The demersal fish assemblages of the infra and circalittoral coastal rocky bottoms of the Aeolian Archipelago (Central Mediterranean Sea) studied by Remotely Operated Vehicle (ROV)

CONSALVO IVAN
Italian National Institute for Environmental Protection and Research, Rome, Italy

La MESA GABRIELE
Italian National Institute for Environmental Protection and Research, Rome, Italy

CANESE SIMONEPIETRO
Stazione Zoologica Anton Dohrn, 80121, Naples, Italy

GIUSTI MICHELA
Italian National Institute for Environmental Protection and Research, Rome, Italy

SALVATI EVA
Italian National Institute for Environmental Protection and Research, Rome, Italy

LOIA MARCO
Italian National Institute for Environmental Protection and Research, Rome, Italy

TUNESI LEONARDO
Italian National Institute for Environmental Protection and Research, Rome, Italy

https://doi.org/10.12681/mms.23297

To cite this article:

CONSALVO, I., La MESA, G., CANESE, S., GIUSTI, M., SALVATI, E., LOIA, M., & TUNESI, L. (2021). The demersal fish assemblages of the infra and circalittoral coastal rocky bottoms of the Aeolian Archipelago (Central Mediterranean Sea) studied by Remotely Operated Vehicle (ROV). Mediterranean Marine Science, 22(1), 27-39. doi:https://doi.org/10.12681/mms.23297
The demersal fish assemblages of the infra and circalittoral coastal rocky bottoms of the Aeolian Archipelago (Central Mediterranean Sea) studied by Remotely Operated Vehicle (ROV)

Ivan CONSALVO1, Gabriele LA MESA1, Simonepietro CANESE2, Michela GIUSTI1, Eva SALVATI1
Marco LOIA1 and Leonardo TUNESI1

1 Italian National Institute for Environmental Protection and Research Via Vitaliano Brancati 60, 00144 Rome, Italy
2 Stazione Zoologica Anton Dohrn, 80121, Naples, Italy

Corresponding author: gabriele.lamesa@ispambiente.it

Contributing Editor: Stelios KATSANEVAKIS

Received: 27 May 2020; Accepted: 27 November 2020; Published online: 8 January 2021

Abstract

Demersal fish assemblages on the rocky bottoms of the Aeolian Archipelago were investigated using a Remotely Operated Vehicle (ROV) within the framework of research activities aimed at drawing up the zoning proposal for a new Italian marine protected area. Visual assessments were conducted around the seven main islands by means of 36 ROV transects. The video material was divided into 3 parts belonging to 3 Archipelago sectors (Western, Central and Eastern) and into 3 depth ranges (20-50, 51-120, 121-190). Thirty taxa of teleosts (29 species and 1 genus) belonging to 16 families were recorded. The assemblages were numerically dominated by some schooling fishes, such as Anthias anthias, Callanthias ruber and Chromis chromis that exhibited a depth-related partitioning of space, and three non-gregarious species, namely Serranus cabrilla, Coris julis and Lappanella fasciata. In terms of species composition, the assemblages observed in the sectors of the Archipelago largely overlapped. No significant sector-related differences were detected in fish species richness, diversity and total density. Species composition and the investigated assemblage parameters were significantly affected by depth. The pattern of variation in species richness among depth ranges differed from one archipelago sector to another. No significant interaction between the depth range and sector factors was observed in terms of species diversity and total density. Diversity values at 20-50 and 121-190 m depth were similar and significantly higher than at 51-120 m depth. Fish total density showed a clear downward trend with increasing depth, although significant differences were detected between the 20-50 and 51-120 m depth layers and the deepest one. Overall, the demersal fish assemblage of the Aeolian Archipelago was poorly diversified and depleted, most likely due to overfishing. This information highlights the importance of adopting specific measures aimed at the recovery of overexploited resources and the restoration of entire marine ecosystems.

Keywords: Demersal fish assemblages; MPA; Mediterranean Sea; Remotely Operated Vehicle.

Introduction

A variety of remotely operated video-based tools and methodologies have been developed over the years to study benthic environments (Bicknell et al., 2016), based on the use of fixed cameras (Cappo et al., 2007; Langlois et al., 2018), or mobile systems such as towed cameras or remotely operated vehicles (ROVs) (Sward et al., 2019).

One of the main advantages of ROVs and other camera-based methodologies is linked to their non-invasive nature that enables exploration of fragile marine ecosystems and those found in marine protected areas (MPAs) (Harter et al., 2009; Karpov et al., 2012; Auster et al., 2016). In addition, ROVs can operate across a broad bathymetric range, well below the safety limit imposed on visual observations based on SCUBA diving (Busby et al., 2005; Boavida et al., 2015). Nevertheless, some limitations are inherently associated with the use of ROVs to investigate fish, mainly related to the different species-specific reaction to the noise and light associated with the use of these vehicles (Ryer et al., 2009; Sward et al., 2019). Attraction or escape from ROVs could lead to a bias in species observation and incorrect estimates of fish population abundance (Trenkel et al., 2004; Lorance & Trenkel, 2006; Stoner et al., 2008).

Results from several investigations performed in different natural and artificial mesophotic habitats suggest that substrate type and depth might considerably influence fish assemblage structure (Bryan et al., 2013; Pacunski et al., 2013; Ajemian et al., 2015; Laidig & Yoklavich, 2016; Smith & Lindholm, 2016). Fish assemblages associated with structurally complex rocky habitat with a high relief morphology have frequently been found to be more diverse than those recorded on low relief rocky
beds or sandy-muddy bottoms (Bryan et al., 2013; Laidig & Yoklavich, 2016; Ross et al., 2015). According to the review of Sward et al. (2019), very few investigations involving the collection of data on demersal fishes using ROVs have been carried out in the Mediterranean mesophotic realm. Some studies include information on the whole fish assemblage, either in natural environments, such as banks (Consoli et al., 2016), or in artificial habitats, such as offshore gas platforms (Andaloro et al., 2013) and shipwrecks (Consoli et al., 2015).

As part of a multidisciplinary environmental research programme, ROV surveys were carried out in the waters of the Aeolian Archipelago (ISPRA, 2019). As in other preliminary studies for the establishment of new MPAs, demersal fish fauna was one of the main faunal component investigated through field surveys, also in relation to their role as ecological indicators of environmental change (Stephens et al., 1988) and climate change (Roesig et al., 2004). Indeed, knowledge of the distribution pattern of fishes, especially those of high commercial and/or conservation value, might have crucial implications for the design of a new MPA (Curley et al., 2002), including the regulation and management of fishing activities (Roberts & Polunin, 1991).

Scientific data on the fish assemblages of the Aeolian Archipelago are scanty and outdated, especially as regards the circalittoral zone. Some information on coastal benthic and nektobenthic fishes was collected within a shallow depth range (2-28 m) by underwater visual census (Vacchi et al., 1997), whereas more recent data concerns the composition of local artisanal fisheries catches (Battaglia et al., 2010 and references therein; Di Natale & Navarra, 2019). Fishing represents one of the most characteristic activities in the Aeolian Archipelago, involving the collection of data on demersal fishes using ROVs have been carried out in the Mediterranean mesophotic realm. Some studies include information on the whole fish assemblage, either in natural environments, such as banks (Consoli et al., 2016), or in artificial habitats, such as offshore gas platforms (Andaloro et al., 2013) and shipwrecks (Consoli et al., 2015).

Scientific data on the fish assemblages of the Aeolian Archipelago is one of the most fascinating island complexes of the Central Mediterranean Sea. It encompasses a large area characterized by a complex geomorphological system linked to the presence of volcanoes, underwater canyons and hydrothermal springs (Chiocci et al., 2008), most of which are located around the islands of Vulcano (Sedwick & Stube, 1996), Stromboli (Kokelaar & Romagnoli, 1995) and Panarea (Tudino et al., 2014). The Aeolian Archipelago is located in the south Eastern Tryanhenian Sea, off the north Eastern coast of Sicily, and covers a total area of 116.3 km². The Archipelago is composed of seven main islands (Lipari, Vulcano, Salina, Stromboli, Panarea, Filicudi and Alicudi) and five islets located around the island of Panarea (Basiluzzo, Dattilo, Lisca Nera, Bottaro and Lisca Bianca), round in shape. Since 2001, the Aeolian Islands have been included on the UNESCO World Heritage list, as an area of outstanding natural landscapes. The Aeolian Archipelago is also on the list of the sites identified by Italian national legislation (Italian Law 979/82, Art. 31) as a candidate MPA.

The seabed surrounding the islands consists of steep rocky cliffs or boulder fields rarely interspersed with gently sloping sandy areas. The distribution of Posidonia oceanica meadows, from a few metres down to 35-40 m depth, both on rocky substrate and volcanic sands containing biogenic detritus, is generally patchy, except in some coastal stretches of Salina, Lipari, and Filicudi (ISPRA, 2019). Pre-coralligenous formations are rare. The circalittoral zone, characterized by coralligenous habitats, shows a strong heterogeneity of the benthic assemblages. According to their relative location within the Archipelago, the islands were ascribed to three main sectors: Western (Alicudi and Filicudi), Central (Lipari, Salina and Vulcano) and Eastern (Panarea and Stromboli) (Fig. 1).

The local fishing fleet is mainly artisanal and small-scale, usually operating within the 12 nm limit, and comprises about 150 small polyvalent boats, most of which are located at Lipari (70%), Salina (11%) and Stromboli (18%) (Battaglia et al., 2010).

Data collection

Data on the demersal fish assemblages of the Aeolian Archipelago were collected during a research cruise carried out with R/V Astrea between August and September 2017. Geophysical data of the island coasts were collected during the cruise using a Kongsberg EM240 Multi-beam echosounder in order to produce high resolution bathymetric maps and identify the most interesting rocky areas to investigate by ROV transects. Investigation of fish assemblages by ROV transects is one of the most frequently used methodologies (Sward et al., 2019). The entire Archipelago was surveyed by means of
36 strip transects running perpendicular to the shore (Fig. 1) and providing around 34 h of imagery (Table 1).

Data on fish assemblages were collected during daylight hours by means of a ROV (MAG98) equipped with a full HD navigation camera and a Blackmagic microstudio 4k cinematographic camera, with a Panasonic Lumix 25-45mm lens and four LED lights (lasers). The camera was located at the front of the ROV oriented at a 45-degree angle to the seafloor yet able to move up and down. ROV equipment also included an underwater acoustic positioning system (Tracklink 1500 MA, Linquest USBL system), providing the georeferenced location of the ROV every second.

Using a standardised protocol, the ROV was deployed in the deepest point of the transect and, after reaching the seafloor, moved towards the shoreline following the seabed profile with a separation of 0.30-1 m. A relatively constant speed of 0.3 m/s was maintained along the route, which is compatible with the presence of vertical cliffs or large boulders and outcrops. Transect length was estimated by mean of GIS (Geographic Information System) software (ESRI ArcMAP 10.1), applied to the ROV track data. A graphic representation of each transect path and location around the coasts of the Archipelago is given in Supplementary Figure S1.

### Video transect analysis

Processing of video transects was performed using the VLC Media Player platform (v.3.0.11, www.videolan.org/vlc) and required multiple steps. Firstly, video segments with poor quality images (i.e. out of focus, too far from the seafloor, clouded by suspended sediment) or collected in open water or over sandy/muddy bottoms were removed from the analysis. Secondly, video from each transect was divided into segments, which were homogeneous in terms of depth and type of hard substrate and thus taken as sampling units. Substrate type was classified into three categories, according to its mesoscale attributes: large rocky outcrops (RO), large boulders (LB), and small blocks (<50 cm height) field (SB). All segments were then stratified into three depth intervals: from the infralittoral (20-50 m) down to the upper (51-120 m) and lower circalittoral (121-190 m) zones (Table 1).

All fishes observed within each segment were recorded and identified to the lowest possible taxonomic level (Fischer et al., 1987). In some cases, digital video frames and video at reduced speed were used to help identify fish species. Fish abundance was estimated by counting single specimens or, with schools larger than 30 individuals, using abundance classes (31-50, 51-100, 101-200, 201-500, >500 individuals). The number of individuals in

---

**Fig. 1:** Map of the study area in the southern Tyrrhenian Sea. The three sectors of the Aeolian Archipelago (1=Western sector; 2=Central sector; 3=Eastern sector) and locations of the ROV transects ( ) and the main fishing ports ( ★ ) are indicated in the inset maps.
Table 1. Characteristics of ROV transects carried out in the three sectors of the Aeolian Archipelago. The number of segments (sampling units) at each transect and depth range are shown. LB=large boulders, SB=small boulders, RO=rocky outcrops. ALDFG=Abandoned, lost or otherwise discarded fishing gear.

| Sector | Transect | Depth (m) (min-max) | Position (start) | Duration (min) | Substrate type | No. of segments by depth range | No. of ALDFG |
|--------|----------|---------------------|------------------|----------------|----------------|-------------------------------|--------------|
|        |          |                     | Latitude  | Longitude     |            | 20-50 m | 51-120 m | 121-190 m |         |
| Western| 22       | 59-166              | 38°33'2.5» N | 14°34'51.9» E | 63           | LB, RO               | 2           | 1          | 4       |
| Western| 23       | 31-145              | 38°33'14.1» N| 14°33'17.8» E | 62           | SB, RO               | 1           | 1          | 1       | 4       |
| Western| 24       | 65-116              | 38°33'45.5» N| 14°32'39.1» E | 71           | LB, RO               | 2           |             |         |
| Western| 25       | 59-99               | 38°33'47.1» N| 14°35'42.2» E | 63           | LB, RO               | 2           |             |         |
| Western| 26       | 66-135              | 38°32'40.4» N| 14°19'42.1» E | 52           | RO                   | 1           | 1          | 1       |
| Western| 27       | 22-151              | 38°32'54.4» N| 14°22'13.7» E | 78           | LB, RO               | 1           | 2          | 1       | 2       |
| Western| 28       | 107-250             | 38°35'15.1» N| 14°29'10.9» E | 34           | RO                   | 1           |             |         |
| Western| 29       | 43-125              | 38°35'44.1» N| 14°32'59.7» E | 50           | RO                   | 1           | 1          |         |
| Central | 1        | 25-147              | 38°25'30.9» N| 14°56'34.4» E | 77           | LB, RO               | 1           | 2          | 2       |
| Central | 2        | 44-162              | 38°22'39.2» N| 14°57'22.4» E | 37           | LB, RO               | 2           |             |         |
| Central | 3        | 85-200              | 38°27'49.0» N| 14°52'15.0» E | 59           | LB, SB, RO           | 1           | 2          |         |
| Central | 4        | 42-154              | 38°26'57.1» N| 14°57'52.7» E | 54           | LB, RO               | 1           | 2          | 1       |
| Central | 5        | 53-123              | 38°29'55.3» N| 14°58'4.6» E  | 29           | LB, SB, RO           | 3           |             |         |
| Central | 6        | 42-160              | 38°22'29.6» N| 15°00'53.9» E | 97           | LB, RO               | 1           | 2          | 1       |
| Central | 7        | 28-163              | 38°23'31.2» N| 15°00'21.2» E | 81           | LB, RO               | 1           | 1          | 1       |
| Central | 8        | 26-126              | 38°32'21.7» N| 14°52'35.5» E | 39           | LB                   | 1           |             |         |
| Central | 9        | 54-128              | 38°34'31.7» N| 14°52'47.9» E | 27           | RO                   | 1           |             |         |
| Central | 10       | 39-112              | 38°32'17.3» N| 14°55'53.6» E | 29           | LB                   | 1           |             |         |
| Central | 11       | 95-131              | 38°31'30.8» N| 14°51'23.2» E | 97           | LB                   | 1           |             |         |
| Central | 12       | 20-53               | 38°31'24.8» N| 14°57'46.8» E | 38           | LB                   | 1           |             |         |
| Central | 13       | 28-130              | 38°24'48.9» N| 14°58'45.8» E | 38           | LB, RO               | 1           |             |         |
| Central | 14       | 60-113              | 38°37'53.1» N| 14°54'22.5» E | 50           | RO                   | 1           |             |         |
| Central | 15       | 39-81               | 38°35'39.0» N| 14°51'18.8» E | 40           | LB, RO               | 1           |             |         |
| Central | 16       | 71-100              | 38°35'24.4» N| 14°49'58.4» E | 37           | RO                   | 1           |             |         |
| Central | 17       | 75-113              | 38°33'3.7» N  | 14°47'58.7» E | 21           | LB                   | 1           |             |         |
| Central | 18       | 84-106              | 38°30'55.6» N| 14°53'47.7» E | 29           | LB, SB               | 2           |             |         |
| Central | 19       | 49-89               | 38°29'1.2» N  | 14°53'14.1» E | 23           | LB                   | 1           |             |         |

Continued
schools was then calculated by considering the midpoint of each abundance class (e.g. 40 individuals for the 31-50 abundance class) (Harmelin-Vivien et al., 1985).

Fish densities (number of individuals/10 m²) were determined by estimating the area viewed (herein referred to as swept area) during each video segment from segment length and width. Segment length was calculated from the latitude and longitude recorded by the ROV tracking system. To estimate segment width, we used the laser spots in the navigation camera images. The space between the paired lasers (measured laser width) was measured with a ruler on the video screen once every 30 seconds. Width estimates were then obtained using the following equation:

\[ width = \frac{\text{measured screen width}}{\text{measured laser width}} \times \text{laser width} \]

where laser width = 50 cm and measured screen width = the horizontal width of the video screen through the laser spots (Laidig & Yoklavich, 2016). The average of the width measures taken for each segment was finally used as segment width.

The trophic level of each species and its membership to a specific functional trophic group were assessed following the review of Stergiou & Karpouzi (2002).

Along each ROV transect, number and distribution of abandoned, lost or otherwise discarded fishing gear (ALDFG) (Macfadyen et al., 2009) were recorded, in order to obtain indirect information on fishing pressure.

### Data analysis

Multivariate and univariate statistical analyses were carried out to assess differences in fish assemblages in relation to two main factors, archipelago sector and depth range. Before running the analyses, the homogeneity of the distribution of substrate types across sectors and depth ranges was tested by χ² analysis, to assess any confounding effect of substrate.

Multivariate differences in the species composition of fish assemblages among sectors and depth ranges were assessed using fish density data. The influence of each variable was evaluated by constrained ordination (with sector or depth as constraining factor) using Canonical Analysis of Principal coordinates, (CAP), based on Bray-Curtis dissimilarities (Anderson & Willis, 2003). The canonical correlations were tested using 4999 random permutations of the raw data. Distinctness of groups was assessed using leave-one-out allocation success (Anderson & Robinson, 2003). The product-moment correlations of the 30 species variables with the two canonical discriminant axes (ρ1 and ρ2) were calculated and only those having relatively strong correlations (i.e. $\sqrt{\rho_1^2 + \rho_2^2} > 0.30$) were considered as valuable and included in the plot.

Univariate analyses were carried out using the same data set in order to ascertain differences in fish species richness, total density and diversity (by the Shannon-Wiener index, $H'$) among sectors and depth ranges.
These differences were tested by two-way permutational analysis of variance (Permutational ANOVA) (Anderson, 2001a; McArdle & Anderson, 2001), with the experimental design consisting of factor Sector (3 levels, fixed) and Depth (3 levels, fixed). The analysis was based on the Bray-Curtis similarity matrix using 4999 unrestricted permutations of raw data (Anderson, 2001b).

Differences in the number of transects with ALDFG among the islands of the Archipelago were tested by χ² analysis. Multivariate and univariate analyses were carried out using PRIMER v6 + PERMANOVA (Plymouth Marine Laboratory, UK).

Results

General description of fish assemblages

Thirty taxa of teleosts (29 species and 1 genus, Trachurus) belonging to 16 families, were recorded during the study (Table 2). Omnivores with preference for animals (Omnivores 2) was the most represented trophic group (15 out of 29 species), followed by carnivores feeding preferentially on decapods and fishes (Carnivores 1) or on fishes and cephalopods (Carnivores 2) (8 and 5 species, respectively). The total number of taxa found in the Central sector (n=26) and in the intermediate depth range (51-120 m) (n=24) was higher than those observed in the other sectors and bathymetric intervals, likely as a result of differences in sampling effort (i.e., number of dives and sampling units). The families with the largest number of species were Labridae and Scorpaenidae (5 and 4 species, respectively), followed by Sparidae and Serranidae (3 species).

The assemblage was quantitatively dominated by some fishes, such as Anthias anthias, Callanthias ruber and Chromis chromis usually observed in large schools, and three non-gregarious species, i.e. Serranus cabrilla, Coris julis and Lappanella fasciata, which in total accounted for 96% of the assemblage.

The lower limit of the bathymetric distribution of the seven species observed during the surveys was noteworthy: Chelidonichthys obscurus was recorded down to 232 m depth; C. chromis, down to 59 m; C. julis, down to 130 m; Gobius kolombatovici, down to 109 m; Symphodus mediterraneus, down to 91 m; Symphodus melanocercus, down to 67 m; and Thorogobius ephippiatus, down to 232 m.

Multivariate and univariate analyses of fish assemblages

No significant differences were detected by Chi-square analysis of the distribution of substrate types with respect to archipelago sector (χ²=8.51, df=4, p=0.07) or depth range (χ²=0.52, df=4, p=0.97).

The results of the canonical analysis of principal coordinates indicated that sampling units belonging to different sectors largely overlapped (squared canonical correlations δ¹² = 0.14 and δ²³ = 0.004; P = 0.42; 39% of sampling units correctly classified) (Fig. 2a, sug-
| Taxa                    | Trophic group | Sector                      | Depth range |
|------------------------|---------------|-----------------------------|-------------|
|                        |               | Western | Central | Eastern | 20-50 | 51-120 | 121-190 |
| **Coris julis**        | Omnivores 2   | 0.55±0.19 | 0.34±0.18 | 3.73±1.90 | 0.19±0.08 | 0.03±0.03 |
| **Lappanella fasciata**| Omnivores 2   | 0.27±0.08 | 0.05±0.02 | 0.01±0.01 | 2.16±2.07 |
| **Symphodus mediterraneus** | Omnivores 2   | 0.003±0.003 | 0.03±0.03 | 0.01±0.01 | 2.94±2.94 |
| **Symphodus melanocercus** | Omnivores 2   | 0.001±0.001 | 0.001±0.001 |
| **Symphodus tinca**    | Omnivores 2   | 0.03±0.03 | 0.94±0.94 | 0.001±0.001 |
| **Mullidae**           |               |          |         |         |        |        |
| **Mullus barbatus**    | Omnivores 2   | 0.01±0.01 |         | 0.003±0.003 |
| **Mullus surmuletus**  | Omnivores 2   | 0.68±0.68 | 0.02±0.02 | 0.002±0.002 | 2.25±2.25 |
| **Muridae**            |               |          |         |         |        |        |
| **Murinae helena**     | Carnivores 2  | 0.04±0.02 |         | 0.01±0.01 | 0.07±0.07 |
| **Phycidae**           |               |          |         |         |        |        |
| **Phycis phycis**      | Carnivores 2  | 0.73±0.73 | 0.02±0.01 | 0.01±0.01 | 2.43±2.42 |
| **Pomacentridae**      |               |          |         |         |        |        |
| **Chromis chromis**    | Carnivores 1  | 6.28±4.98 | 7.16±4.97 | 29.37±8.76 | 1.35±1.33 | 1.38±1.38 |
| **Scorpaenidae**       |               |          |         |         |        |        |
| **Scorpaena elongata** | Carnivores 1  | 0.01±0.01 | 0.02±0.02 |         | 0.06±0.04 |
| **Scorpaena notata**   | Omnivores 2   | 0.81±0.79 | 0.02±0.02 | 0.02±0.01 | 2.59±2.59 |
| **Scorpaena porcus**   | Carnivores 1  | 0.01±0.001 | 0.01±0.01 | 0.003±0.002 |
| **Scorpaena soroa**    | Carnivores 1  | 0.85±0.84 | 0.02±0.01 | 0.01±0.006 | 2.77±2.77 |
| **Sebastidae**         |               |          |         |         |        |        |
| **Helicolenus dactylopterus** | Carnivores 1 | 0.09±0.06 | 0.02±0.02 |         | 0.49±0.28 |
| **Serranidae**         |               |          |         |         |        |        |
| **Anthias anthias**    | Carnivores 1  | 48.66±7.57 | 51.04±10.27 | 67.50±30.99 | 61.74±6.17 | 4.28±1.96 |
| **Serranus cabrilla**  | Omnivores 2   | 0.36±0.07 | 0.29±0.09 | 0.36±0.04 | 2.02±1.89 |
| **Serranus scriba**    | Carnivores 1  | 0.01±0.001 | 0.02±0.02 |         |         |
| **Sparidae**           |               |          |         |         |        |        |
| **Boops boops**        | Omnivores 1   | 0.37±0.37 | 2.77±2.77 | 3.36±3.36 | 1.21±1.21 |
| **Dentex gibbosus**    | Carnivores 2  | 0.52±0.47 | 0.16±0.16 | 1.55±1.55 |
| **Diplodus vulgaris**  | Omnivores 2   | 0.05±0.03 | 0.07±0.04 | 0.01±0.01 |
| **Triglidae**          |               |          |         |         |        |        |
| **Chelidonichthys obscurus** | Omnivores 2 | 0.32±0.32 | 0.01±0.01 | 1.04±1.04 |
| **Trigla lucerna**     | Omnivores 2   | 0.001±0.001 | 0.001±0.001 |
| **Zeidae**             |               |          |         |         |        |        |
| **Zeus faber**         | Carnivores 2  | 0.004±0.003 | 0.03±0.01 | 0.01±0.01 | 3.46±3.46 |
gesting no clear sector-related differences in fish assemblage structure. The Leave-one-out allocation procedure showed that the assemblage recorded in the Western sector was less variable and easier to predict than those inhabiting the Central and Eastern sectors (percentage of points correctly allocated to each group: Western sector = 52.6%; Central sector = 41.3%; Eastern sector = 17.7%).

The species contributing mostly to the pattern observed in relation to the archipelago sector were *Muraena helena* and *Dentex gibbosus* that were most frequently or exclusively recorded in the Central sector, in contrast to *C. ruber* (occurring also in the Western and Eastern sectors).

The results from CAP obtained using depth as the independent variable revealed a clear separation among sampling units belonging to different depth ranges. Along the first axis, the sampling units of the deepest range (121-190 m) segregated from those located at the other depth ranges (20-50 m and 50-120 m), which in turn were separated along the second axis (squared canonical correlations $\delta_1^2 = 0.72$ and $\delta_2^2 = 0.52$; $P = 0.0002$; 84.1% of sampling units correctly classified) (Fig. 2b).

Three groups of species contributed mostly to the depth-related differences observed in the assemblage structure. One group included 4 species (*Helicolenus dactylopterus*, *Aulopus filamentosus*, *C. ruber* and *T. ephippiatus*) that showed a negative correlation with the first axis (i.e. arrows pointing to the left side of the plot) and occurred preferentially in the deepest layer (121-190 m). Another group of species (i.e., *C. chromis*, *C. julis* and *Diplodus vulgaris*) plotted in the lower right side of the plot in relation to their preferences for the shallowest depth range (20-50 m). Finally, the arrows for *S. cabrilla*, *A. anthias* and *G. kolombatovici* that were mostly recorded at 51-120 m depth, pointed to the upper right of the plot.

The patterns of variation in species richness (S), diversity (H’) and total density across sectors and depth ranges are given in Figure 3. The results of Permutational

\[ \text{http://epublishing.ekt.gr} \ | \ e-Publisher: EKT | Downloaded at 04/06/2021 19:09:57 |
ANOVA indicate significant variability of S among depth ranges, but also a significant interaction between the factors Depth and Sector (Table 3). Pairwise comparisons between sectors revealed significant differences in species richness only in the deepest depth range (121-190 m), between the Central and Western sectors. The highest values of S were always observed at 121-190 m depth, even though significant differences were detected only when compared with the other depth layers and the intermediate layer (51-120 m) in the Central and Eastern sectors, respectively.

Neither species diversity nor total density of fish differed significantly among sectors, whilst they did when compared across depth ranges (Table 3). The $H'$ values at 20-50 and 121-190 m depth were comparable and significantly higher than those recorded at intermediate depth.

**Table 3.** Results of Permutational ANOVA (PERMANOVA) testing for differences in species richness, diversity ($H'$) and total density among sectors and depth ranges. The test was done on the basis of Bray-Curtis similarities, using 4999 unrestricted permutations of raw data. * P < 0.05, *** P < 0.001, ns: non-significant (P > 0.05).

| Effect | df | Richness | Diversity ($H'$) | Total density |
|--------|----|----------|------------------|---------------|
|        |    | MS       | Pseudo-F         | MS            | Pseudo-F     | MS            | Pseudo-F     |
| Sector (S) | 2  | 1782.4   | 16.7ns           | 33.9          | 0.8ns        | 2419.6        | 14.2ns        |
| Depth (D)  | 2  | 7357.1   | 69.0***          | 628.7         | 14.2***      | 13898.0       | 81.5***       |
| S x D      | 4  | 2279.5   | 21.4*            | 28.5          | 0.6ns        | 1905.8        | 11.2ns        |
| Residual   | 73 | 1065.8   | 14.3             | 44.3          | 1704.2       |               |               |
| Total      | 81 |          |                  |               |              |               |               |
Fish total density shows a clear decreasing trend with increasing depth, but the pairwise comparisons detected significant differences only between the first two depth layers (20-50 and 51-120 m) and the deepest one.

A total of 59 ALDFG, including mainly nets, longlines and handlines, were recorded during the surveys (Table 1). They were located along most transects, in the intermediate depth range (51-120 m) in particular, and frequently interacting with sessile macro-invertebrates. As suggested by the χ² analysis, the differences in the proportion of dives with and without ALDFG among the islands were just below the significance threshold (χ²=12.58, d.f.=6, p=0.0501). The highest contributions to the observed variation were made by the number of dives without gears, which at Lipari and Salina and at Panarea were respectively fewer and more abundant than expected.

Discussion

The analysis of data collected within the framework of this work provided the opportunity to increase knowledge on deep demersal fish assemblages inhabiting the coastal rocky seabed of the Aeolian Archipelago.

The list of fishes recorded during our surveys encompassed 30 taxa of teleosts, a relatively low number of species compared to similar studies conducted in other areas. An ROV investigation carried out by Consoli et al. (2016) on some banks located in the Strait of Sicily provided a list of 52 demersal fish species. The higher number of species reported by these authors is likely due to two reasons. Firstly, several species reported by Consoli et al. (2016) were recorded only in the upper infralittoral zone, i.e. outside the depth range explored in our surveys. Secondly, the banks are frequently reported as biodiversity hotspots and aggregation areas for large predators (Sahyoun et al., 2013; La Mesa et al., 2017), such as groupers, which were absent from our inventory.

From a methodological point of view, some limitations in terms of fish species detection were inherently associated with the ROV. As documented in other works, the catchability of fishes is largely influenced by species-specific mobility and reaction to the ROV system (Sward et al., 2013). Most of the demersal fishes recorded in this study belong to common species of Labridae, Sparidae and Serranidae, commonly observed along the Mediterranean coasts (Quignard & Tomasini, 2000). The records of two rare species, *Lappanella fasciata* and *Gobius kolombatovici*, which were represented by a conspicuous number of individuals, are noteworthy. Specimens of *L. fasciata* were always seen close to gorgonian colonies, as previously documented by Sartoretto et al. (1997) and Dulčić et al. (2006). Kovacić & Miller (2000) described *G. kolombatovici* as a bottom-dwelling and secretive species, usually inhabiting mixed habitats with rocks and soft sediment. In agreement with the typical habitat reported by Kovacić & Miller (2000), boulders and rocky walls characterised all the sighting locations of *G. kolombatovici* in our study area. *G. kolombatovici* has been reported in the Adriatic Sea (Kovacić & Miller, 2000) and the north-western Mediterranean (Francour & Mangialajo, 2007).

The low number of species recorded in this study, those of commercial interest in particular, is an indication of a depleted population due to overfishing, as also suggested by data on catch and landings of commercial species in the Archipelago (Battaglia et al., 2010; Di Natale & Navarra, 2019).

It was not possible to assess the level of fishing pressure in the study area accurately, since no scientifically sound data on the use of the coasts of the Archipelago by fishing activities were available. According to the data on the type, presence, and distribution of ALDG, which we used as a proxy of fishing pressure, it is reasonable to assume that the entire Archipelago is used as fishery grounds by both professional and recreational fishermen. No data on the extent of recreational fishing activity in the Aeolian Islands are currently available; nevertheless, illegal activities (e.g., non-compliance with the regulations on bag limit and permitted gears) are probably an additional challenge for the management of halieutic resources (Álvarez et al., 2019).

The overexploitation of both demersal (*Dentex dentex*, *Mullus surmuletus*, *Physix physix*, *Sciaena umbra*, *Scorpaena scrofa*) and pelagic species (*X. gladius*, *C. ruber*) belonging to high trophic levels, could explain the considerable abundance of species belonging to low trophic levels (Ashworth & Ormond, 2005), such as *A. anthias*, *C. chromis* and *C. ruber*. The distribution of these gregarious zooplanktivorous (Carnivores 1, according to Stergiou & Karpouzi, 2002) species showed a clear habitat partitioning by depth: *C. chromis* in the upper depth range (20-50 m), *A. anthias* and *C. ruber* in the deeper ranges (51-120 m and 121-190 m depth, respectively).

Numerical dominance of zooplanktivorous fish, such as *A. anthias* and *C. ruber*, has been reported in several studies focused on the fish fauna of seamounts in the Mediterranean and the Atlantic (Pakhorukov, 2008; Christiansen et al., 2009; Porteiro et al., 2013 and references therein; Consoli et al., 2016). Zooplanktivorous fish have been found to play a major role in the transfer of energy from the water column to the benthic environment, where they represent an important food resource for benthic and bentho-pelagic piscivores (Weaver et al., 2001; Porteiro et al., 2013). Predation by the scorpionfish *H. dactylopterus* on *A. anthias* and *C. ruber* has been reported by Gomes-Pereira et al. (2014). Few piscivorous fishes (Carnivores 2, according to Stergiou & Karpouzi, 2002), potentially benefiting from preying on the huge amount of gregarious zooplanktivorous, were recorded during our surveys. In this group, the most abundant were *A. filamentosus* and *Zeus faber*, followed by *P. physix* and *Muraena helena*.

The multivariate analysis did not discriminate be-
between the three sectors of the Aeolian Archipelago with respect to their fish assemblage composition. Similarly, the sector-related differences in species richness detected in the univariate analysis were very weak, except in the deepest depth range. It should also be noted that no fish species of conservation concern was recorded in the Archipelago during our surveys; hence, we did not have robust empirical evidence to support a differentiation between sectors in terms of conservation needs.

In agreement with similar studies (D’Onghia et al., 2004; Busby et al., 2005, Consoli et al., 2016, Porteiro et al., 2013), depth was the most significant variable influencing the structure of the Aeolian demersal fish assemblages. The most evident boundary line seems to be located around 120 m depth, where a drastic change in species composition and a significant decrease in overall abundance did occur, similarly to the trend of fish abundance already reported by Consoli et al. (2016). The variability in species richness and diversity with depth displayed quite a similar pattern. After a decrease in the transition from the infralittoral to the upper circalittoral zone, both parameters increased to a different extent depending on the archipelago sector.

Although depth has been recognised as one of the most important drivers influencing the distribution of fish fauna in the marine environment, the results of this work demonstrate that knowledge of the bathymetric distribution of some species remains incomplete, mainly due to the scarcity of exploration studies in deep-water environments. Indeed, the lower limit in the vertical zonation of seven species observed during the surveys fell outside their known depth range (Froese & Pauly, 2020).

In conclusion, despite the high structural heterogeneity and morphological diversity of the seabed of the Aeolian Archipelago, our findings indicate a poorly diversified demersal fish assemblage, most likely reflecting a high fishing pressure situation, extending to the sectors furthest away from the main fishing ports. Such a widespread depletion of fish diversity did not allow the identification of areas of greater value but stressed the need for sustainable use of halieutic resources in the Archipelago during our surveys; hence, we did not have robust empirical evidence to support a differentiation between sectors in terms of conservation needs.

Acknowledgements

This study was carried out in the framework of the research activities under the “Convenzione DPNM MAT-TM-ISPRRA per la collaborazione all’istituzione delle aree marine protette “Capo Milazzo”, “Grotte di Ripalta - Torre Calderina”, “Costa del Monte Conero” e “Capo Testa - Punta Falcone”, signed on June 16, 2014 and funded by the Italian Ministry of the Environment, Land and Sea. We are grateful to two anonymous referees for their helpful suggestions.

References

Ajemian, M.J., Wetz, J.J., Shipley-Lozano, B., Dale Shively, J., Stunz, G.W., 2015. An analysis of artificial reef fish community structure along the northwestern gulf of Mexico Shelf: Potential impacts of “rigs-to-reefs” Programs. PLoS ONE 10(5): e012635.

Álvarez H., Perry A.L., Blanco J., García S., Aguilar R., 2019. Towards the creation of a marine protected area in the Aeolian Islands. Results of the 2018 Aeolian Expedition. Oceania, Madrid. 136 pp.

Andaloro, F., Ferraro, M., Mostarda, E., Romeo, T., Consoli, P., 2013. 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). Helgoland Marine Research, 67 (2), 241-250.

Anderson, M.J., 2001a. A new method for non-parametric multivariate analysis of variance. Austral Ecology, 26, 32-46.

Anderson, M.J., 2001b. Permutation tests for univariate or multivariate analysis of variance and regression. Canadian Journal of Fisheries and Aquatic Sciences, 58, 626-639.

Anderson, M.J., Robinson, J., 2003. Generalised discriminant analysis based on distances. Australian and New Zealand Journal of Statistics, 45, 301-318.

Anderson, M.J., Willis, T.J., 2003. Canonical analysis of principal coordinates: A useful method of constrained ordination for ecology. Ecology, 84, 511-525.

Ashworth, J.S., Ormond, R.F.G., 2005. Effects of fishing pressure and trophic group on abundance and spillover across boundaries of a no-take zone. Biological Conservation, 121, 333-344.

Auster, P.J., Sánchez-Jiménez, A., Rodríguez-Arrieta, J.A., Quesada, A.J., Pérez, C. et al., 2016. Facilitative behavioral interactions between deepwater piscivores at Isla del Coco National Park and Las Gemelas Seamount, Costa Rica. Revista de Biología Tropical, 64, 187-196.

Battaglia, F., Romeo, T., Consoli, P., Scotti, G., Andaloro, F., 2010. Characterization of the artisanal fishery and its socio-economic aspects in the central Mediterranean Sea (Aeolian Islands, Italy). Fishing Research, 102, 87-97.

Bicknell, A.W.J., Godley, B.J., Sheehan, E.V., Cotier, S.C., Witt, M.J., 2016. Camera technology for monitoring marine...
biodiversity and human impact. *Frontiers in Ecology and the Environment*, 8, 424-432.
Boavida, J., Assis, J., Reed, J., Serrão, E.A., Gonçalves, J.M.S., 2015. Comparison of small remotely operated vehicles and diver-operated video of circalittoral benthos. *Hydrobiologia*, 766, 247-260.
Bryan, D.R., Kilfoyle, K., Gilmore Jr., R.G., Spieler, R.E., 2013. Characterization of the mesopelagic reef fish community in south Florida, USA. *Journal of Applied Ichthyology*, 29, 108-117.
Busby, M.S., Mier, K.L., Brodeur, R.D., 2005. Habitat associations of demersal fishes and crabs in the Pribilof Islands region of the Bering Sea. *Fishery Research*, 75, 15-28.
Cappo, M., Harvey, E.S., Shortis, M.R., 2007. Counting and measuring fish with baited video techniques-an overview. *Oceanography*, 8, 424-432.
Curley, B.G., Kingsford, M.J., Gillanders, B.M., 2002. Spatial characteristics and possible failure mechanisms. *Geomagnetism and Paleomagnetism Marine Geology and Geophysics*. Free Access.
Christiansen, B., Martin, B., Hirch, S., 2009. The bentheopelagic fish fauna on the summit of Seine Seamount, NE Atlantic: composition, population structure and diets. *Deep-Sea Research II*, 56, 2705-2712.
CoGe.P.A., 2013. Piano di gestione Locale dell’Unità Gestionale comprendente l’Arcipelago delle isole Eolie. FEP 2007-2013, 1-64.
Consoli, P., Esposito, V., Battaglia, P., Albobelli, C., Perzia, P., et al., 2015. Fishery bycatch, fishing mortality and habitat complexity on banks of the Strait of Sicily (central Mediterranean Sea) from remotely-operated vehicle (ROV) exploration. *PLoS One*, 11, e0167809.
Consoli, P., Martino, A., Romeo, T., Sinopoli, M., Perzia, P., et al., 2015. The effect of shipwrecks on associated fish assemblages in the central Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom*, 95(1), 17-24.
Curley, B.G., Kingsford, M.J., Gillanders, B.M., 2002. Spatial and habitat-related patterns of temperate reef fish assemblages: implications for the design of Marine Protected Areas. *Marine Freshwater Research*, 53, 1197-1210.
Di Natale, A., Navarra, E., 2019. Updated assessment of the fishing activities and the current trade/transformation chains for the halieutic products in the Aeolian Islands. *Flora Mediterranea and Marine Geology and Geophysics*. Free Access.
D’Origny, G., Politiou, C.Y., Boziano, A., Lloris, D., Rotllant, G., et al., 2004. Deep-water fish assemblages in the Mediterranean Sea. *Scientia Marina*, 68 (Suppl. 3), 87-99.
Dulčić, J., Furlan, D.M., Biped, L., 2006. First confirmed record of *Lappanella fasciata* (Cocco, 1833) in the Adriatic Sea. *Journal of Applied Ichthyology*, 22, 536-537.
Fischer, W., Schneider, M., Bauchot, M.L., 1987. Fiches FAO d’identification des espèces pour les besoins de la pêche. (Révision 1). Méditerranée et mer Noire.Zone de pêche 37. Volume II. Vertébrés. Publication préparée par la FAO et la Commission des Communautés Euro-péennes (Projet GCP/INT/422/EEC) financée conjointement par ces deux organisations. Rome, FAO, Vol.2, 761-1530.
Francour, P., Mangialajo, L., 2007. *Gobius kobombatovici*, a common species of Gobiidae in the north-western Mediterranean Sea? *Cybium*, 31(3), 389-390.
Froese, R., Pauly, D., 2020. Fishbase. http://www.fishbase.org. (Accessed 19 May 2020).
Gomes-Pereira, J.N., Porteiro, F.M., Santos, R.S., 2014. Interactions between fish species on seamount coral habitat. *Acta Ichthyologica*, 17, 193-201.
Guidetti, P., Claudet, J., 2010. Comanagement practices enhance fisheries in marine protected areas. *Conservation Biology*, 24 (1), 312-318.
Harmelin-Vivien, M.L., Harmelin, J.G., Chauvet, C., Duval, C., Galzin, R., et al., 1985. The underwater observation of fish communities and fish populations: Methods and problems. *Revue d’Ecologie (Terre Vie)*, 40, 467-540.
Harter, S.L., Ribera, M.M., Shepard, A.N., Reed, J.K., 2009. Assessment of fish populations and habitat on Oceluna Bank, a deep-sea coral marine protected area off eastern Florida. *Fishery Bulletin*, 107, 195-206.
ISPRA, 2019. Studi a supporto dell’istituzione dell’area marina protetta “Isole Eolie”. Rome, ISPRA. 175 pp.
Karpov, K.A., Bergen, M., Geibel, J.J., 2012. Monitoring fish in California Channel Islands marine protected areas with a remotely operated vehicle: the first five years. *Marine Ecology Progress Series*, 453, 159-172.
Kokelaar, P., Romagnoli, C., 1995. Sector collapse, sedimentation and clast population evolution at an active island-arc volcano. Stromboli, Italy. *Bulletin of Volcanology*, 57, 240-262.
Kovačić, M., Miller, P.J., 2000. A new species of *Gobius* (Teleostei: Gobiidae) from the northern Adriatic Sea. *Cybium*, 24(3), 231-239.
Laidig, T.E., Yoklavich, M.M., 2016. A comparison of density and length of Pacific groundfishes observed from 2 survey vehicles: a manned submersible and a remotely operated vehicle. *Fishery Bulletin*, 114, 386-396.
La Mesa, G., Salvati, E., Agnesi, S., Tunesi, L., 2017. Assessment of coastal fish assemblages before the establishment of a new marine protected area in the central Mediterranean: its role in formulating a zoning proposal. *Mediterranean Marine Science*, 18 (1), 11-21.
Langlois, T., Williams, J., Monk, J., Bouchet, P., Curey, L., et al., 2018. Marine sampling field manual for benthic stereo BRUVS (Baited Remote Underwater Video). In Field Manuals for Marine Sampling to Monitor Australian Waters, Przeslawski R, Foster S (Eds). National Environmental Science Programme (NESP). pp.82-104.
Lorance, P., Trenkel, V.M., 2006. Variability in natural behaviour, and observed reactions to an ROV, by mid-slope fish species. *Journal of Experimental Marine Biology and Ecology*, 332, 106-119.
Macfadyen, G.; Huntington, T.; Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reports and Studies No.185; FAO Fisheries and Aquaculture Technical Paper, No. 523. Rome, UNEP/FAO. 115p.
McArdle, B.H., Anderson, M.J., 2001. Fitting multivariate models to community data: a comment on distance-based redundancy analysis. Ecology, 82, 290-297.

Pacuski, R. E., Palsson, W. A., Gono, H.G., 2013. Estimating fish abundance and community composition on rocky habitats in the San Juan Islands using a small remotely operated vehicle. Washington, DC:Washington Department of Fish and Wildlife, Fish Program, Fish Management Division. 47 pp.

Pakhorukov, N.P., 2008. Visual observations of fish from sea-mounts of the Southern Azores region (the Atlantic Ocean). Journal of Ichthyology, 48, 114-123.

Porteiro, F.M., Gomes-Pereira, J.N., Pham, C.K., Tempera, F., Santos, R.S., 2013. Distribution and habitat association of benthiic fish on the Condor seamount (NE Atlantic, Azores) from in-situ observations. Deep-Sea Research II, 98, 114-128.

Quignard, JP, Tomasini, JA, 2000. Mediterranean fish biodiversity. Biologia Marina Mediterranea, 7, 1-66.

Roberts, C.M., Polunin, N.V.C., 1991. Are marine reserves effective in management of reef fisheries? Reviews in Fish Biology and Fisheries, 1, 65-91.

Roessig, J.M., Woodley, C.M., Cech Jr, J.J., Hansen, L.J., 2004. Effects of global climate change on marine and estuarine fishes and fisheries. Reviews of Fish Biology and Fisheries, 14, 251-275.

Ross, S.W., Rhode, M., Quattrini, A.M., 2015. Demersal fish distribution and habitat use within and near Baltimore and Norfolk canyons, U.S. middle Atlantic slope. Deep-Sea Research I, 103, 137-154.

Ryer, C.H., Stoner, A.W., Iseri, P.J., Spencer, M.L., 2009. Effects of simulated underwater vehicle lighting on fish behaviour. Marine Ecology Progress Series, 391, 97-106.

Sahyoun, R., Bussoetti, S., Di Franco, A., Navone, A., Panzalis, P. et al., 2013. Protection effects on Mediterranean fish assemblages associated with different rocky habitats. Journal of the Marine Biological Association of the United Kingdom, 93, 425-435.

Sartoreto, S., Francour, P., Harmelin, J.G., Charbonnel, E., 1997. Observation in situ de deux Labridae profonds, Lappanella fasciata et Acanthurinus palloni en Méditerranée nord-occidentale. Cybium, 1, 37-44.

Sedwick, P.N., Stuben, D., 1996. Chemistry of shallow submarine warm springs in an arc-volcanic setting: Volcano Island, Aeolian Archipelago, Italy. Marine Chemistry, 53, 147-161.

Smith, J.G., Lindholm, J., 2016. Vertical stratification in the distribution of demersal fishes along the walls of the La Jolla and Scripps submarine canyons, California, USA. Continental Shelf Research, 125, 61-70.

Stephens, Jr., J.S., Hose, J.E., Love, M.S., 1988. Fish Assemblages as Indicators of Environmental Change in Nearshore Environments. In Marine organisms as indicator, D.F. Soule & G.S. Keppel (eds.). Berlin: Springer, 91-105.

Stergiou, K.I., Karpouzi, V.S., 2002. Feeding habits and trophic levels of Mediterranean fish. Reviews in Fish Biology and Fisheries, 11, 217-254.

Stoner, A.W., Clifford, H.R., Parker, S.J., Auster, P.J., Wakefield, W.W., 2008. Evaluating the role of fish behavior in surveys conducted with underwater vehicles. Canadian Journal of Fisheries and Aquatic Science, 65, 1230-1243.

Sward, D., Monk, J., Barrett N., 2019. A systematic review of remotely operated vehicle surveys for visually assessing fish assemblages. Frontiers in Marine Science, 6, 134.

Trenkel, V.M., Lorance, P., Mahévas, S., 2004. Do visual transects provide true population density estimates for deepwater fish? ICES Journal of Marine Science, 61, 1050-1056.

Tudino, T., Bortoluzzi, G., Aliani, S., 2014. Shallow-water gaseohydrothermal plume studies after massive eruption at Panarea, Aeolian Islands, Italy. Journal of Marine Systems, 131, 1-9.

Vacchi, M., La Mesa, M., La Mesa, G., 1997. Studio preliminare del popolamento ittico costiero delle Isole Eolie (Tirreno meridionale, Mediterraneo). p. 489-497. In: Proceedings of the 15th Congress of the Italian Association of Oceanology and Limnology, Vulcano Island, 18-21 September 2002.

Weaver, D.C., Dennis, G.D., Sulak, K.J., 2001. Northeastern Gulf of Mexico coastal and marine ecosystem program: community structure and trophic ecology of the fishes on the Pinnacles Reef Track. Final Synthesis Report. U.S. Department of the Interior, Geological Survey, USGS BSR-2001-0008 and Minerals Management Service Gulf of Mexico OCS Region, New Orleans, LA, OCS Study MMS 2002-034. 92 pp.

Villa, F., Tunesi, L., Agardy, T., 2002. Optimal zoning of marine protected areas through spatial multiple criteria analysis: the case of the Asinara Island National Marine Reserve of Italy. Conservation Biology, 16 (2), 1-12.

Supplementary data

The following supplementary information is available online for the article:

**Fig. S1:** Path and location of ROV transects around the coasts of the Aeolian Archipelago.