	*Spicara maena*	13	*Trigla lucerna*	9	<0.01
Labrus merula	5	<0.05	*Spond. cantharus*	9			

Table 4 – Results of the Wilcoxon test for the species censused in CSL and in CY.

Visual census				
Significantly more abundant on CSL			**Differences not significant**	
Species	n	α	Species	n
Symphodus tinca	20	<0.005	***Mullus surmuletus***	5
Coris julis	17	<0.005	*Spicara maena*	13
Diplodus annularis	15	<0.005		
Symphodus cinereus	12	<0.005		
Serranus scriba	11	<0.005		
Labrus viridis	10	<0.005		
Diplodus sargus	8	<0.005		
Diplodus vulgaris	5	<0.05		
Chromis chromis	7	<0.01		
Symphodus ocellatus	7	<0.01		
Symphodus roissali	7	<0.01		

Table 5 – Results of the Wilcoxon test for the species caught in CSL and in P.

Trammel net				
Significantly more abundant on CSL			**Differences not significant**	
Species	n	α	Species	n
Mullus surmuletus	9	<0.005	***Diplodus annularis***	11
Bothus podas	5	<0.05	*Scorpaena porcus*	11
			Symphodus tinca	9
			Dentex dentex	7
			Diplodus vulgaris	6

Table 6 – Results of the Wilcoxon test for species censused by scuba divers in CSL and in P.

Visual census							
Significantly more abundant on CSL			**Differences not significant**		**Significantly more abundant on P**		
Species	n	α	Species	n	**Species**	n	α
Symphodus tinca	8	<0.005	*Diplodus annularis*	7	*Chromis chromis*	8	<0.005
Coris julis	8	<0.025	*Serranus scriba*	5	*Boops boops*	7	<0.01
					Spicara maena	7	<0.05

Table 7 – Results of the Wilcoxon test for species caught by trammel net in CSL and in CMA.

Trammel net							
Significantly more abundant on CSL			**Differences not significant**		**Significantly more abundant on CMA**		
Species	n	α	Species	n	**Species**	n	α
Mullus surmuletus	10	<0.005	*Diplodus annularis*	11	*Bothus podas*	9	0.01
Scorpaena porcus	10	<0.005	*Dentex dentex*	6	*Pagellus erythrinus*	7	0.01
Symphodus tinca	8	<0.005	*Lithognatus mormyrus*	5	*Trigla lucerna*	8	0.025
					Solea lascaris	6	0.025
					Mullus barbatus	5	0.05
					Uranoscopus scaber	5	0.05

Table 8 – Results of the Wilcoxon test for the species censused in CSL and in CMA.

Visual census				
Significantly more abundant on CSL			**Differences not significant**	
Species	n	α	Species	n
Symphodus tinca	8	<0.005	***Symphodus cinereus***	5
Coris julis	6	<0.025		
Diplodus annularis	6	<0.025		
Serranus scriba	5	<0.05		