Cabled video-observatory monitoring of seasonal rhythms in a Mediterranean coastal fish community

Fernando Condal, Jacopo Aguzzi, Francesc Sardà, Marc Nogueras, Javier Cadena, Antoni Mànuel

Cabled video-observatory monitoring of seasonal rhythms in a Mediterranean coastal fish community

[1,]*Fernando Condal, [1,]*Jacopo Aguzzi, [1]Francesc Sardà, [2]Marc Nogueras, [2] Javier Cadena, [2]Antoni Mànuel

[1]   Instituto de Ciencias del Mar (ICM-CSIC). Paseo Maritimo de la Barceloneta, 37-49, 08003 Barcelona, Spain.
[2]   SARTI Research Group. Electronics Department (Universitat Politècnica de Catalunya; UPC), Rambla de la Exposición 24, 08800 Vilanova i la Geltrú-Barcelona, Spain.
[*]   Authors to whom correspondence should be addressed; E-Mail: fernandocondal@gmail.com; jaguzzi@cmima.csic.es; Tel.: +34-93-230-9540; Fax: +34-93-230-9555.

Abstract- The obtention of time series in the structure and biodiversity of marine populations is of great interest in spite of increasing anthropic perturbations of direct type (e.g. fishing or littering) or of more indirect nature as the climate change. However, the lack of reliable and long-lasting sampling/observational technology deeply constrains our understanding of ecosystem functioning and its response to any perturbation. For the first time, we continuously monitored the seasonal variation in individuals for different fish species within a Western Mediterranean marine protected area by means of the cabled video-observatory OBSEA (20 m depth). During 1 year (from June 2009 to July 2010), frames for fish visual counting were acquired by a digital still camera portraying two different reef and water locations, at each daylight hour within the two central weeks of each month. In images we reported the total of counted fishes, the total of fishes per species, the number of species, the Shannon Diversity and Mean Trophic Level. A comprehensive faunistic list including not only fishes but also diving seabirds was obtained. Significantly higher number of species and their abundances were observed in images including the artificial reef location versus those of the water column. A seasonal variability was observed in Diplodus vulgaris, Chromis chromis, Diplodus sargus, Diplodus annularis, Dentex dentex, Spondyliosoma cantharus, Symphodus melanocercus, having this phenomenon an effect on monthly Shannon Diversity Index estimates. The seasonal variation of these species was not linked to their Trophic Level. Moreover, a weak intra-day (i.e. morning versus afternoon) variation in fish counts was also reported, being not significant. Present results indicate that cabled video-observatories are a reliable and powerful method to monitor seasonal changes in species composition and biodiversity, potentially providing important data for the modelling of marine ecosystem functioning.

Keywords: OBSEA, image analysis, fish community, cabled video-observatory, seasonal rhythms, artificial reef, intra-day variation, biodiversity, Diplodus vulgaris, Chromis chromis, Diplodus sargus, Diplodus annularis, Dentex dentex, Spondyliosoma cantharus, Symphodus melanocercus.

INTRODUCTION

The history of humanity is developing from millennia along marine coasts, which in response are the first line of impact of an apparently unstoppable anthropization (Longhurst, 1998). In recent years, the scientific community expressed a growing interest in the development of a suitable technology for the autonomous and prolonged monitoring of ecosystems at all depth of continental margins in response to growing social, economic, and governmental management and exploitation concerns (Claudet and Pelletier, 2004; Carpenter et al., 2006; Liu et al., 2007). Among these environments there are shallow coastal areas, where the monitoring of temporal variations in animals' populations, resulting community structure, and overall biodiversity, is of strategic importance for anthropogenic disturbances evaluation (Harvey et al., 2001; Seaman, 2007). In this monitoring, the capability of study diel and seasonal variations in fish abundances is of central importance (Willis et al., 2000; Harvey et al., 2002; Aguzzi et al., 2012). However, fish stocks vary at different temporal scales for the effect of behavioural responses of animals to habitat changes (Francour, 1997; Harvey et al., 2001). The correct evaluation of these temporal variations is of importance for important management issues such as the establishment of Marine Protected Areas (Willis et al., 2000; Harmelin-Vivien et al., 2008b).

In the past decade, a strong technological implementation took place in relation to the biological and habitat long-term monitoring of the marine environment from the seabed to the overwhelming water column (Cline et al., 2004; Person et al., 2006). Multiparametric benthic cabled observatories appeared within the context of a newborn cabled observatory science (Aguzzi et al., 2012). These platforms are powered from land by cables which also provide a constant data feedback. When bearing cameras, these can be used to visually count individuals for different species linking population assessment and overall biodiversity estimations down to behavioural regulation at different temporal scales (Aguzzi et al., 2011c). Moreover, digital imaging systems can acquire and store images to be used not only for individual counting, but also for more broad objectives related to faunal exploration and its monitoring in spite of different biological hazards (Favali and Beranzoli, 2006; Person et al., 2006; Zenetos et al., 2010).

To our knowledge, the fish community seasonal monitoring at hourly frequency has never been attempted before. Presently, seasonal behavioral rhythms of fishes are poorly studied for the lack of a suitable monitoring technology allowing the prolonged and high-frequency monitoring of populations. Before cabled video-observatories, the majorly employed sampling methods for the fish fauna assessment were net- or visually based surveys, depending from the targeted depth. Unfortunately, net-based methods can be highly destructive (e.g. trawling) and visual surveys can alter fish behavior and hence detection (Harmelin-Vivien et al., 1985; Bohnsack and Bannerot 1986; Bortone and Hastings, 1986; Willis et al., 2000; Harvey et al., 2002; Edgar et al., 2004; Watson et al., 2005; Harmelin-Vivien and Francour 2008a). In this context, one of the potential applications of cabled video-observatories is the non-invasive monitoring of seasonal variations in the number of fish coastal populations. In this study, we used one of these coastal platforms to carry out a seasonal photographic sampling of fish community within a western Mediterranean marine reserve. Our aim was to describe the seasonal fluctuations in species counts along with derived temporal effects on estimated biodiversity levels. We also tested for counts variations at the intra-day (i.e. hourly) frequency by comparing morning versus evening counts, in order to assess the occurrence of diel (i.e. 24-h based) swimming rhythms the modulation of which can be coupled with seasons.

MATERIAL AND METHODS

The western Mediterranean expandable SEAfloor OBservatory (OBSEA) is a cabled multiparametric platform deployed in 2009 within the framework of the EU infrastructural project ESONET. The platform (Fig. 1) is located close to an artificial reef at 20 m depth in the Marine Reserve *Colls i Miralpeix*, 4 km off *Vilanova i la Geltrú* (Catalonia, Spain). The platform is endowed with a digital video camera (OpticCam) (see Figure 1) that can provide images of the environment surrounding the OBSEA at 360º, with a resolution of 640 x 480 pixels (Aguzzi et al., 2011c).

To our knowledge, the photo-monitoring of a fish community by a still camera, has never been attempted before at hourly frequency, over a continuous period of 12 months. Therefore, a protocol of image acquisition has been implemented in relation to the sampling of fish species within a heterogeneous environment. In order to obtain images fully representative of the habitat complexity surrounding the OBSEA, which likely include the highest number of species as possible, four different fields of view were selected (Fig. 2): two focusing at the artificial reef and two focusing at water column (just above a algae field of *Caulerpa racemosa*). These positions were codified according to their order of appearance during the

rotation of the camera over 360º: 1, first reef location; 2, the first water column location; 3, the second water column location; and finally, 4, the second reef location.
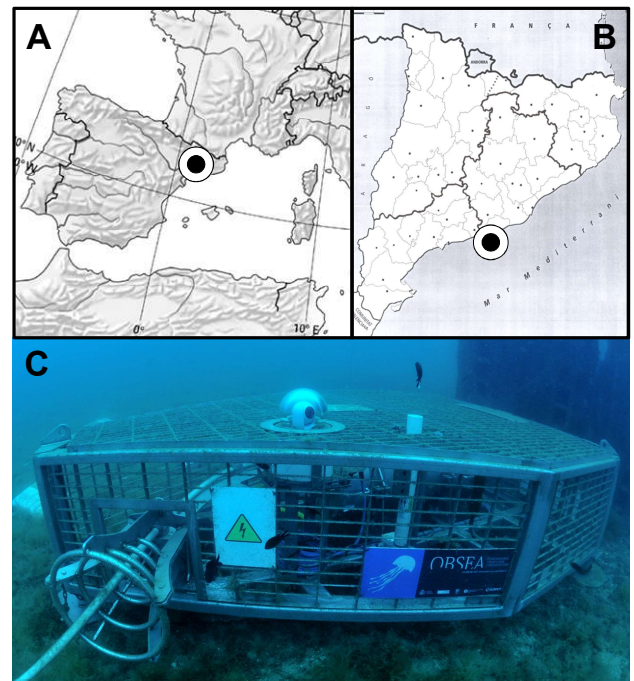

Figure 1. The western Mediterranean (A) and the included Catalan Sea (B) areas where the study was conducted (indicated by the black and white circle) in front of the coast of *Vilanova i la Geltrú*. Submerged multiparametric OBSEA platform with the video camera is also presented (C; adapted from Aguzzi et al., 2011c).

The protocol of image acquisition

In order to study the temporal patterns of abundance variation at monthly and hourly time scales, frames were acquired from June 2009 to July 2010 at hourly frequency (i.e. at the beginning of each hour), within daylight phase, during alternate days within the two central weeks of each month. According to this scheduling, images were acquired over 84 days. No nocturnal image was taken, given the absence of illumination system.

Species determination and statistical analyses

Species identification was carried out with the help of the Marine Fauna Identification Guide of Lousy (2006) and the web data base of Froese and Pauly (2000). In frames where fishes appeared in schools and banks and counts were too large, we arbitrarily set a maximum in observations as equal to 50 (Tessier et al., 2004). In those days when strong water turbidity, elevated cloud cover strongly affected the fish visibility, frames were discarded. Only those species considered as the most recurrent in images were considered for statistical analysis.
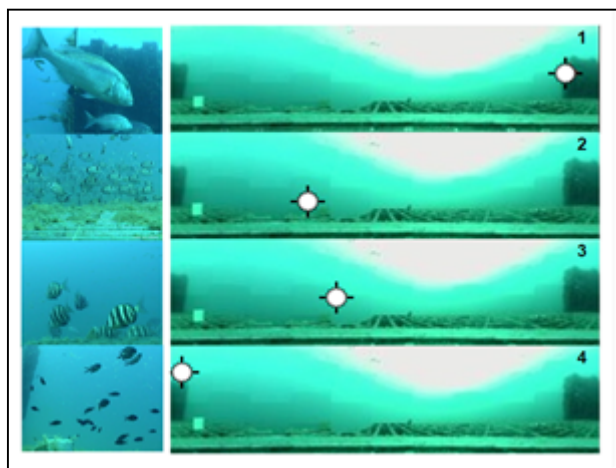
Figure 2. The 4 camera fields of view (on the right) selected for fish counting at the OBSEA location. A 360º mosaic made by 8 consecutive frames was created and a white star was positioned in order to indicate the centre of the different fields of view in relation to the habitat elements of relevance: the artificial reef (no. 1 and 4), and the water column (no. 2 and 3). A sample of observed fish species within the field of view as it appears at the enlargement used for counting is reported on the left. Picture 1) *D. dentex* (3) and *S. melanocercus* (4); 2) *D. sargus* (1) and *D. vulgaris* (>50); 3) *D. dentex* (2) and *D. cervinus* (8); and 4) *C. chromis* (21).

A set of community parameters were measured per each image: the total number of fishes; the number fishes per species; the number of species; the Shannon Diversity Index (H) (Krebs, 1989); and finally, the mean Trophic Level. This latter is the average of indexes of all fishes appearing in pictures and it accounts for the species positioning within the marine food web (Pauly and Watson, 2005).

The occurrence of seasonal fluctuations in visual counts was screened at first by representing row visual count data for each species by month. Mean values of observations per month were then computed and added in superposition with the picture values. We did not plot the total number of fishes by month since the number of pictures suitable for an efficient analysis was variable.

Statistical analysis was carried out comparing following effects on parameters measured in frames: space by selecting four camera fields of view (see Figure 2); season by grouping images for months of winter (January, February and March), spring (April, May and June), summer (July, August and September), and autumn (October, November and December); intra-day period by grouping images taken in the morning (sunrise to 12 a.m.) *versus* those taken in the afternoon (12 p.m. to sunset).

Kruscal-Wallis and Wilcoxon Mann-Whitney statistical tests for nonparametric distribution were used to examine differences in data because these do not comply with normality and homocedasticity conditions. When differences between the groups were found, Bonferroni-Dunn's post-hoc test was used to classify the data into equal groups. XL-Stat 2009 (Windows Excel package) was used for that data analyses.

Finally, in order to detect the level of similarity in seasonal patterns of abundance variation among all species, the software Heatmap.2 from R-statistics was used. The software uses mean monthly counts of species, standardized by the percentage of the maximum. Then, the software was used to carry out a cluster analysis in order to group species according to the similarity in their seasonal mean abundance variation. Finally, it was used to draw a map of standardized mean abundances. This was done in order to better visualize the common pattern of seasonal variation within species of each recognized cluster.

RESULTS

In this study, we collected a total of 3536 pictures. Out of these, 2871 as the majority (81%) were obtained under good visibility conditions. After a preliminary screening of images, we considered the following numbers of frames per month as suitable for our analysis: June, 198; July, 274; August, 266; September, 305; October, 316; November, 402; December, 221; January, 204, February, 226; March, 259; April, 348; May, 290.

A total of 33465 fishes were counted in all selected frames. The majority of them (22506 as the 67%) were classified at the species level, being the rest not classifiable since appearing too distant within the field of view. A total of 22 different fish species were recognized during the sampling period (Table 1), belonging to 8 different families: Caragnidae, Centracanthidae, Labridae, Mullidae, Scorpaenidae, Serranidae, Sparidae, and finally Pomacentridae.

Fish species apart, other species were also identified. It is the case chondrichthyes of the genus Myliobatis or the cephalopods (*Loligo vulgaris* and *Octopus vulgaris*). We also identified different individuals of cormoran (*Phalacrocorax aristotelis* and *P. carbo*) while engaged in fishing activity.

Total number of counted fishes per species and the percentage of species occurrences within the whole frame set are also reported in Table 1. The two-banded seabram (*Diplodus Vulgaris*) and the Damselfish (*Chromis chromis*) represented together the 72.6% of all classified fishes. Conversely, *Boops boops* and *Spicara maena* appeared in a reduced number of frames but in big schools (i.e. 50 or more individuals). In fact, schooling was observed few times in the whole frame set (i.e. 6%).

Image parameters related to the fish community showed a variability that depended form the different fields of

view considered (see Table 1). These parameters were: Total counted fish; Total classified fish; Species number; Shannon Diversity Index (H) and mean Trophic Level. Post-hoc comparison analysis showed the occurrence of significant effects of field of view with higher values for the previously quoted parameters at the artificial reef fields of view (i.e. no. 1 and 4; see Figure 2). Species showing higher numbers in its proximity were: *C. chromis*, *D. dentex*, *D. annularis*, *D. cervinus*, *D. puntazzo*, *D. sargus*, *D. vulgaris*, *E. marginatus*, *O. melanura*, *S. scrofa*, *S. maena*, *S. melanocercus*, and *S. tinca*. Conversely, *P. pagrus* and *S. mediterraneus* showed higher mean values in images taken at the water column field of view (no. 2 and 3; see Figure 2).

The major part of species presented differences in relation to the season. We identified this temporal trend in 17 out 22 species (see Table 1). Post-hoc analysis (i.e. the Bonferroni-Dunn test) showed maximum count values in summer for the majority of them. Winter presented the lowest count values while spring and autumn attained similar estimates. Species seasonally unaffected were *B. boops*, *S. dumerili*, *S. melanocercus*, and *S. tinca*.

Elaborations for the mean Trophic Level per image were also computed on a seasonal basis. Maximum and minimum values of 2.31 in summer and 1.37 in winter respectively were reported, with an average estimate of 1.96.

We also evidenced intra-day differences in those image parameters related to the fish community (see Table 1). Images taken within the morning to evening window showed the occurrence of significant differences in parameters such as Species number and mean Trophic Level. These differences were higher for both parameters in the evening (i.e. 1.15<1.18 and 1.91<2.01, respectively). Conversely, no intra-day differences in Shannon Diversity Index (H) were reported. This Index can be maintained around the same values all day by the replacement of some species by another, and also by the proportion.

The plotting over consecutive months of total count data when pooling together all species with a seasonal pattern of abundance variation in Table 1, indicated the occurrence of a drop from January to April (Fig. 3). A maximum occurred instead in June (15.8 mean number of individuals per picture).

Such seasonal trend in global counts resulted to be the product of in variations for different species, which experiments a monthly fluctuation of different strength (Fig. 4). Of all species showing seasonal variation only 6 were object of further temporal analysis (i.e. *Diplodus vulgaris*, *D. sargus*, *D. annularis*, *Chromis chromis*, *Spondyliosoma chantarus*, *Dentex dentex*), being their total count above 350 individuals (see Table 1). The seasonal trend of count variation was more pronounced in *D.*

vulgaris, S. cantharus, D. annularis, and *D. dentex,* being this fluctuation more dampened in *C. chromis* and *S. sargus.*

The Hetamap graph resumed the common patterns of seasonal variation in species counts of Table 1. Five different clusters of species with similar seasonal trend of variation were identified (Figure 6): 1) *S. mediterraneus, S. tinca, D. dentex, D. puntazzo* and *B. boops,* which presented broad increments in Summer 2009 and minima from Autumn 2009 to Spring 2010; 2) *S. cabrilla, E. marginatus* and *S. dumerili,* which presented broad increments from Summer to Autumn 2009 and minima from Winter to Spring 2010; 3) *S. cantharus, O. melanura, S. porcus, P. pagrus, D. anularis* and *T. trachurus,* which presented broad increments both Autumn 2009 and Spring 2010 and minima in both Summer 2009 and Winter 2010; 4) *S. melanocercus, D. sargus, C. julis, S. maena, M. barbatus, D. vulgaris,* and *D. cervinus,* which presented broad increments from Summer to Autumn 2009 and also in Spring 2010 and minima in Winter 2010; and finally, 5) *C. chromis* that showed soft increments from Summer to Autumn 2009.

The analysis of seasonal variations in detected levels of images H revealed maximum and minimum value of 0.45 in June 2010 and 0.06 in March 2010 respectively, with an average estimate of 0.24 (see Table 1). This trend of seasonal variation was also confirmed by plotting H values as computed form each picture over the 12 months (Fig. 5). A variation of H over the season is observable. A maximum of diversity was observed in May and June 2010, with a minimum occurring in March. As a consequence, in winter 2010 the lowest H' mean values were reported, while the highest mean values occurred in both summer 2009 and spring 2010.
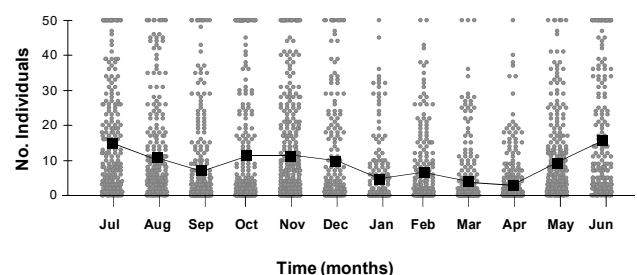

Figure 3. Mean value for Total counted fish in 12 months sampled (black box), and all image values for each month sampled (grey dots).

Species	Total	Average	%	Camera fields of view					Seasons					Intra-day		
				KW	1	2	3	4	KW	Winter	Spring	Summer	Autumn	WM	M	A
B. boops	150	0.04	0.67													
C. chromis	8082	2.29	35.91	***	D (3.73)	B (1.30)	A (0.92)	C (2.70)	***	B (3.07)	A (1.33)	C (2.27)	AB (2.70)			
C. julis	126	0.04	0.56						***	A (0.02)	B (0.06)	B (0.05)	A (0.02)			
D. dentex	366	0.10	1.63	***	B (0.16)	A (0.05)	A (0.02)	A (0.05)	***	A (0)	A (0)	B (0.28)	A (0.05)			
D. annularis	464	0.13	2.06	***	C (0.18)	BC (0.13)	A (0.10)	B (0.12)	***	C (0.19)	B (0.09)	A (0)	C (0.28)			
D. cervinus	143	0.04	0.64	***	B (0.06)	A (0.02)	A (0.01)	A (0.03)	***	A (0)	A (0.02)	B (0.11)	A (0.01)			
D. puntazzo	23	0.01	0.10	***	B (0.01)	A (0)	A (0)	A (0)	*							
D. sargus	1099	0.31	4.88	***	B (0.42)	A (0.15)	A (0.17)	B (0.44)	***	A (0.07)	B (0.29)	C (0.52)	B (0.25)			
D. vulgaris	8485	2.40	37.70	***	C (3.12)	A (1.45)	A (2.21)	B (2.66)	***	A (0.04)	B (1.58)	D (3.96)	C (2.83)			
E. marginatus	25	0.01	0.11	*	AB (0.01)	AB (0)	A (0)	B (0.01)	***	AB (0)	A (0)	C (0.01)	BC (0.01)			
M.barbatus	57	0.02	0.25						***	A (0)	B (0.05)	A (0.01)	A (0)			
O. melanura	177	0.05	0.79	***	B (0.13)	A (0.02)	A (0.01)	A (0.04)	***	A (0.02)	B (0.11)	A (0.02)	A (0.05)			
P. pagrus	202	0.06	0.90	***	A (0.03)	B (0.18)	A (0.01)	A (0.02)	***	A (0)	B (0.22)	A (0)	A (0.01)			
S.porcus	93	0.03	0.41	***	A (0.01)	AB (0.03)	A (0.02)	B (0.06)	***	A (0)	B (0.10)	A (0.01)	A (0.01)			
S.dumerili	19	0.01	0.08													
S. cabrilla	23	0.01	0.10						**	A (0)	AB (0)	B (0.01)	AB (0.01)			
S.maena	1478	0.42	6.57	**	B (0.55)	A (0.29)	A (0.36)	AB (0.50)	*	A (0.01)	B (0.34)	AB (0.97)	B (0.10)			
S. cantharus	1009	0.29	4.48						***	A (0.11)	B (0.48)	A (0.19)	B (0.33)			
S. mediterraneus	85	0.02	0.38	***	A (0.01)	B (0.06)	A (0.01)	A (0.03)	**	AB (0.01)	B (0.03)	B (0.04)	A (0.01)			
S. melanocercus	266	0.08	1.18	***	A (0.07)	A (0.05)	A (0.04)	B (0.13)								
S. tinca	45	0.01	0.20	**	A (0)	AB (0.01)	A (0)	B (0.03)								
T. trachurus	85	0.02	0.38						***	A (0)	A (0)	A (0)	B (0.91)			
Total counted	33465	9.46		***	D (14.67)	B (5.58)	A (5.04)	C (11.03)	***	A (5.55)	B (7.35)	D (11.89)	C (11.10)			
Total classified	22506	6.36		***	D (8.93)	B (4.06)	A (4.12)	C (7.48)	***	A (3.62)	B (4.76)	C (8.73)	B (6.82)			
Number of species	22	1.17		***	D (1.55)	B (0.95)	A (0.69)	C (1.32)	***	A (0.67)	B (1.19)	C (1.46)	B (1.13)	*	1.15	1.18
H'		0.24		***	D (0.33)	B (0.19)	A (0.11)	C (0.28)	***	A (0.11)	B (0.26)	C (0.31)	B (0.22)			
Mean Trophic level		1.96		***	D (2.42)	B (1.82)	A (1.35)	C (2.09)	***	A (1.37)	B (1.96)	C (2.31)	B (1.93)	**	1.91	2.01
Total number of pictures	3536															

Table 1. Species list and image parameters at the OBSEA cabled video-observatory. Image parameters related to Total and Average of video-counts and Percentage of a species representation with respect of the Total of classified fishes are reported along statistic results of Kruscal-Wallis (KW) on counts and cameras fields of view (1, 2, 3 and 4; see Figure 2) and seasons. Post-hoc classifications with Dunn test (A, B, C, and D with relative averages in parentheses) appears form columns from five to eight (field of views) and ten to thirteen (seasons). Finally, the column fourteen report the Wilcoxon Mann-Whitney test (WM) results when comparing number of counted fishes per species and the other biological parameters in morning (M) and the afternoon (A) frames. Significance levels are as follow: *** $p = 0.001$; ** $p = 0.01$; * $p = 0.05$.
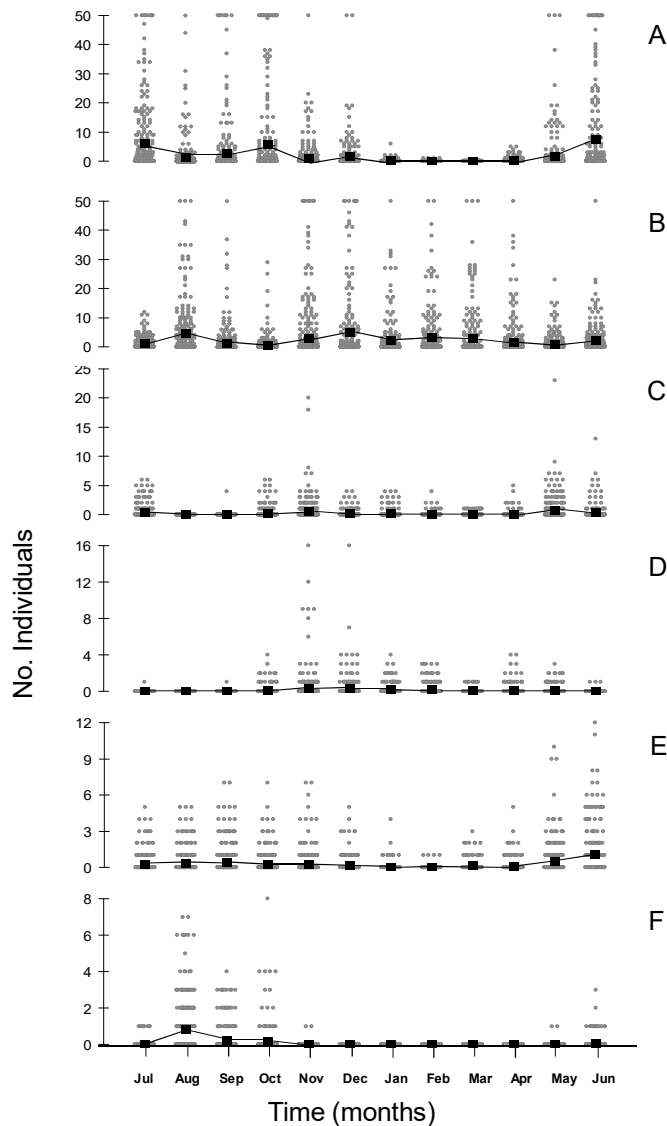
Figure 4. Mean number of fish identified by month and all image values for the most representative species in 12 sampled months (black box and grey dots): Common two-banded seabream (A: *Diplodus vulgaris*), Damselfish (B: *Chromis chromis*); Black seabream (C: *Spondylosoma cantharus*); Annular seabream (D: *Diplodus annularis*); White seabream (E: *Diplodus sargus*) and Common dentex (F: *Dentex dentex*).
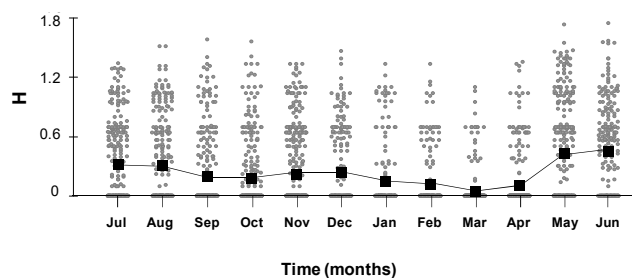

Figure 5. Mean Shannon Diversity Index (H) per month sampled and all image values (black box and grey dots).

DISCUSSION

In this study, we monitored for the first time the seasonal variation in fish counts for different species at hourly frequency by means of the OBSEA cabled video-observatory. Seasonal variations in visually counted individuals were evidenced for the most important species in terms of abundance. In some species, we also detected some level of intra-day variation when comparing morning *versus* evening frames, as an indication of diel rhythms in swimming activity.

The seasonal and intra-day variability

A marked temporal variability in species counts was detected over the seasonal cycling, being such variation much more reduced at the intra-day time scale (hourly sampling between sunrise and sunset). Notwithstanding is interesting to link the reported seasonal fluctuations in population abundances to changes in the behaviour of the constitutive individuals, which depend on the day-night alternation (Aguzzi and Company, 2010).

The majority of analysed species presented a common rhythmicity with peak in abundances chiefly positioned at summer months and consistent drops in winter (see Figure 5). In spring and autumn similar abundances were reported and these have been considered periods of transition in the Mediterranean area (Harmelin-Vivien et al., 1985; Relini et al., 2002a,b; Santos et al., 2005). Only few exceptions to this seasonal trend were reported, as in the case of *B. boops*, *S. dumerili*, *S. melanocercus* and *S. tinca*. However, of these only *S. melanocercus* showed appreciable counting levels (N=266), when compared for example, to *B. boops*, which appeared in big shoals in just only three images.

Seasonal variations in video-counts are likely due to the bidirectional movement of individuals in and out from coastal areas. Migration and recruitment from or toward deeper zones are the main two factors that explain season variability in fish biomasses in coastal areas (Francour, 1997). Also, unidirectional ontogenetic migrations likely take place in relation to the movement of juveniles which join adults in coastal areas at summer time. For some Mediterranean species an increase in biomass was already observed in coastal areas during the warm months as result of recruitment (Harmelin-Vivien et al., 1985).
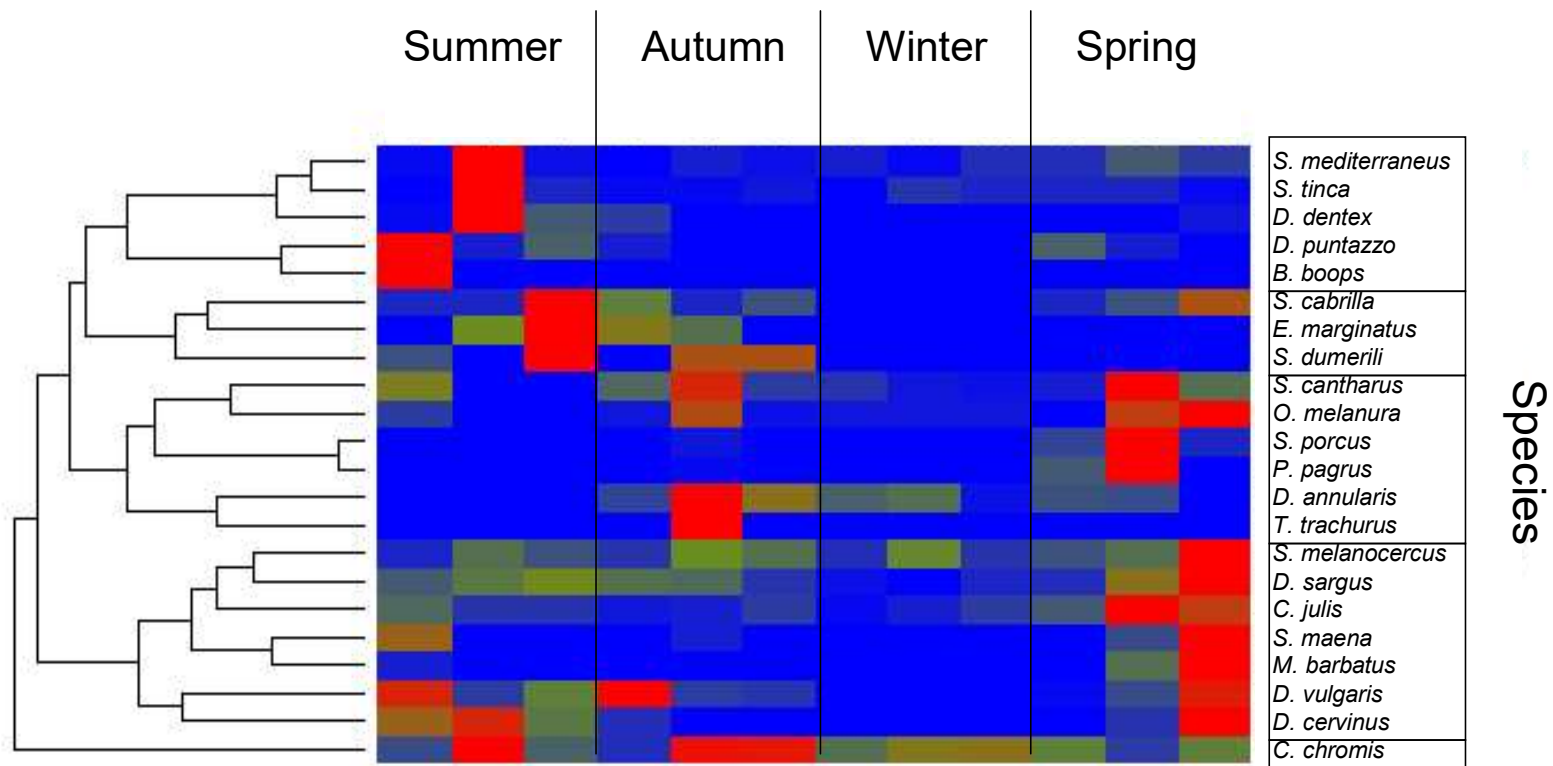
Summer | Autumn | Winter | Spring

Species

S. mediterraneus
S. tinca
D. dentex
D. puntazzo
B. boops
S. cabrilla
E. marginatus
S. dumerili
S. cantharus
O. melanura
S. porcus
P. pagrus
D. annularis
T. trachurus
S. melanocercus
D. sargus
C. julis
S. maena
M. barbatus
D. vulgaris
D. cervinus
C. chromis

Color Key and Histogram

Count

Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun

Value

Time (months)

Figure 6. Heatmap cluster analysis for all species found in 12 months. In each one of the boxes in draw there is represented the mean value of species appereence for that month, standardized by the maximum mean value found in all months for each species (the standardized value is represented by a color from blue=0, to red=1). Cluster analysis is done after find the most similar patterns of distribution along the whole season.

In this study, the weakly detected intra-day variability in visually counted fishes could be an indication of swimming diel rhythms. Intra-day variability was tested in image parameters such as the Species number and mean Trophic Level (see Table 1). The number of species increased in frames taken in the second half of the photophase (i.e. from morning 1.15 to an evening 1.18). This increment was performed by species having a higher mean Trophic Level (from 1.91 in the morning to 2.01 in the evening), suggesting that in the OBSEA area the arrival of top predators coincides with the dampening of environmental illumination before sunset. Several studies already shown that sunset is an important transition time between day and night species, often representing an important opportunity for fish predators to spot out their prey (Robertson and Howard, 1978; Gibson et al., 1998).

Fluctuations in visually sampled fishes require a detailed knowledge of the species behavioural life-habits in order to be interpreted in terms of activity or inactivity phases. A drop in counts may be provoked by a decrease in animals swimming rate with the consequent decrease in spotting chance (Aguzzi et al., 2011a, b). Alternatively, animals may show a translational movement in or out form the study areas, according to the day-night alternation similarly to seasonal migration patterns (Hyndes et al., 1999). These seasonal migration patterns may be associated to reproduction or feeding exigencies (Reebs, 2002). In our case, species analysed in detail showing seasonal displacement to the coast in order to reproduce are only *D. dentex* due to disappearance in early spring while reproduction (Froese and Pauly, 2000). The presence of seasonal and diel activity rhythms in fish behaviour related to both migration (the former rhythm) active swimming (the latter rhythm) is of interest for marine chronobiology. A biological clock measuring the photophase length at a 24-h base *via* the activation or suppression of behaviour may represent the mechanism of generation of seasonal rhythms (Aguzzi and Company, 2010). Behavioural alterations that occur when the photophase exceed a certain length (i.e. photoperiodic responses) may be the base of detected seasonal rhythms in ontogenetic migrations due to growth or reproduction (Pittman and Mc Alpine, 2001).

The detected faunistic composition and the "reef-effect"

In this study, several faunistic observations were carried out, resulting in the computing of a comprehensive list of resident marine species in the area, including seabirds. Our results indicated that the local fish composition is similar to other Western Mediterranean areas. Valle et al. (2001) found 21 different species by bottom trawling in *Posidonia oceanica* beds within the *Tabarca* Marine Reserve (Alicante, SW Mediterranean). From those species, 15 (71%) were also detected by visual image analysis at OBSEA site. Bayle-Sempere et al. (2001) also carried out scuba diving visual census to estimate fish abundance in artificial reefs that were installed in the *Tabarca* reserve. They found 32 different species. Out of these, 14 (43%) also appeared in *Colls i Miralpeix* Marine Reserve, where the OBSEA is located. Further north, in the *Port-Cros* Marine Reserve (France), Francour (1997) found 17 species and 8 (47%) of those also appeared in our study area.

Faunistic differences were instead detected when comparing our results with those obtained in other adjacent European areas outside the Mediterranean where artificial reefs are installed. For example, Santos et al. (2005) detected in Algarve (Portugal) artificial reefs, 33 species by visual censuses. Out of these, the presence of only 11 (33%) was recorded in present study.

In this study, we reported the dominance of Sparidae species in the OBSEA area. We judge this effect related to the presence of an artificial reef. Other authors similarly confirmed the increase of Sparidae in artificial reefs areas (Pickering et al., 1999; Charbonnel et al., 2002; Relini, 2002b). Anyway, the artificial reef exerted a strong influence not only on the distribution of Sparidae (e.g. *D. vulgaris*) but also on other species (e.g. *C. chromis*), as well as on resulting community composition (e.g. Total fish counted and Shannon Diversity Index). In fact, we observed marked differences in the presence and abundance of the majority of species in relation to the camera fields of view (see Table 1). Post-hoc tests indicated that these could not be considered as spatial replicates.

Artificial barriers usually increase the diversity and abundance of fishes (Watson et al., 2005). Such an artificial reef effect was already reported in other studies in the western Mediterranean area, indicating the occurrence of a general dynamic (Pickering et al., 1999; Bayle-Sempere et al., 1994, 2001; Charbonnel et al., 2002; Relini et al., 2002a). Habitat heterogeneity increases the number of fish species and the complexity of their interactions, leading in turn to the increment of community stability in front of perturbations (Montoya et al., 2006; Carpenter et al., 2006). Such increment of species is the product of colonisation by sedentary animals and plants that require hard substrates in order to carry out their life cycle (Seaman, 2007), which in turn promote the recruitment of juveniles for different fish and crustacean decapod species (Pitcher and Seaman, 2000; Moreno, 2002; Jensen, 2002)

The effects of fish attraction by reefs should be discussed in relation to animal behaviour. Regarding to *D.*

vulgaris, we observed that schools are often located on one side of the reef or the other, depending on the water flow direction (not quantified in this study). This behaviour optimizes the swimming efficiency, reducing the drag in front of strong current episodes in *D. vulgaris* as well as in several other species observed preferentially in reef proximity (Bayle-Sempere et al., 2001). Other authors point toward the feeding behaviour. Charbonel et al. (2002) argue that fish come to reefs in order to increase their feeding efficiency. They concluded that energy is transferred from artificial reefs to fish through decapods, amphipods and juvenile fish, which are usually concentrated in these submerged structures (Relini et al., 2002a).

In this study we observed how large fishes reside close to the reef while feeding. Anyway, we also observed that other smaller species come by as in the case of cleaners. It is not still clear whether cleaner species feeds mostly on parasites like copepods or skin, scales and body mucus (Arnal and Morand, 2001; Zander and Sötge, 2002). The cleaner Labridae *S. melanocercus* was one of the few fishes that spent all year around at the OBSEA location (see Table 1). That data, along with other observations where big fishes were commonly observed as object of Labridae cleaning, suggests that OBSEA structures including the artificial reef could be an important cleaning site.

Our visual observations referring to the preferential presence of several fish species close to the artificial barrier support the importance of these structures for fishery management (Jensen, 2002). Many authors already emphasised the value of reef in conservation given their multiple use (e.g. provision of specific habitat for aquaculture and fisheries activities, as well as tourism and diving; Pickering et al., 1999; Bayle-Sempere et al., 2001). However, the debate on the efficacy of reef installation is still open because it is not clear whether artificial reefs concentrate species and biomasses by acting as hot spots for the recruitment of individuals attracted from nearby founds (Bayle-Sempere et al., 1994, 2001; Pickering and Withmarsh, 1997; Pitcher and Seaman, 2000). In these submerged infrastructures, as in Marine Protected Areas it is essential to collect data in order to study the process of colonisation and species habitat use through space and time (Claudet and Pelletier, 2004; Seaman, 2007; Harmelin-Vivien et al., 2008b). Due to the disadvantages of visual surveys carried out by divers (Harvey et al., 2002), our underwater video-imaging sampling showed significant advantages.

Conclusions

In this study, we successfully employed a novel observational technology (i.e. the cabled video-observatory) to monitor the occurrence of seasonal and intra-day changes in a coastal fish community, as result of a modulation of animals' behaviour. We noticed an important variation in fish biodiversity according to the season, suggesting that this temporal parameter should be included in the planning of sampling strategies for exploration and management, in order to prevent census and assessment errors. Some of the technological advantages are evident (e.g. the high frequency of video-sampling over extended temporal windows), although other drawback can also be listed (e.g. variable frames quality for water turbidity of environmental illumination drop at cloudiness, especially close to sunset and sunrise). Although, we surely detected the majority of species in the *Colls i Miralpeix* Marine Reserve, the faunal list of fishes may be incomplete, given the still character of our observations. Despite the high number of sampled pictures during the whole year, more nocturnal, small (including juveniles), or more crypto-benthic species could have been neglected. This indicates that cabled video-observatory sampling strategies should be coupled with other wandering video-sampling methods, being data collected over a complete 24-h cycle.

REFERENCES

Aguzzi, J. & Company, J.B. 2010. Chronobiology of deep water continental margin decapods. Advances in Marine Biology, an Annual Review 58, 155-225.

Aguzzi, J., Company, J.B., Costa, C., Menesatti, P., Garcia, J.A., Bahamon, N., Puig, P., Sardà, F., 2011a. Activity rhythms in the deep-sea: a chronobiological approach. Front. Biosci. 1;16:131-50.

Aguzzi J., Company J.B., Costa C., Matabos M., Azzurro E., Mànuel A., Menesatti P. Sardà F., Canals M., Delory E., Cline D., Favali P., Juniper S.K., Furushima Y., Fujiwara Y., Chiesa J.J., Marotta L., Priede I.M. 2012. Biorhythms challenge to stock and biodiversity assessments: cabled observatories video-

solutions. Oceanography and Marine Biology: an Annual Review 50, 233-284.

Aguzzi J., Costa C., Furushima Y., Chiesa J.J., Company J.B., Menesatti P., Iwase R., Fujiwara Y. 2011b. Behavioural rhythms of hydrocarbon seep fauna in relation to internal tides. Marine Ecology Progress Series 418: 47-56.

Aguzzi, J., Mànuel, A., Condal, F., Guillén, J., Nogueras, M., Del Rio, J., Costa, C., Menesatti, P., Puig. P., Sardà, F., Toma, D., Palanques, A., 2011c. The New Seafloor Observatory (OBSEA) for Remote and Long-Term Coastal Ecosystem Monitoring. Sensors 11, 5850-5872.

Arnal, C., Morand, S., 2001. Importance of ectoparasites and mucus in cleaning interactions in the Mediterranean cleaner wrasse *Symphodus melanocercus*. Marine Biology 138: 777-784.

Bayle-Sempere, J. T., Ramos-Esplá, A. A., García, J. A., 1994. Intra-annual variability of artificial reef fish assemblage in the marine reserve of Tabarca (Alicante, Spain, SW Mediterranean). Bulletin of Marine Science, 55(2-3): 824-835.

Bayle-Sempere, J.T., Ramos-Esplá, A. A., J. A. Palazón., 2001. Análisis del efecto producción-atracción sobre la ictiofauna litoral de un arrecife artificial alveolar en la reserva marina de Tabarca (Alicante). Boletín Instituto Español de Oceanografía 17(1 y 2): 73-85.

Bohnsack, J. A., Bannerot, S. P., 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report NMFS,41:1-15.

Bortone, S. A., Hastings, R. W., 1986. Quantification of reef fish assemblages: a comparison of several in situ methods. Northeast Gulf Science 8(1):1-22.

Carpenter, S. R., DeFries, R., Dietz, T., Mooney, H. A., Polasky, S., Reid, W. V., Scholes, R. J., 2006. Millenium ecosistem assesment: Research needs. Science Vol. 314:257-258.

Charbonnel, E., Serre, C., Ruitton, S., Harmelin, J., Jensen, A., 2002. Effects of increased habitat complexity on fish assemblages associated with large artificial reef units (French Mediterranean coast). Journal of Marine Science, 59: S208-S213.

Claudet, J., Pelletier, D., 2004. Marine protected areas and artificial reefs: A review of the interactions between management and scientific studies. Aquatic Living Resources, 17, 129-138.

Cline, D.E., Edginton, D.R., Mariette, J., 2004. An Automated visual event detection system for cabled observatory video. In Proceedings of 3rd International Conference on Computer Vision and Pattern Recognition (CVPR), Washington, DC, USA.

Colemenero A., Aguzzi J., Lombarte A., Bozzano A. 2010. Sensory constraints in temporal segregation in two species of anglerfish (Lophius budegassa and L. piscatorius). Marine Ecology Progress Series 416: 255-265.

Edgar, G. J., Barret, N.S., Morton, A.J., 2004. Biases associated with the use of underwater visual census techniques to quantify the density and size-structure of fish populations. Journal of Experimental Marine Biology and Ecology 308: 269-290.

Favali, P., Beranzoli, L. 2006. Seafloor observatory science: A review. Annals of Geophysics 49, 515-567.

Francour, P., 1997. Fish assemblages of *Posidonia oceanica* beds at Port-Cros (France, NW Mediterranean): Assessment of composition and long-term fluctuations by visual census. Marine Ecology, 18 (2): 157-173.

Froese, R. and D. Pauly. Editors. 2019.FishBase. World Wide Web electronic publication. www.fishbase.org.

Gibson, R. N., Pihl, L., Burrows, M. T., Modin, J., Wennhage, H., Nickell, L.A. 1998. Diel movements of juvenile plaice *Pleuronectes platessa* in relation to predators, competitors, food availability and abiotic factors on a microtidal nursery ground. Marine Ecology Progress Series Vol. 165:145-159.

Harmelin-Vivien, M. L., J. G. Harmelin, C. Chauvet, C. Duval, R. Galzin, P. Lejeune, G. Barnabe, F. Blanc, R. Chevalier, J. Declerc and G. Laserre., 1985. Evaluation des peublements et populations de poissons. Mèthodes et problemes. Rev. Ecol. (Terre Vie) 40: 467-539.

Harmelin-Vivien, M., Francour, P., 2008a. Trawling or visual censuses? Methodological bias in the assessment of fish populations in seagrass beds. Ecology 3: 41-51.

Harmelin-Vivien, M., Le Diréach, L., Bayle-Sempere, J., Charbonnel, E., García-Charton, J. A., Ody, D., Pérez-Ruzafa, A., Reñones, O., Sánchez-Jerez, P., Valle, C., 2008b. Gradients of abundance and biomass across reserve boundaries in six Mediterranean marine protected areas: Evidence of fish spillover? Biological Conservation 141: 1829-1839.

Harvey, H., Fletcher, D., Shortis, M., 2001. A comparison of the precision and accurancy of estimates of reef-fish lengths determined visually by divers with estimates produced by stereo-video system. Fisheries Bulletin 99: 63-71.

Harvey, H., Fletcher, D., Shortis, M., 2002. Estimation of reef fish lengh by divers and stereo-video. A First comparison of the accurancy and precision in the fiel don living fish under operacional conditions. Fisheries Research 57: 255-265.

Hyndes, G. A., Platell, M. E., Potter, I. C., Lenanton, R. C., 1999. Does the composition of the demersal fish assemblages in temperate coastal waters change with depth and undergo consistent seasonal changes? Marine Biology 134:335-352.

Jensen, A., 2002. Artificial reefs of Europe: perspective and future. Journal of Marine Science, 59: S3-S13.

Krebs, C., 1989. Ecological Methodology, 2nd ed. Addison-Welsey Educational Publishers, Inc., Menlo Park, CA.

Liu, J., Dietz, T., Carpenter, S. C., Alberti, M., Folke, C., Moran, E., Pell, A. N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C. L.,Schneider, H., Taylor, W. W., 2007. Complexity of coupled human and natural systems. Science Vol. 317: pg.14.

Longhurts, A.R., 1998. Ecological geography of the sea. Academic Press, London.

Montoya, J. M., Pimm, S. L., Solé, R. V., 2006. Ecological networks and their fragility. Nature 442: 259-263.

Moreno, I., 2002. Effects of substrate on the artificial reef fish assemblage in Santa Eulalia Bay (Ibiza, western Mediterranean). ICES Journal of Marine Science, 59: 144-149.

Pauly, D., Watson, R., 2005. Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. Phil. Trans. R. Soc. Biol. Sci. 360: 415-423.

Person, R., Aoustin, Y., Blandin, J., Marvaldi, J., Rolin, J. F., 2006. From bottom landers to observatory networks. Annals of Geophysics 49: 581-593.

Pickering, H. Whitmarsh, D., 1997. Artificial reefs and fisheries exploitation: a review of the 'Attraction versus Production' debate, the influence of design and its significance for policy. Fisheries Research 31: 39-59.

Pickering, H., Whitmarsh, D., Jensen, A., 1999. Artificial reefs as a tool to aid reahabilitation of coastal ecosystems: Investigating the potential. Marine Pollution Bulletin. Vol. 37, Nos. 8-12, pp. 505-514.

Pitcher, T., J., Seaman, W., 2000. Petrarch's Principle: how protected human-made reefs can help the reconstruction of fisheries and marine ecosystems. Fish and fisheries 1, 73-81.

Pittman S.J., McAlpine C.A. 2001. Movements of marine fish and decapods crustaceans: Process, theory and application. Advances in Marine Biology, 44, 206-295.

Reebs, S.G. 2002. Plasticity of diel and circadian activity rhythms in fishes. Reviews of Fish Biology and Fisheries 12, 349–371.

Relini, G., Relini, M., Torchia, G., De Angelis, G., 2002a. Trophic relationships between fishes and artificial reef. ICES Journal of Marine Science, 59: 36-42.

Relini, G., Relini, M., Torchia, G., Palandri, G., 2002b. Ten years of censuses of fish fauna on the Loano artificial reef. ICES Journal of Marine Science, 59: 132-137.

Robertson, A. I., Howard, R. H., 1978. Diel trophic interactions between vertically-migrating zooplankton and their fish predators in an eelgrass community. Marine Biology, Vol. 48, n. 3, 207-213.

Santos, M., N., Monteiro, C., Lasserre, G., 2005. Observations and trends on the intra-annual variation of the fish assemblages on two artificial reefs in Algarve coastal waters (southern Portugal). Scientia Marina, 69(3). 415-426.

Seaman, W., 2007. Artifial habitats and the restoration of degraded marine ecosystems and fisheries. Hydrobiologia 580:143-155.

Tessier, E., Chabanet, P., Pothin, K., Soria, M. Lasserre, G., 2004. Visual censuses of tropical fish aggregations on artificial reefs: slate *versus* video recording techniques. Journal of Experimental Marine Biology and Ecology 315: 17-30.

Valle, C., Bayle-Sempere, J.T., Ramos-Esplá, A. A., 2001. Estudio multiescalar de la ictiofauna asociada a praderas de *Posidonia oceanica* (L.) Delile, 1813 en Alicante (sudeste ibérico). Boletín Instituto Español Oceanografía 17(1 y 2): 49-60.

Watson, D. L., Harvey, E.S., Anderson, M.J., Kendrick, G.A., 2005. A comparison of temperate reef fish assemblages recorded by three underwater stereo-video techniques. Marine Biology 148: 415-425.

Willis, T. J., Millar, R. B., Babcock, R.C., 2000. Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. Marine Ecology Progress Series 198: 249-260.

Zander, C., D., Sötje, I., 2002. Seasonal and geographical differences in cleaner fish activity in the Mediterranean Sea. Hegol. Mar. Res. 55:232-241.

Zenetos, A., Gofas, S., Verlaque, M., Cinar, M.E., García Raso, J.E., Bianchi, C.N., Morri, C., Azzurro, E., Bilecenoglu, M., Froglia, C., Siokou, I., Violanti, D., Sfrisio, A., San Martín, G., Giangrande, A., Katagan, T., Ballesteros, E., Ramos-Esplá, A., Mastrototaro, F., Ocaña, O., Zingone, A., Gambi, M.C., Streftaris, N., 2010. Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. Medit. Mar. Sci., 11/2: 381-493.