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ORIGINAL ARTICLE

Assessing the suitability of a remotely operated vehicle (ROV) to study the fish community associated with offshore gas platforms in the Ionian Sea: a comparative analysis with underwater visual censuses (UVCs)

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Abstract The effectiveness of a remotely operated vehicle (ROV) to describe the fish communities of three gas platforms located offshore Crotone (Italy, Ionian Sea) was investigated by comparing its observations with underwater visual censuses (UVCs). The study was carried out at two depth layers (0–6 and 12–18 m). Moreover, the ROV was used to survey three deeper depth layers up to 76 m. Overall, the ROV surveys failed to give a truthful representation of the fish communities underestimating the number of species and their abundances as compared to UVCs. The main discrepancies in data regarded crypto-benthic and nekto-benthic species, whereas the ROV proved to be a suitable method to census low-mobile and abundant planktivorous species. The differences between the fish assemblage described by the ROV, with respect to the one depicted by UVC, should be considered in the light of the technical limits of the recording camera, whose resolution and field of vision is clearly lower than the diver's eye. In addition, video images did not allow for the acquisition of a correct estimate of the distance between the individuals and the platform structures. This led, almost certainly, to an under- or over-estimation of fish abundance as regards to the censused volume. In spite of this, as a result of its capacity to reach depths inaccessible to scuba divers and then to add complementary information, the ROV could be used jointly with UVCs, in studies having as their objective the description of the fish communities associated with offshore platforms.

Keywords ROV · Gas platforms · UVC · Fish community · Mediterranean Sea · Census techniques

Introduction

The extraction of fossil fuels from offshore fields has rapidly expanded in the last decades, becoming the leading activity in the exploitation of marine mineral resources. As a main consequence, thousands of offshore platforms have proliferated over the world's oceans, and many more will likely be implemented in the future (Pulsipher and Daniel 2000). More recently, various Mediterranean countries have decided to grant new licenses to open oil exploitation in the Mediterranean Sea. For this reason, and in the light of the recent Deepwater Horizon oil spill in the Gulf of Mexico, understanding the role played by extractive platforms in marine ecosystems becomes an important worldwide issue.

Assessment of fish communities associated with artificial structures can be carried out by means of a number of sampling approaches. These include destructive methods, e.g. fishing gears (Fabi et al. 2004; Løkkeborg et al. 2002), and conservative methods which may be direct, e.g. visual census by SCUBA diving (Andaloro et al. 2011; Consoli et al. 2007; Rilov and Benayahu 2000; Wilhelmsson et al. 2006),

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or indirect with submersibles or remotely operated vehicles (ROVs) (Love et al. 2000; Okamoto 1989).

Given that each methodology offers advantages and disadvantages, comparative analyses should be carried out in order to determine the best approach for studying fish communities of particular habitats. In this direction, Okamoto (1989) has compared ROV visual censuses with other techniques in an aquarium tank while Spanier et al. (1994) stressed the need to conduct comparative studies of the relative utility of scuba versus ROV technologies for observing the behavior of marine animals. Moreover, several studies have also tested census techniques by means of underwater video recordings from a fixed point (Francour et al. 1999), video-operator (Bortone et al. 1991; Harvey et al. 2002; Tessier et al. 2005) or submersibles (Love et al. 2000). ROV, equipped with high definition video cameras, are increasingly used as a tool for underwater investigation, being capable to reach depths inaccessible to scuba divers and to record data even in adverse operative conditions. Besides being employed in several industrial sectors and as a fundamental support to underwater archaeological researches, ROVs have been utilized with success in the field of marine biology and ecology (Bergström et al. 1987; Hamner and Robison 1992). More in detail, visual censuses by means of ROVs have been conducted to describe several benthonic communities (Auster et al. 1991; Kaufmann et al. 1989; Norcross and Mueter 1999), to test their effectiveness in estimating fish species abundance (Adams et al. 1995; Bergström et al. 1987) and to observe the behavior of some species, also in relation to the presence of the ROV itself (Lorance and Trenkel 2006; Spanier et al. 1994).

In offshore platform environments, no studies have been conducted with the aim of evaluating the capability of an ROV to describe and represent the fish community also in relation to other visual census techniques.

In the present study, an in situ experiment was carried out in three different offshore gas platforms located in the Ionian Sea (central Mediterranean Sea), in order to test the appropriateness of the ROV in describing the fish community by comparing its observations with underwater visual censuses (UVCs). The first objective was qualitative, i.e., to evaluate how many species the ROV could determine in comparison with UVCs, while the second objective was quantitative, i.e., to compare the number of individuals by species recorded by the two methods on the same area units.

Moreover, the ROV was tested at depths where UVCs could not be carried out. Finally, the advantages and disadvantages of the ROV are discussed and summarized.

Materials and methods

Study site

The study was carried out randomly on three dates (October 2005, February 2006 and May 2006) in three offshore gas platforms (Luna A, Luna B and Hera Lacinia) located in the southern Ionian Sea (central Mediterranean Sea), respectively, 5.3, 6.2 and 2.6 km offshore (Fig. 1). Two of them (Luna A and Luna B) are 8-leg platforms while the third one (H. Lacinia) is a 4-leg platform. All these platforms lie on a sandy seabed in 75, 90 and 30 m of water, respectively, and are fixed to the sea floor by concrete or steel legs, which are connected by an assemblage of cross beams.

The platforms were colonized by several invertebrates providing shelter and food to cryptic and nekto-benthic fish species. The most represented sessile organisms were *Mytilus galloprovincialis*, Balanidae indet., *Ostrea* sp., and *Arbacia lixula* (personal observation).

Sampling methods

Fish species and their abundance were recorded by UVC and a ROV (“Hyball” of Hydrovision Ltd) equipped with a high resolution video camera, compass, rate gyro and two fixed 100 W quartz halogen lights aimed forward and two 75 W lights mounted on the camera chassis.

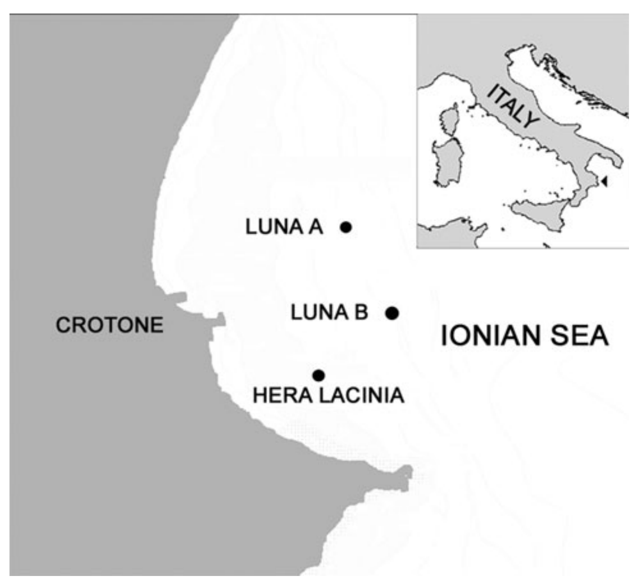

Fig. 1 Study area located in the Ionian Sea off Crotone (Calabria, Italy)

At each sampling month, ROV and UVC surveys were performed randomly on three out of 8 pillars at Luna A and B platforms (8-leg) and out of 4 at Hera Lacinia platform (4-leg). Two depth ranges were chosen: 0–6 and 12–18 m thus dividing pillars into 6 m-high units.

During both UVC and ROV surveys, the underwater "Mobile Point Count" technique was adopted in order to study fish assemblages. This technique, specifically designed for offshore platforms by Rilov and Benayahu (2000) and applied, for the first time, by Consoli et al. (2007) and Andaloro et al. (2011) in the Mediterranean Sea, was chosen because it is particularly suitable for the analysis of species strictly associated with the pillars and also for detecting benthic and cryptic species (Consoli et al. 2007; Andaloro et al. 2011).

The diver (in the case of UVCs) or the ROV, turning around each unit and looking toward the pillar, censused all fishes occurring up to 3 m from it. In particular, they began, firstly, to record the more conspicuous and easily identifiable fishes from a maximum distance of 3 m from the pillar (so that to have an entire view of the census unit) and straight after, approached the pillar and counted the benthic and crypto-benthic species. Since the pillars had a radius of 1 m, the total censused volume corresponded to a cylinder of 7 m of diameter and 6 m high, from which the volume of the pillar (1 m of diameter, 6 m high) was subtracted. The resulting volume was 225.7 m^3.

A total of 108 observation units were carried out in study period. Moreover, the ROV was used to survey three deeper depth layers: 22–28 m at H. Lacinia, Luna A and Luna B, 50–56 m at Luna A and Luna B and 70–76 m at Luna B. ROV and UVC trials were carried out in different moments of the same days by exploring the same horizontal units within a maximum time of 5 min.

Fish abundance was estimated by counting single specimens to a maximum of 10 individuals, and using abundance classes (11–30, 31–50, 51–100, 101–200, 201–500, >500) for schools. This recording system leads to a similar degree of error over a wide range of abundances, ensuring homogeneity of variance after log-transformation of the data (Frontier 1986; Guidetti et al. 2003). ROV trials were recorded on video tapes and four different researchers contributed to both underwater and video data recordings thus reducing any systematic error between methods.

Fish taxa were pooled into ecological categories on the basis of their spatial organization and behavior in relation to the platform: PLA, planktivorous fishes (e.g., *Chromis chromis*, *Anthias anthias* and *Boops boops*) which form schools and are strictly associated to the artificial structures mostly for shelter and reproduction issues; NEC-BEN, nekto-benthic species (mostly Sparids) feeding on sessile organisms; CRY, crypto-benthic fish (e.g., Blennids and Scorpaenids) which are visually and/or behaviorally cryptic and keep them in close association with the substratum (La Mesa et al. 2006); PEL, pelagic fish (e.g. Scombrids and Carangids) attracted by the artificial structures.

Data analyses

The fish community was described by means of fish abundance (*N*), species richness (*S*) and frequency of occurrence (%O) data.

A three-way *permutational multivariate analysis* of variance (PERMANOVA) (PERMANOVA; Anderson 2001; McArdle and Anderson 2001) was used to test for differences between fish assemblages with regard to the factors method (2 levels, fixed), platform (3 levels, fixed) and period (3 levels, random) at each depth layer. The analysis was based on Gower distances calculated on $\log(x + 1)$ transformed data, and each term of the analysis was tested using 4,999 random permutations of appropriate units (Anderson and ter Braa 2003). This permutation method is generally thought to be best suited because it provides the best statistical power and the most accurate Type I error (Anderson and Legendre 1999).

Moreover, to test whether ROV and UVC recorded different average abundances of each of the four ecological categories at each depth layer, a three-way *permutational univariate analysis* of variance (permutational ANOVA) was performed considering the same factors used in the multivariate analyses. This univariate analysis was also used to detect significant differences between the mean values of species richness recorded by both methods. Unlike multivariate analyses described above, we used a Euclidean distance in this univariate model. Data were transformed at the $\log(x + 1)$ in order to reduce the weighting of abundant categories and increase that of the rarer ones.

Both univariate and multivariate analyses were employed using the software package PRIMER 6 with PERMANOVA +add-on (Anderson et al. 2008).

Whereas ANOVA/MANOVA assumes normal distributions, PERMANOVA works with any distance measure that is appropriate to the data and uses permutations to make it distribution free. Thus, the same *F*-statistics were calculated, but *p* values were obtained by permutation.

A two-dimensional non-metric multidimensional scaling (nMDS) plot was generated on the basis of Gower similarity matrix of abundance data averaged per platform.

Moreover, the similarity percentage procedure SIMPER (Clarke and Warwick 1994) was used to identify the fish species mostly contributing to the differences between the methods. In this case, crypto-benthic fish were pooled into a single group.

Finally, a rough cost estimate for both methods was provided considering the rent of the boat, ROV and diving equipment, the manpower needed for the surveys, video analysis and data elaboration.

Results

Overall, the ROV censuses allowed for the identification of 17 fish taxa belonging to 12 families (Table 1). However, 4 of these taxa were observed only at the depth layers where the UVCs were not performed. *Spicara* spp. and *Trachurus* spp. were not identified to the species level due to the difficulties in determining the above. The families of Sparidae were the most represented with 5 species. The majority of the taxa belonged to the ecological category of nekto-benthic fish followed by planktivorous fish. Crypto-benthic fish were the least represented category with only two species.

The UVC recorded 24 fish taxa in 9 families, with Blennidae and Sparidae being the most diverse with 7 species each. The majority of taxa belonged to the nekto-benthic (8 species) and crypto-benthic (9 species) fish categories.

A first assessment of the methods was done by comparing the average abundance and frequency of occurrence of fish taxa at each depth layer (Table 1). At 0–6 m, the ROV and UVC detected 9 and 16 fish taxa, respectively. Both methods were able to census all the planktivorous species, whereas the differences in crypto-benthic species richness were notable, with 6 fish taxa censused by UVC against 1 recorded by the ROV (*Parablennius gattoruggine*). The species observed most frequently by both methods was the damselfish *Chromis chromis* (%O = 81.5 and 74.1, respectively by UVC and ROV), characterized, moreover, by the highest abundance values.

At the following depth layer (12–18 m), the ROV censused 9 taxa while the UVC 19. Also at this depth, the difference in crypto-benthic fish taxa identification was clear (6 taxa by UVC and none by ROV). The damselfish was the most frequent species observed by the ROV (%O = 55.6), whereas, by means of UVC, high values of frequency of occurrence were observed for *Thalassoma pavo*, *Scorpaena maderensis* and *C. chromis* (Table 1).

At the deeper layers (22–28, 50–56 and 70–76 m), the ROV recorded 13, 9 and 4 fish taxa, respectively, and new species (such as *Epinephelus aeneus*, *Pomatomus saltator*, *Sarda sarda*, and *Phycis phycis*) were recorded. Both in terms of abundance and occurrence, *A. anthias* was the dominant species at these depths showing extremely high values of abundance at 50–56 and 70–76 m (378.6 and 443.3, respectively; Table 1). The dense schools formed by this species screened, in many cases, the pillar's surface reducing the capability of the ROV to census the crypto-benthic fish.

The *permutational multivariate analysis* (PERMANOVA) showed highly significant differences between the assemblages censused by the two methods at both depth layers (0–6 m: $F = 21.31$; $p < 0.01$—12–18 m: $F = 18.97$; $p < 0.01$), and these differences were consistent for each platform and sampling period (interaction terms "Method × Platform" and "Method × Period", not significant).

The nMDS plots (Fig. 2), confirming PERMANOVA results, showed a clear-cut separation between the fish assemblages censused by the ROV and UVC at both depth layers.

SIMPER identified the Ecological groups contributing the most to the dissimilarities between the methods at each depth layer (Table 2). Crypto-benthic species contributed largely to differentiating the fish communities described by the two methods together with the most abundant planktivorous species (*C. chromis, B. boops, O. melanura* at 0–6 m and *A. anthias, C. chromis, B. boops* at 12–18 m).

With regard to the census of the different ecological categories, ROV and UVC showed a different suitability (Fig. 3). At both depth layers, UVC methods censused a higher number of *planktivorous* fishes than ROV; in spite of this, permutational univariate analysis showed significant differences between the two methods (Table 3) only at 12–18 m ($p < 0.05$). A significant effect for the period was detected ($p < 0.05$), which indicates that *planktivorous* abundances differed according to the factor period.

Abundance of *pelagic* fish resulted slightly higher when assessed with ROV rather than UVC only at 12–18 m ($p < 0.01$), but, in any case, univariate analyses were not able to find significant differences according to the factor method.

The number of *crypto-benthic* and *nekto-benthic* individuals censused by UVC was significantly higher at both depth layers ($p < 0.01$), although, for the first group, these differences varied according to the factor platform ($p < 0.01$) at 12–18 m depth. Finally, The UVC observed a significantly higher number of species at all platforms and at both depth layers ($p < 0.01$) (Fig. 4; Table 3). On the other hand, the interaction terms "Method × Platform" and "Methods × Period" were significant at 0–6 m, indicating that these differences varied across platforms and sampling periods.

Table 1 Mean abundance and percentage occurrence of fish taxa recorded by the ROV and UVCs at the five depth layers

Taxa	0–6 (m)						12–18 (m)						22–28 (m)			50–56 (m)			70–76 (m)		
	ROV			UVC			ROV			UVC			ROV			ROV			ROV		
	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O
PLA																					
Anthias anthias	2.8	2.8	3.7	1.6	1.5	11.1	38.2	11.3	48.1	86.3	32.7	66.7	106.1	31.0	66.7	378.6	49.8	100.0	443.3	87.6	100.0
Boops boops	24.4	10.0	22.2	18.8	12.9	33.3	25.2	9.2	25.9	34.4	15.2	37.0	12.7	6.6	18.5						
Chromis chromis	29.5	9.2	74.1	44.4	11.4	81.5	29.8	8.7	55.6	36.6	9.5	81.5	24.8	7.7	55.6	42.5	24.5	27.8			
Oblada melanura	15.0	8.0	22.2	22.3	8.4	40.7	9.3	5.8	22.2	10.3	6.4	22.2	5.0	3.6	11.1						
Spicara spp.	2.8	2.8	2.8	8.7	6.1	14.8	7.0	5.7	7.4	12.3	6.6	25.9	1.5	1.5	3.7						
Trachurus spp.										0.0	0.0	3.7									
PEL																					
Pomatomus saltator													3.0	2.1	7.4						
Sarda sarda																4.2	4.2	5.6			
Seriola dumerilii	1.5	1.5	7.4	1.5	1.5	7.4	3.0	1.2	29.6	0.4	0.2	14.8	4.2	1.5	33.3	4.4	2.6	16.7	7.6	4.6	33.3
NEC-BEN																					
Diplodus annularis				0.0	0.0	3.7															
Diplodus puntazzo										0.0	0.0	3.7									
Diplodus sargus							0.1	0.1	3.7	0.5	0.3	14.8	0.3	0.3	7.4						
Diplodus vulgaris	0.8	0.7	11.1	1.9	1.1	11.1	1.1	0.8	14.8	2.5	1.5	37.0	1.1	0.7	33.3	3.3	1.6	33.3	2.2	2.2	11.1
Epinephelus aeneus													0.0	0.0	3.7						
Phycis phycis																0.1	0.1	5.6	0.2	0.2	11.1
Serranus cabrilla				0.0	0.0	3.7							0.0	0.0	3.7						
Serranus scriba										0.0	0.0	3.7									
Spondyliosoma chantarus										3.4	2.4	14.8	0.0	0.0	3.7	0.5	0.4	11.1			
Thalassoma pavo	0.7	0.2	44.4	8.6	2.0	81.5	0.6	0.3	29.6	10.9	2.8	85.2	0.2	0.1	7.4	0.1	0.1	5.6			
CRY																					
Coryphoblennius galerita				0.1	0.1	7.4															
Lipophrys trigloides				0.3	0.1	22.2															
Murena helena										0.0	0.0	3.7				0.2	0.1	22.2			
Parablennius gattoruggine	0.1	0.1	7.4	0.6	0.2	48.1				0.1	0.1	7.4									
Parablennius incognitus				0.1	0.1	7.4				0.1	0.1	11.1									
Parablennius pilicornis				0.1	0.1	7.4															

Table 1 continued

Taxa	0–6 (m) ROV			0–6 (m) UVC			12–18 (m) ROV			12–18 (m) UVC			22–28 (m) ROV			50–56 (m) ROV			70–76 (m) ROV		
	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O	Av. Ab.	SE	%O
Parablennius rouxi										0.7	0.2	44.4									
Parablennius zvonimiri										0.4	0.2	25.9									
Scorpaena maderensis				6.4	0.9	96.3				4.2	0.7	85.2									

PLA Planktivorous fish, *PEL* Pelagic fish, *NEC -BEN* Nekto-benthic fish, *CRY* Crypto-benthic fish, *Av. Ab.* average abundance, *SE* standard error, *%O* percentage occurrence

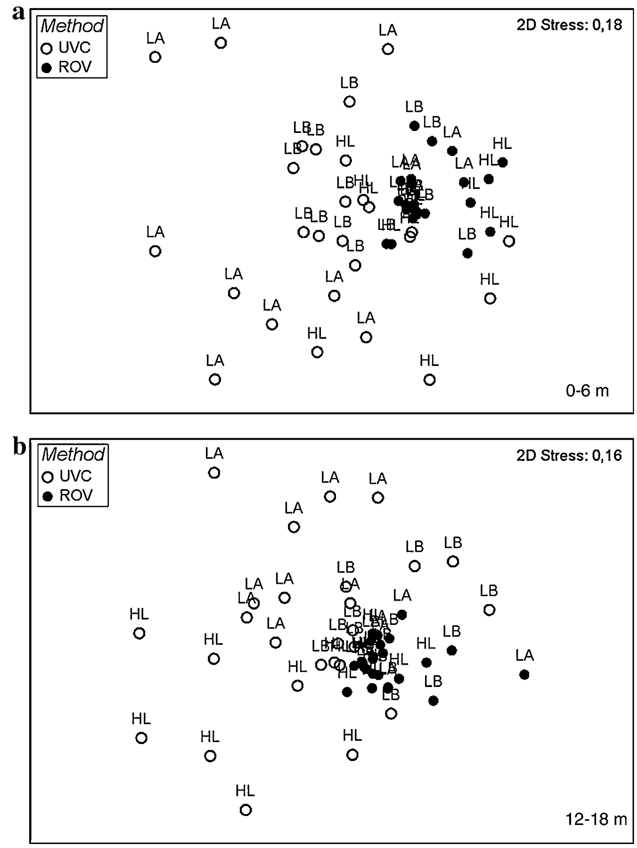

Fig. 2 Two-dimensional non-metric multidimensional scaling (nMDS) ordinations of abundance data at 0–6 m (**a**) and 12–18 m (**b**). *LA* Luna A, *LB* Luna B, *HL* Hera Lacinia

The study by means of ROV and UVCs required four diver-researchers and a ROV driver and was carried out in 18 days. Nevertheless, considering that ROV and UVC trials were performed in different moments of the same days, this 18-day period can be divided in two (9 days for each methods; Table 4). The four researchers needed other 3 days to analyze the ROV videos. In order to save money, both ROV and diving equipments were rent. Overall, the total costs needed to achieve both survey were almost the same (13.080 and 13.500€, respectively). However, the ROV technique required other 3 days for the video analyses thus increasing a little bit the total coast (14,700€).

Discussion

The present study allowed for the identification of the strengths and weaknesses of the ROV as a tool for studying the fish community associated with offshore gas platforms.

The ROV did not allow for a complete description of the fish assemblage associated with the platforms. This was confirmed by the multivariate analysis which highlighted a

Table 2 SIMPER of the fish taxa contributing most (%) to dissimilarity between the methods ROV and UVC at 0–6 and 12–18 (m)

Fish taxa/ecological group	0–6 m (average dissimilarity = 75.31)		
	UVC Av. Ab.	ROV Av. Ab.	%
Chromis chromis	5.02	3.88	25.07
Boops boops	1.97	2.24	16.81
Oblada melanura	2.61	1.54	16.61
Cryptobenthic	2.63	0.07	16.55
Thalassoma pavo	2.36	0.54	11.10
Spicara spp.	0.92	0.32	4.18
Fish taxa/ecological group	12–18 m (average dissimilarity = 76.98)		
	UVC Av. Ab.	ROV Av. Ab.	%
Anthias anthias	6.20	3.94	22.60
Chromis chromis	4.74	3.55	17.25
Boops boops	3.06	2.50	15.04
Cryptobenthic	2.17	0.00	10.89
Thalassoma pavo	2.67	0.37	9.52
Oblada melanura	1.20	1.16	6.68
Spicara spp.	1.47	0.69	5.39
Diplodus vulgaris	0.78	0.35	4.32

Species belonging to the crypto-benthic group were pooled

Av. Ab. average abundance

higher diversity of the same fish assemblage when investigated by means of UVCs. Similar conclusions were drawn by Francour et al. (1999) in natural habitats by comparing UVC with video recordings from a fixed point.

In terms of species richness, the major differences concerned the group of crypto-benthic species, with the ROV capable of detecting only one large-sized species (*Parablennius gattoruggine*), in comparison with 9 species recorded by the UVCs. Most of the difficulties encountered by the ROV in identifying crypto-benthic species (the majority of which belonged to the family Blennidae) is related to their small size and to their tendency to hide in holes or crevices. This cryptic behavior, which represents a well-known constraint also for the UVC methodology (Smith 1988; Willis 2001), make these fish not visible to the camera. Similarly, the ROV was less accurate than UVCs in detecting the species belonging to the nekto-benthic group, in accordance with other studies (Bortone et al. 2000; Tessier et al. 2005). The latter authors explain these results by the fact that the video recording device have a much more limited field of view than the diver's eye, and this reduces the probability of detecting species present in low abundances. In this study, this result seemed more related to the better capacity exhibited by the divers to move around the pillars and thus to census the individuals hidden by the platform structures.

In general, future researches having as their objective the study of the crypto-benthic and nekto-benthic species should avoid using ROV devices, if UVC methodology can be applied. The ROV seemed to be successful in censusing some pelagic species as confirmed by their relatively high occurrences and abundances. Anyhow, the repetitive passage of the same individuals in front of the camera, which demonstrated an attractive behavior toward it, could have biased the results obtained.

In the case of high mobile species such as nekto-benthic and pelagic fish, an increase in the observation time could strongly enhance the probability of the ROV to detect their individuals, as also suggested by many authors for UVC (Bortone et al. 2000; Harmelin-Vivien et al. 1985; Stoner et al. 2008).

However, the chance of counting the same individuals several times should be considered, possibly producing an overestimation of fish abundance. Finally, the ROV device was found to be an appropriate method with which to census planktivorous fish, both from a qualitative and quantitative point of view, mostly in relation to their high abundance and low mobility. The same result was obtained by Tessier et al. (2005) who consider it functional to employ video recording for the estimation of permanent species present in high densities, especially those which tend to school. It should be observed that, although the abundances of the latter group were comparable in value, for the most permanent species (*C. chromis* at 0–6 m and *A. anthias* at 12–18 m), the UVCs revealed significantly higher abundances than the ROV

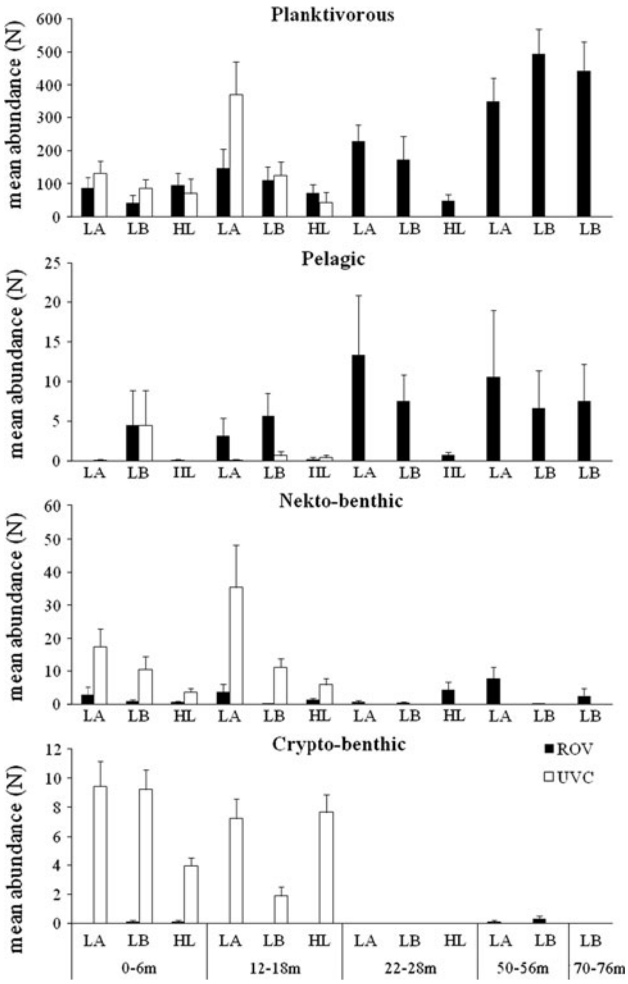

Fig. 3 Mean abundance (*N*) of the four ecological groups at each platform and depth layer. *LA* Luna A, *LB* Luna B, *HL* Hera Lacinia. *Vertical bars* represent the standard error from mean

did, in accordance with other studies (Francour et al. 1999; Tessier et al. 2005).

Unlike UVC performed by divers, the ROV can be implemented without expertise in the identification of marine life (Hill and Wilkinson 2004). The video method also requires much less time in the field than UVC methodology and is therefore useful for sampling a large area or a number of sites. It requires, however, much more laboratory time spent in image analysis (Lam et al. 2006). The most relevant potentiality of the ROV, in agreement with Bortone (1992) and Lam et al. (2006), reside in its capability to reach depths not accessible to scuba divers and to operate in unfavorable diving conditions such as limited visibility, adverse weather, and unpredictable, rapid water currents dangerous for divers. In this study, these features improved the dataset adding seven new species to the platforms' fish community. What is more, there is no time limit for how long time the vehicle can stay submerged and video recordings represent a permanent record which can be re-examined as many times as needed. Francour et al. (1999) highlight the minor invasiveness of the ROV in comparison with the presence of scuba divers, the possibility of recording at dawn and dusk by means of highly sensitive cameras and, at last, the ability to gather data for a longer time than a single dive.

The differences between the fish assemblage described by the ROV, with respect to the one depicted by UVC, should be considered in the light of the technical limits of the recording camera, whose resolution and field of vision is clearly lower than the diver's eye. In addition, video images did not allow for the acquisition of a correct estimate of the distance between the individuals and the platform structures. This led, almost certainly, to an under- or over-estimation of fish abundance as regards to the censused volume. With regard to the ROV, the device employed, mostly in relation to the presence of the tether, showed some difficulties of movement within the platforms' environment, limiting the observation of their inner sectors. Some of these difficulties are probably issues which even an excellent technology cannot overcome (Norcross and Mueter 1999); however, up to a certain extent, some technical features of the ROV might improve its suitability. On the basis of our experience, we learned that the power of the thrusters, the lighting apparatus and the video camera resolution are chiefly important for the use of ROV in the fish census around vertical pillars.

Conclusions

Given that the specific methods employed often define the limitations of the data (Bortone et al. 2000), the results of this study suggest the use of ROVs specifically to estimate abundance of permanent and low-mobile species and to explore depths where UVCs cannot be performed. Therefore, limits and capabilities of ROVs should be taken into account in order to formulate appropriate experimental designs and to maximize the collectable information. The methods of studying biodiversity presented in this study appear to be highly reproducible and suitable for monitoring fish diversity in such complex and artificial habitats like gas platforms. As assessing biodiversity in these highly complex contexts is a challenge for the near future, a reliable method would be able to influence the international research in this field. Indeed, these techniques are highly specific, cost-effective, and sufficiently affordable for all research teams to get both accurate and highly repeatable data. In conclusion, the above-mentioned considerations could allow for the lowering of the costs of future surveys aimed at studying fish assemblages associated with extractive platforms.

Table 3 Summaries of three-way crossed *permutational univariate analyses* testing for effects of method, platform and season on the abundance of each ecological category and on species richness, at each of the two investigated depth layers (0–6 and 12–18 m)

	df	Planktivorous	Pelagic	Nekto-benthic	Crypto-benthic	Species richness
0–6 m						
Method	1	0.176 n.s.	1 n.s.	0.001**	0.001**	0.001**
Platform	2	0.204 n.s.	0.324 n.s.	0.069 n.s.	0.055 n.s.	0.101 n.s.
Period	2	0.047*	0.029*	0.001**	0.021*	0.031*
Meth × Plat	2	0.132 n.s.	0.83 n.s.	0.597 n.s.	0.007**	0.004**
Meth × Period	2	0.071 n.s.	1 n.s.	0.056 n.s.	0.841 n.s.	0.023*
Plat × Period	4	0.454 n.s.	0.353 n.s.	0.539 n.s.	0.849 n.s.	0.031*
Meth × Plat × Period	4	0.31 n.s.	0.938 n.s.	0.16 n.s.	0.317 n.s.	0.042*
Res	36					
Total	53					
12–18 m						
Method	1	0.008**	0.111 n.s.	0.001**	0.001**	0.001**
Platform	2	0.001**	0.148 n.s.	0.022 n.s.	0.001**	0.616 n.s.
Period	2	0.001**	0.923 n.s.	0.002**	0.663 n.s.	0.121 n.s.
Meth × Plat	2	0.005**	0.399 n.s.	0.05 n.s.	0.001**	0.686 n.s.
Meth × Period	2	0.001**	0.968 n.s.	0.017 n.s.	0.664 n.s.	0.087 n.s.
Plat × Period	4	0.468 n.s.	0.548 n.s.	0.108 n.s.	0.092 n.s.	0.409 n.s.
Meth × Plat × Period	4	0.318 n.s.	0.815 n.s.	0.588 n.s.	0.099 n.s.	0.490 n.s.
Res	36					
Total	53					

Significance levels: *$p < 0.05$; **$p < 0.01$; *n.s.* not significant, *Meth* method, *plat* platform

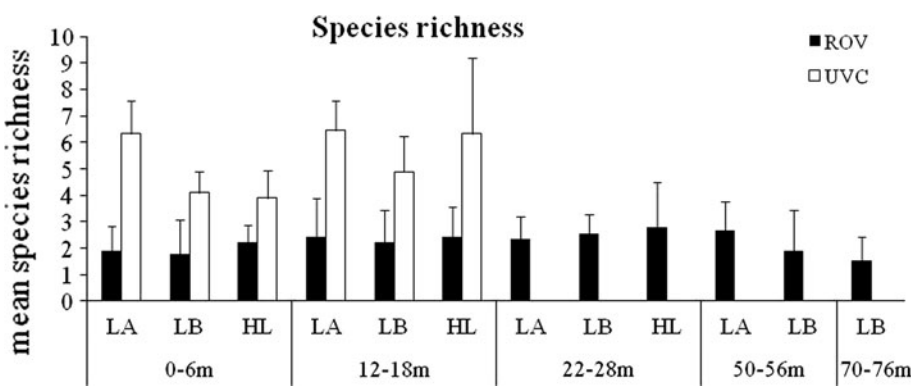

Fig. 4 Mean number of species (species richness) at each platform and depth layer. *LA* Luna A, *LB* Luna B, *HL* Hera Lacinia. *Vertical bars* represent the standard error from mean

Table 4 Cost estimates for ROV and UVC surveys

	UVC survey	ROV	
		Survey	Video analysis
Number of days needed	9	9	3
Number of operators	4	1	4
Daily manpower cost (1 operator)	100.00€	Included in the equip. rent	100.00€
Daily equipment rent	120.00€	500.00€	
Daily boat rent	1,000.00€	1,000.00€	
Total coasts	13,080.00€	13,500.00€	1,200.00€
Average daily coast	1,453.33€	1,500.00€	400.00€

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