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Temporal and Spatial Variation of the Fish Assemblage Around a Gas Platform in the Northern Adriatic Sea, Italy

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Abstract

The “Barbara NW” platform, located in the northern Adriatic Sea 56 km offshore and at 68.5 m depth, was monitored for investigating the temporal and the horizontally spatial extent to which the gas platform attracted different fish species during the three years after its deployment (2000-2002). Fish were sampled with a trammel net both at the rig and at an open-sea control site placed at a distance of about 1.8 km, on the same type of seabed. At each survey, the catch obtained around the platform was subdivided based on the distance from the jacket (submerged part of the platform). Six strata, each 34 m wide, were identified up to 204 m horizontally from the rig. The platform showed its aggregation effect within the first year after installation. Catch rates significantly declined at increasing distances from the rig. The value recorded inside a 34 m radius from the structure was significantly higher than those obtained at distances greater than 140 m and at the control site. Reef-dwelling benthic fish, partially reef-dwelling pelagic and nekto-benthic species dominated inside the stratum closest to the rig, whilst the organisms which had no affinity towards hard substrates prevailed in the farther strata and at control site.

Keywords: Gas platform, fish assemblage, catch rates, trammel net, Adriatic Sea.

İtalya'da Kuzey Adriyatik Denizinde Gaz Platformu Çevresindeki Balık Stoklarının Zamansal ve Mekansal Varyasyonu

Özet

“Barbara NW” platformu Kuzey Adriyatik Denizi'nde kıyıdan 56 km uzakta ve 68,5 m derinliğe yerleştirilmiştir. Bu platform konuşlandırıldıktan sonra üç yıl boyunca (2000-2002) monitör aracılığı ile farklı balık türlerinde zamansal ve horizontal dağılımı araştırılmıştır. Balıklar, platforma ortalama 1,8 km mesafede hem dipte av ekipmanı ile hem de açık denize yerleştirilen tuzak ağıyla örneklenmiştir. Her bir operasyonda av, platformun suyun içinde kalan kısmından elde edilmiştir. Her 34 m'lik genişlikte ekipmandan yatay olarak 204 m yukarıya kadar altı katman tanımlanmıştır. Platform kurulumun ardından bir sene içerisinde toplama etkisini göstermiştir. Av oranları ekipmandan uzaklık arttıkça önemli düşüş göstermiştir. Yapıdan 34 m içerideki kaydedilen değer 140 m'den daha büyük mesafelerden ve kontrol bölgesinden elde edilenlerden önemli derecede daha yüksektir. Resif özellik gösteren alanda yaşayan bentik balıklar, kısmen resif yaşayan pelajik ve nekton bentik türler ekipmana yakın olan katmanlarda üstünlük gösterirken, sert substratlara ilgisi/affinitesi olmayan organizmalar daha uzak katmanlarda ve kontrol bölgesinde baskın gelmişlerdir

Anahtar Kelimeler: Gaz platformu, balık topluluğu, av oranları, tuzak ağı, Adriyatik Denizi.

Introduction

The seabed of the Northern Adriatic Sea is mostly sandy-mud with a very low proportion of naturally exposed hard substrates. Since the 1960s an increasing offshore gas production has occurred in this region, leading to the construction of more than 90 gas platforms which represent around 90% of the overall offshore platforms existing in the Mediterranean Sea and constitute one of the greatest artificial reef system of this basin. Fabi *et al.* (2002, 2004) showed evidence that these platforms aggregate considerable amounts of demersal and pelagic fish of great importance for recreational and commercial fisheries. In accordance with observations in other areas (Menge and Sutherland, 1976; Gallaway *et al.*, 1981; Bohnsack and Sutherland, 1985; Bohnsack *et al.*, 1991; Stanley and Wilson, 2000; Løkkeborg *et al.*, 2002), it is also likely that rigs affect ecological processes, by providing habitats that potentially favor

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the growth rates and survival of marine organisms. Indeed, they can furnish shelter for protection from predation and trawling, additional food supply and spawning substrate, and can act as a visual attractant for organisms not strictly dependent on hard bottoms (Fabi *et al.*, 1998). Keenan *et al.* (2007) suggested that platforms provide an enhanced foraging for associated fish community, which may gain a trophic subsidy through an extended foraging opportunity after dark and positive concentration of phototaxic prey taxa. On the other hand, Love *et al.* (2000) pointed out that great concentrations of juveniles around the platforms could attract predators, hence reducing survival rates of some species.

Fish abundance and species composition can change dramatically with proximity to platform, location, and time of deployment (Sonnier *et al.*, 1976; Putt, 1982; Gerlotto *et al.*, 1989; Stanley and Wilson, 1996, 1997; Løkkeborg *et al.*, 2002). Monitoring studies carried out in the Adriatic Sea highlighted diverse fish species composition and densities at platforms placed at different depths, higher abundances at the rigs in respect to the natural sandy-mud habitat and temporal changes of the rig fish assemblages (Fabi *et al.*, 2002, 2004).

Following these findings, this study was aimed at investigating the temporal and the horizontally spatial extent to which the gas platform Barbara NW attracted different species of fish during the three years after its deployment (2000-2002).

Materials and Methods

Site Description

Barbara NW (B_p) is a 4-leg gas platform located 56 km offshore on a sandy-mud seabed, at 68.5 m depth, far from natural hard substrates and at 8 km of distance from an artificial archipelago of nine gas platforms named "Campo Barbare" (Figure 1). The B_p jacket (submerged part of the platform) was installed in February 1999. The drilling operations finished in June of the same year and the production started soon after. The platform covers approximately 100 m^2 of the sea surface and 730 m^2 of the seabed, and encloses nearly 25,000 m^3 of water (Figure 2).

Sampling Design

Fish were collected at B_p and at an open-sea control site (B_c) located about 1.8 km off. Sampling was carried out with experimental bottom trammel nets, appositely designed to reduce their selectivity (inner panel: 6 m high, stretched mesh size 72 mm and 0.18 mm transparent monofilament; outer panels: 3 m high, stretched mesh size 400 mm and 0.30 mm transparent monofilament). The nets were lowered into the water at dusk and hauled in at dawn (an average deployment time of 12 h). Two fleets, each one composed by eight trammel nets (each 34 m long), were used as near to the platform as the boat could go for safety reasons (~ 5-10 m) and some meters of net were s*et al*ong the platform. The two fleets of trammel net were set from the platform to a distance of about 200 m (Figure 3). Only one fleet of 16 trammel nets (each 34 m long) was employed at B_c. The platform and the control site were sampled simultaneously in order to operate in the same weather conditions. From January 2000 to December 2002 approximately 12 sampling per year were carried out at both B_p and B_c (a total of 34 trials per site). Onboard, the catches obtained at B_p were treated separately based on the distance of the nets from the platform.

All specimens in catches were identified at the lowest taxonomic level and individually weighed to the lowest gram.

Pelagic (P), nekto-benthic (NB) and benthic (B) fish, as well as mollusks and crustaceans were treated separately.

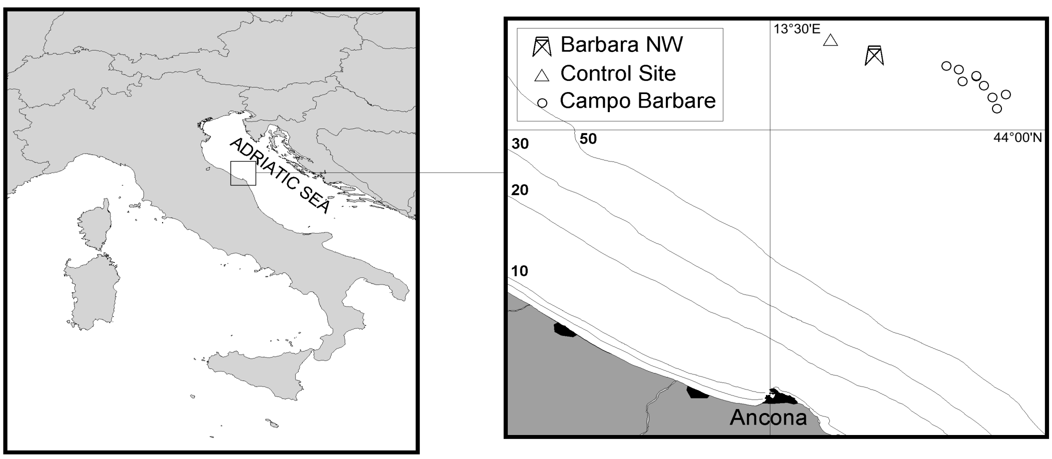

Figure 1. Location of the Barbara NW gas platform and the open-sea control site. The gas platform field "Campo Barbare" is also reported.

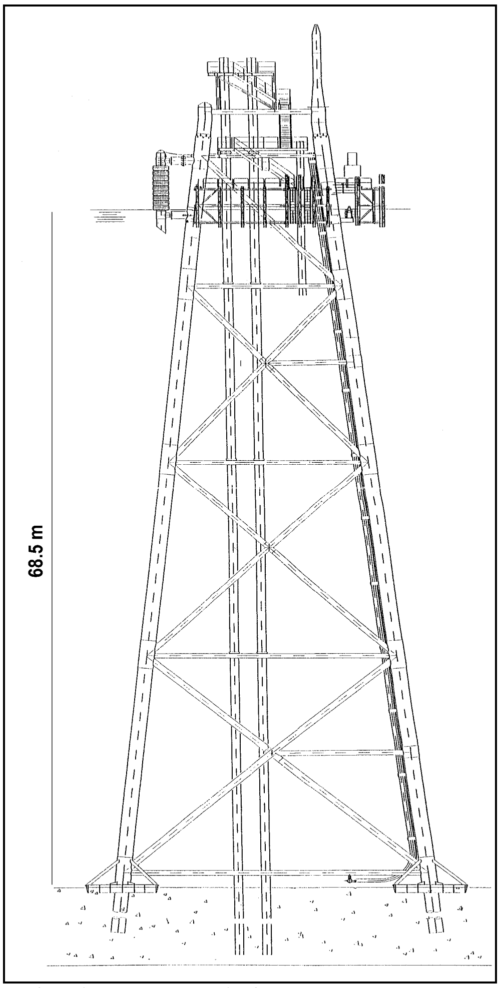

Figure 2. Scheme of the steel jacket of Barbara NW gas platform.

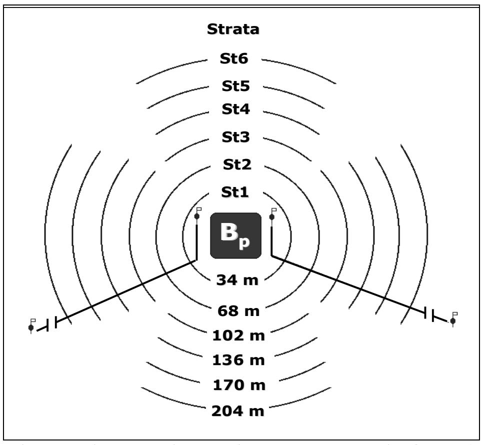

Figure 3. Setting of the two trammel nets close to the Barbara NW gas platform (B_p) and location of the spatial strata St1-St6.

Because of differences in the net set time (longer in winter than in summer) and because the net was sometimes damaged, indexes of abundance (number of individuals; N) and biomass (W) were standardized for a 12 h set period and 50 m of net.

Data Analysis

B_p spatial influence in the surroundings was investigated comparing the catches rates obtained inside strata placed at increasing distances from the platform. The distance increment (i.e., the width of each stratum) corresponded to the length of one trammel net (34 m). Therefore, six strata (St1-St6) were analyzed up to a radius of 204 m from the jacket (Figure 3). The species caught inside the same stratum with both fleets were pooled together. B_c captures were considered as the furthest stratum (St7).

Statistical univariate and multivariate analyses were employed to evaluate spatial and temporal variations in fish assemblage among strata and years.

An unbalanced fixed effect, two-way Analysis of Variance (ANOVA; Lindman, 1992) was utilized to compare abundances and biomass of the total catches and of the main species categories using strata and years as the main factors, the latter being considered as first (Yr1), second (Yr2) and third year (Yr3) after construction. Prior to performing statistical analysis, normal distribution and homogeneity of variances were evaluated by Kolmogorov-Smirnov and Bartlett tests (Lindman, 1992), respectively. Based on the tests, N and W data were log-transformed [log (x + 1)]. The Tukey HSD test corrected for unbalanced samples was used to make comparisons across all pairs of group means when corresponding ANOVA tests were highly significant ($P<0.001$) or significant ($P<0.01$). As this transformation was not sufficient to satisfy the above-mentioned assumptions for crustaceans Kruskall-Wallis test (Siegel and Castellan, 1988) was applied in this case to evaluate differences between strata and between years. In addition, Spearman's coefficient was computed to verify correlations between catch rates and strata (Legendre and Legendre, 1998).

Multivariate analyses were performed to identify spatial and temporal changes in the composition of fish assemblage using PRIMER 6.1.11 and PERMANOVA + 1.0.1 ecological software package. Fish assemblage structures were analyzed by Principal Coordinate analysis (PCO, i.e. metric multidimensional scaling) based on Bray-Curtis similarities matrix of log(x + 1)-transformed species data (Anderson and Willis, 2003). Centroids of the assemblage at each strata and year were displayed on the PCO ordination because of the large number of replicate samples (Anderson 2001). Differences between community structures at different strata and years were assessed by permutational multivariate analysis of variance (PERMANOVA; Anderson, 2001). A posteriori multiple pairwise comparisons were performed by permutational procedure (Anderson, 2001). Finally, Similarity Percentages (SIMPER; Clarke, 1993) were calculated to quantify the individual contribution of each species to any observed difference among strata according to the PERMANOVA and PCO results.

Because univariate and multivariate analysis on abundance and biomass gave the same results, only those for abundance were reported.

Results

Total abundances were statistically different among strata (Figure 4, Tables 1, 2). The mean value, indeed, was high inside St1 (17.3±3.3 ind/50 m/12 h), decreased inside St2 (10.6±1.8 ind/50 m/12 h), slightly declining till St6 (5.6±1.1 ind/50 m/12 h) and, finally, dropped again inside St7 (1.8±0.3 ind/50 m/12

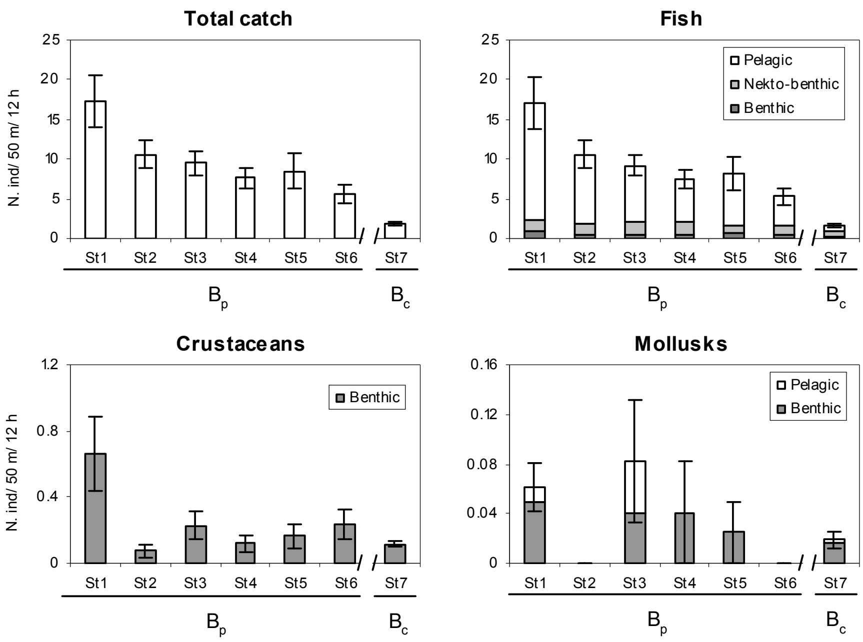

Figure 4. Mean catch rates (± SE) of all species combined (Total catch) and of fish, crustaceans and mollusks per set of 50 m and 12 h obtained inside each stratum (St1–St6) around the gas platform Barbara NW (B_p) and at the open-sea control site (B_c = St7).

Table 1. Mean abundance (ind/50 m/12 h) of species caught inside the strata (St1–St6) around the gas platform Barbara NW and at the open-sea control site (St7). P = pelagic; NB = nekto-benthic; B = benthic; 1st: 1st year after construction; 2nd: 2nd year after construction; 3rd: 3rd year after construction; No. of hauls inside each stratum = 11

										B_p											B_c	
Species		St1			St2			St3			St4			St5			St6			St7		
		Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3
Fish	Groups																					
Blennius ocellaris	B			0.02																		
Chelidonichthys lucerna		0.65	0.15	0.08	0.05	0.26	0.2	0.27	0.11	0.09	0.15		0.02	0.05	0.45	0.25	0.29	0.35		0.17	0.22	0.13
Citharus linguatula															0.12							
Conger conger			0.08												0.13							
Eutrigla gurnardus		0.03	0.02																	0.02	0.03	0.02
Lepidotrigla cavillone			0.02		0.05					0.06												
Lophius budegassa			0.02																		0.01	
Lophius piscatorius		0.01		0.01				0.05		0.05	0.1								0.09	0.01		
Microchirus variegatus		0.01		0.02	0.12					0.06								0.1				0.01
Mullus barbatus barbatus		0.01	0.08	0.04	0.05		0.07		0.05	0.05		0.1	0.02		0.05	0.1					0.01	0.01
Mullus surmuletus		0.01	0.05	0.01					0.13			0.06				0.11						
Phycis blennoides		0.02																				
Phycis phycis			0.02	0.02			0.05					0.13				0.1						
Polyprion americanus								0.05														
Psetta maxima		0.02	0.02																			
Scophthalmus rhombus																						0.01
Scorpaena notata			0.16	0.07	0.11		0.04	0.11	0.15	0.06		0.07			0.11	0.19						
Scorpaena porcus		0.24	0.43	0.11	0.05	0.38	0.07	0.11	0.06		0.24	0.58			0.29	0.04		0.12				
Solea solea		0.03	0.04	0.03		0.06	0.11							0.05	0.13	0.04			0.22	0.06	0.07	0.06
Squalus acanthias								0.14			0.12									0.11	0.02	0.07
Torpedo marmorata			0.02	0.03			0.05								0.23							
Trachinus draco										0.05											0.01	*
Trigla lyra																				0.03		
Total benthic fish		1.03	1.11	0.44	0.43	0.7	0.59	0.73	0.5	0.42	0.61	0.94	0.04	0.1	1.51	0.83	0.29	0.57	0.31	0.4	0.37	0.31
Diplodus vulgaris	NB			0.01																		
Merlangius merlangus		0.28																		0.04		0.01
Merluccius merluccius		0.64	0.09	0.07	0.19		0.27	0.39	0.21	0.4	0.27	0.58	0.48	0.14	0.25	0.51	0.44	0.56	0.19	0.45	0.47	0.58
Myliobatis aquila																						0.01
Pagellus acarne		0.02	0.05	0.04	0.05					0.19												
Pagellus bogaraveo		0.17	0.06	0.31	0.17	0.09	0.05						0.11	0.1								
Pagellus erythrinus		0.06	0.12	0.08	0.17			0.02				0.19		0.1								
Pagrus pagrus			0.02									0.08	0.11									
Serranus hepatus		0.02																				
Sparus aurata						0.05						0.05										
Trisopterus minutus		0.7	1.11	0.57	1.97	0.49	0.58	0.95	0.37	1.54	0.23	1.2	0.46	1.53	0.54		0.15	0.09				
Zeus faber			0.02																			
Engraulis encrasicolus		0.83	0.1	0.23		0.45	0.69	0.22	0.05	0.05			0.58	0.07			0.01	0.02				
Total nekto-benthic fish		1.89	1.47	1.08	2.55	0.63	0.9	1.36	0.58	2.13	0.5	2.1	1.16	1.87	0.79	0.51	0.59	0.65	0.19	0.49	0.47	0.6
Alosa fallax	P	0.04	0.02	0.01	0.06		0.07					0.13		0.12	0.12		0.11	0.04				
Boops boops		5.24	4.32	7.59	3.09	5.64	3.19	2.51	1.7	3.95	2.52	4.1	6.03	1.28	2.48		0.01	0.04				
Engraulis encrasicolus		0.83	0.1	0.23		0.45	0.69	0.22	0.05	0.05			0.58	0.07			0.01	0.02				

Table 1.(continued)

		B_p																		B_c		
Species		St1			St2			St3			St4			St5			St6			St7		
		Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3
Fish	Groups																					
Naucrates ductor	P																0.01					
Prionace glauca																						
Pteroplatytrygon violacea				0.01											0.04		0.01					
Sarda sarda													0.11				0.02					
Sardina pilchardus		0.24	0.28	0.04	0.7	0.9				0.22	0.16	0.94		0.44			0.29	0.02				
Sardinella aurita		0.02																				
Scomber japonicus		0.57	0.47	1.38	0.38	0.57	0.25	0.52	0.05	0.05	0.42	0.42	0.27	0.33	0.08		0.07					
Scomber scombrus		0.34	0.12	0.03	0.15	0.1	0.11			0.11			0.86	0.31			0.15	0.25				
Seriola dumerili			0.02																			
Spicara maena		1.35	0.72	0.49	0.99	0.57	0.52	0.04	0.74	0.29		0.27		0.59	0.09		0.04					
Spicara smaris			0.02																			
Trachurus mediterraneus		7.45	3.72	6.29	0.92	2.04	3.88	1.26	2.44	1.45	0.86	1.18	0.09	2.05				0.02				
Trachurus trachurus		2.06	0.06	0.02	0.12	0.06	0.87				0.11			0.24								
Total pelagic fish		18.14	9.85	16.09	6.41	10.33	9.58	4.55	4.98	6.12	4.07	7.04	7.94	5.43	2.81		0.72	0.39				
Total fish		21.06	12.43	17.61	9.39	11.66	11.07	6.64	6.06	8.67	5.18	10.08	9.14	7.4	5.11	1.34	1.6	1.61	0.5	0.89	0.84	0.91
Crustaceans																						
Homarus gammarus	B	0.02																				
Maja squinado			0.01	0.03		0.06		0.16							0.22		0.01	0.02				
Nephrops norvegicus		1.09	0.31	0.27		0.02	0.46		0.15	0.05	0.22	0.33	0.09	0.6			0.08	0.05				
Palinurus elephas			0.02																			
Parapenaeus longirostris				0.01																		
Total crustaceans		1.11	0.34	0.31		0.08	0.46	0.16	0.15	0.05	0.22	0.33	0.09	0.6	0.22		0.09	0.07				
Mollusks																						
Bolinus brandaris	B		0.02																			
Eledone cirrhosa			0.02																	0.02	0.01	
Eledone moschata													0.13									0.01
Illex coindetii			0.02			0.03					0.06	0.07								0.01		
Octopus vulgaris				0.02								0.08										
Sepia officinalis						0.01					0.11										0.01	
Total mollusks			0.06	0.02		0.04					0.17	0.15	0.13							0.03	0.02	0.01
Total		22.17	12.83	17.94	9.39	11.78	11.53	6.8	6.21	8.72	5.57	10.56	9.36	8	5.33	1.34	1.69	1.68	0.5	0.92	0.86	0.92

* = < 0.01

Table 2. Results of the 2-way ANOVA applied to the abundance of the total catches and of the main species categories caught inside the spatial strata St1-St7 in the 1st, 2nd and 3rd year after construction

Source	Sum of squares	df	Mean square	F-ratio	p-value	Tukey test
Total catches						
Year	0.88	2	0.44	3.04	0.0501	
Stratum	8.63	6	1.44	10.01	0.0000**	1>>6; 1- 4>>7; 5>7
Year by Stratum	1.80	12	0.15	1.04	0.4117	
Residual	31.05	216	0.14			
Total	42.36	236				
Pelagic fish						
Year	1.74	2	0.87	4.49	0.012*	Yr1; Yr2>> Yr3
Stratum	20.64	6	3.44	17.78	0.000**	1>> 2-7
Year by Stratum	0.58	12	0.05	0.25	0.995	
Residual	38.11	216	0.18			
Total	61.84	236				
Nekto-benthic fish						
Year	0.91	2	0.45	5.47	0.005**	Yr2>> Yr1
Stratum	8.67	6	1.45	17.40	0.000**	1>> 2-6; 7>> 2-6
Year by Stratum	0.54	12	0.04	0.54	0.888	
Residual	16.36	216	0.08			
Total	26.52	236				
Benthic fish						
Year	0.73	2	0.37	6.04	0.003**	Yr2>> Yr3
Stratum	4.87	6	0.81	13.43	0.000**	7>> 2-6
Year by Stratum	0.50	12	0.04	0.69	0.757	
Residual	11.91	216	0.06			
Total	17.93	236				

**: >> = highly significant. *: > = significant

h). Tukey test gave a highly significant difference comparing St1 with both St6 and St7. The catch rates recorded inside St7 resulted also statistically lower than those obtained inside St2-St5 (Table 2). This trend was confirmed by the Spearman's coefficient that showed a significant negative correlation between abundance and distance from the platform ($r = -0.447$, $p < 0.01$). No significant variations were evidenced among years (Table 2).

Fish and crustaceans represented respectively the first and second group in order of importance in the catches obtained at B_p and B_c (Figure 4, Table 1). Mollusks were very scarce everywhere, therefore they were not considered in the subsequent analysis.

Pelagic and nekto-benthic fish represented the first and second most important group respectively in each stratum and each year, with the only exception of St7 in Yr3, when nekto-benthic fish became dominant in catches (Table 1).

Pelagic fish inside St1-St6 mainly consisted of *Boops boops*, *Spicara maena*, and *Trachurus mediterraneus* (Table 1). The catch rates of this group significantly decreased with increasing distances from the platform till to reach the minimum value in St6 (Figure 4, Table 2). Moreover, they were significantly more abundant in Yr1 and Yr2 than Yr3 both at B_p and B_c (Tables 1, 2).

Nekto-benthic fish consisted almost exclusively of *Merluccius merluccius*, *Pagellus acarne* and *Trisopterus minutus* (Table 1). This group of species was significantly higher inside St1 and St7, due to the high catch rates of *T. minutus* and *M. merluccius*, respectively. Moreover, they were significantly more abundant in Yr2 than in Yr1 (Tables 1, 2).

Benthic fish mainly consisted of scorpaenids (*Scorpaena porcus* and *Scorpaena notata*) in the area close to the B_p, while in B_c the catches were dominated by *Solea solea* and *Chelidonichthys lucernus* (Table 1). This group showed catch rates significantly higher in St7 than St2-St6. Moreover, a significant decrease of benthic fish was observed from Yr2 to Yr3 (Table 2).

Finally, crustaceans included almost exclusively *Nephrops norvegicus*, which was constantly caught in most of strata (Table 1). A significant difference was observed between strata, due to the high abundance in St1 (Kruskall-Wallis test: $H = 26.257$, $P<0.001$; Figure 4), whilst the catch rates were similar over the years (Kruskall-Wallis test: $H = 4.670$, $P= 0.095$).

Fish assemblage changed at different strata and years as shown by the PCO ordination (Figure 5), which explains more than the 65% of total variation. The first axis drove the separation between the platform strata St1-St6 to the furthest one (St7), while the second axis showed a differentiation pattern of the former ones, grouping together the strata St2-St6. This was confirmed by PERMANOVA, which revealed significant difference for each factor (strata and year) separately, while the interaction was not significant. The pairwise tests better pointed out the patterns evidenced by the PCO plot (Table 3).

SIMPER analysis showed the main species contributing to strata differentiation (Table 4). The major dissimilarities in the pairwise comparisons were obtained between St7 and all the other strata placed in the surroundings of B_p mainly for the constant and greater occurrence of *M. merluccius* and *Scomber scombrus* at the former stratum and of *T.*

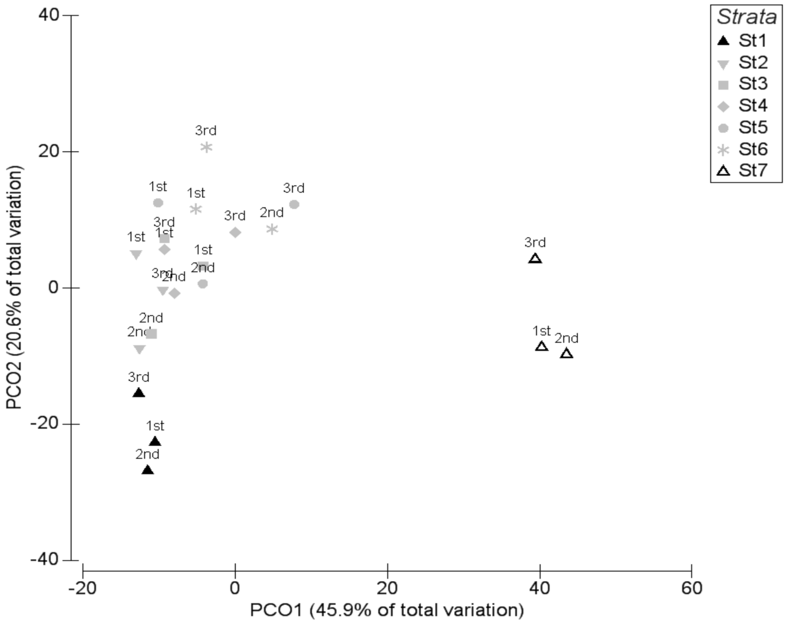

Figure 5. Principal coordinate analysis (PCO) of the centroids of 21 samples units (3 yrs x 7 strata) based on the abundance data. Each number indicates year after construction (1^{st}, 2^{nd}, 3^{rd}).

Table 3. Summary of results of PERMANOVA comparing assemblages of fishes over 3 years after construction (1^{st}, 2^{nd} and 3^{rd}) at 7 strata (St1-St7) around the gas platform Barbara NW, and post hoc pairwise comparisons of years at each site

PERMANOVA Source	df	MS	*F*	p	
Year	2	9625	3.5165	0.001**	
Strata	6	16612	6.0691	0.001**	
Year x Strata	12	2487.4	0.9088	0.743	
Residual	197	2737.1			
Post hoc comparison of years (*t*, p)			Post hoc comparison of strata (*t*, p)		
1^{st} vs. 2^{nd}	1.81	0.001**	St1 vs. St2	1.94	0.001**
1^{st} vs. 3^{rd}	1.94	0.001**	St1 vs. St3	2.06	0.001**
2^{nd} vs. 3^{rd}	1.96	0.001**	St1 vs. St4	2.26	0.001**
			St1 vs. St5	2.47	0.001**
			St1 vs. St6	2.87	0.001**
			St1 vs. St7	5.00	0.001**
			St2 vs. St3	1.02	0.411
			St2 vs. St4	0.91	0.591
			St2 vs. St5	1.34	0.059
			St2 vs. St6	1.33	0.088
			St2 vs. St7	4.42	0.001**
			St3 vs. St4	0.82	0.720
			St3 vs. St5	1.06	0.335
			St3 vs. St6	1.24	0.142
			St3 vs. St7	4.08	0.001**
			St4 vs. St5	1.02	0.431
			St4 vs. St6	0.96	0.458
			St4 vs. St7	3.76	0.001**
			St5 vs. St6	0.64	0.911
			St5 vs. St7	3.47	0.001**
			St6 vs. St7	3.51	0.001**

** = highly significant

mediterraneus and *B. boops* inside the other ones. St1 also resulted very dissimilar from St2-St6 for a greater abundance of some pelagic fish (*T. mediterraneus*, *B. boops*, *Scomber japonicus*).

Discussion

The greater suitability of passive fishing gears with respect to other sampling methods in studying

Table 4. Results of SIMPER analysis showing the percentage contribution of the three most important species to the dissimilarity of catches between the spatial strata St1, St2-St6 and St7

Strata	Dissimilarity	Species	Av. Abundance		Av. Diss.	Contribution (%)
1 *and* 2-6	55.70	*Trachurus mediterraneus*	4.50	1.21	8.76	15.73
		Boop boops	4.69	1.74	7.89	14.16
		Scomber japonicus	1.76	0.53	3.33	5.99
1 *and* 7	61.58	*Boop boops*	4.69	0.52	9.26	15.04
		Trachurus mediterraneus	4.50	0.36	9.15	14.86
		Merluccius merluccius	0.84	2.23	3.16	5.12
2-6 *and* 7	62.22	*Merluccius merluccius*	0.52	2.23	6.84	10.99
		Boop boops	1.74	0.52	4.70	7.56
		Scomber scombrus	0.24	1.26	4.16	6.68

abundance and spatial distribution of fish assemblage associated with gas and oil platforms has been widely demonstrated. In fact, active gears and vessel-based hydroacustic cannot be used close to the platform for safety reasons (Løkkeborg *et al.*, 2002; Soldal *et al.*, 2002). Stationary hydroacustic measurements from the rig can give truthful estimation of the fish assemblage along the surrounding water column, but they do not allow accurate identification when more species are found in mixed pools (Fabi and Sala, 2002; Sala *et al.*, 2007). Whereas, video and visual inspections of the submerged part of the platforms (Hastings *et al.*, 1976; Scarborough-Bull and Kendall, 1994; Love *et al.*, 1994, 1999; Rooker *et al.*, 1996; Rilov and Benayahu, 2000; Wilson *et al.*, 2003; Consoli *et al.*, 2007) cannot assure data collection on a regular basis in waters characterized by frequent high turbidity, as in the northern Adriatic Sea (Revelante and Gilmartin, 1976, 1992; Krasakopoulou and Souvermezoglou, 1999). Moreover, the presence of the observers can affect the fish behaviour so altering the population pattern.

In this context the trammel net was chosen because it is commonly known as being less selective than other passive gears. Moreover, the gear used was an experimental trammel net designed to further reduce the selectivity thanks to its technical features. However, the limited height of the net in relation to the water column and its selectivity may have under-sampled small pelagic fish (e.g. *Engraulis encrasicolus* and *Sardina pilchardus*) and large pelagic fish (e.g. *Thunnus thynnus* and *Seriola dumerili*) both around the platform and at the control site. In spite of this, in interpreting the results, a linear relationship between catch rate and fish abundance was assumed.

The results obtained further corroborate that the presence of oil and gas platforms in the marine environment induces qualitative and quantitative changes in the fish communities inhabiting the natural habitat (e.g. Hastings *et al.*, 1976; Gerlotto *et al.*, 1989; Scarborough-Bull and Kendall, 1994; Rooker *et al.*, 1996; Stanley and Wilson, 1997; Love *et al.*, 1999, 2000; Soldal *et al.*, 2002; Wilson *et al.*, 2003; Fabi *et al.*, 2004; Emery *et al.*, 2006).

B_p showed its influence on the fish assemblage within the first year after the end of installation, without significant variations in the subsequent years.

From the qualitative point of view, it was observed an enrichment of the natural fish assemblage due to the constant occurrence of reef-dwelling benthic fish, such as scorpenids, and of mobile, pelagic and nekto-benthic species, which show a partial affinity towards submerged hard substrates (e.g. *B. boops and T. capelanus*).

In quantitative terms, instead, the aggregation effect was especially consistent for partially-attracted pelagic fish, which tend to concentrate around substrates rising from the seabed, but may also be observed in open-sea areas away from rocky habitats. The catches of partially-attracted pelagic fish showed the same pattern of the total catch, characterized by a decreasing trend at increasing distance from the structure. The same effect was observed at Annalisa platform placed 35 km offshore and at 53-54 m depth in the northern Adriatic Sea (Fabi *et al.*, 2004). Moreover, it appears amplified in respect to that induced by bottom artificial reefs deployed along the Adriatic coast (Bombace *et al.*, 1994, 1999), probably due to the major extension of the rigs along the entire water column.

The analysis of the overall catch rates recorded inside the different strata, aimed to evaluate the area influenced by B_p, evidenced high differences between the region closest to the jacket and the more external ones (St6 and St7), while the other strata occupied an intermediate position. This was also confirmed by Spearman's coefficient, which highlighted a significant decrease of values with the increase of distance from B_p. Indeed, the nets set in the region closest to the platform (0-34 m) gave catch rates two times as higher as those obtained in the strata St2-St5 (35-170 m), three time as higher as those obtained in St6 (171-204 m), and nine times as higher than those recorded at B_c. Therefore, it can be stated that the radius of influence of the platform on the fish assemblage of the natural habitat extended up to St5, that is about 170 m from the jacket. These results are consistent with those reported by studies carried out in the North Sea with set nets and video inspections, which revealed a decline in fish densities with the increase of distance from the platform, and the highest fish concentration within 50-100 m from each installation (Løkkeborg *et al.*, 2002). On the other hand, the local area of influence defined in this study was much greater than those estimated in the Gulf of Mexico by Stanley and Wilson (2000) for adult populations and by Lindquist *et al.* (2005) for larval and juvenile fish assemblages, using respectively hydroacoustic methods and light traps. It was also greater than the zone of influence reported by Gerlotto *et al.* (1989) in Cameroon waters with hydroacoustic surveys. Keenan *et al.* (2007), studying the importance of the artificial light field around offshore platform for the associated fish community, indicated that the influence of non-natural illumination could extent more than 20 m away from the structure.

However, in this study the analysis of catch composition suggested a more complex interaction between the platform and the different species. In fact, high differences among strata were observed in the fish assemblage composition both at category and species level according with their behavior.

In general, reef-dwelling benthic fish, partially reef-dwelling pelagic and nekto-benthic species clearly dominated inside the stratum closest to the rig.

The most relevant species driving these patterns included some gregarious predators, such as the pelagic swimmers *T. mediterraneus* and *S. japonicus* and the bottom layer swimmer *T. minutus.* They were mainly represented by large individuals which likely concentrated around B_p not only for their tendency to aggregate near submerged hard substrates, but also for the greater food availability. In fact, besides lower risk of predation and shelter from currents, higher prey densities is one of the possible explanations suggested for the tendency of fish to congregate at artificial habitats (Bohnsack *et al.*, 1991, Page *et al.*, 2007).

Differently, the density of the scorpaenids, was greater in the stratum closest to the rig, that extends until 35 m from the structure. The greater occurrence of scorpaenids close to B_p may be strictly connected with either prey availability and the occurrence of shell mounds formed by mussels (*Mytilus galloprovincialis*) falling from the rig on to the seabed and thus creating a suitable habitat (Love *et al.*, 1999, 2007; Fabi *et al.*, 2004). Interestingly, a study carried out on age and growth of *S. porcus* and *S. notata* by otolith reading evidenced that, the scorpenids inhabiting offshore platforms were larger and older and showed higher growth rate in respect to natural reef populations (Scarcella *et al.*, 2011)

On the other hand, species like *S. solea* and *C. lucerna*, which are typical on the natural sand-muddy seabed, showed a homogeneous distribution, indicating that the presence of the platform does not affect the spatial pattern of these species in the natural habitat.

This study only focused on one platform; however, the results obtained may be extended to most of the rigs placed in the northern Adriatic Sea at depth higher than 50 m, as they have the same dimensions and the associated fish assemblages are similar to that found around B_p (Fabi *et al.*, 2004, 2006). The estimated area of influence of these platforms on the fish assemblage appears narrower than the 0.5 km radius protection zone established by the present regulation around each platform for safety reasons. As all types of fisheries are forbidden inside these protection zones, and taking into account the high number of platforms existing in the northern Adriatic sea, from an ecological perspective these structures could actually play a relevant role in the protection and enhancement of some fish stocks.

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