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*Research Article*

# A preliminary survey of marine cave habitats in the Maltese Islands

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**Abstract.** The Mediterranean Sea is a hotspot for marine biodiversity. Past studies of Mediterranean marine caves have revealed the unique biocoenotic and ecological characteristics of these habitats, which are protected by European Union legislation. The Maltese Islands have an abundance of partially and fully submerged marine caves with different geomorphological characteristics, yet there have been no systematic studies on these habitats and their associated species. This study is a first synthesis of existing information on the biotic assemblages and physical characteristics of Maltese marine caves. The work combines a review of the available information with a preliminary survey of some marine caves in Gozo, during which several species were recorded for the first time for the Maltese Islands. Characteristic species recorded from local marine caves are highlighted, including several species of red and brown algae, sessile invertebrates including bryozoans, ascidians and sponges, and mobile forms including crustaceans and fish. A marked zonation from the cave entrance to the inside of the caves was identified: photophilic algae at the mouth of the cave are progressively replaced by more sciaphilic species, followed by a middle section dominated by sessile invertebrates, and then a completely dark inner section that is mostly devoid of sessile organisms. Several species protected by national and international legislation were found to occur.

**Keywords:** Mediterranean marine caves, sciaphilic, cave biota, sessile biotic assemblages, species distribution patterns

## 1 Introduction

The Mediterranean Sea is a hotspot for marine biodiversity and ranks among the most important of such regions worldwide (Bianchi et al., 2012), although much research remains to be done to assess and monitor the biodiversity it supports, and to better understand its marine ecosystems. Despite numerous national and international programs of research on the flora and fauna of the Mediterranean Sea, its biodiversity still remains insufficiently studied (Coll et al., 2010). The description of new species, especially of invertebrates from poorly known groups or from groups which thrive in habitats that are difficult to explore such as the deep sea and marine caves, is an ongoing process and new discoveries continually add to previous estimates of overall Mediterranean species diversity. In particular, increased effort to study the species diversity and the ecology of poorly known habitats is required, as are long-term monitoring programs of marine species and habitats.

Past studies of Mediterranean marine caves have revealed the unique biocoenotic and ecological characteristics of these habitats. Sessile benthic species associated with cave habitats typically show a marked zonation from the cave entrance to the inward end of the cave: photophilic algae at the mouth of the cave are rapidly replaced by encrusting coralline algae and other more sciaphilic species. Thereafter a middle section tends to be dominated by sessile invertebrates such as sponges, corals, and bryozoans, while the completely dark inner section tends to be mostly devoid of sessile organisms (Laborel & Vacelet, 1958; Riedl, 1966). This characteristic zonation is thought to be a consequence of the strong environmental gradients that exist, especially those related to light intensity and water movement, as one proceeds inwards from the cave mouth (Bussotti,

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Terlizzi, Fraschetti, Belmonte & Boero, 2006; Gili, Riera & Zabala, 1986; Harmelin, Vacelet & Vasseur, 1985; Riedl, 1966, and references therein). Moreover, some caves are characterised by unique features because of their physical structure and location, such as for example the '3PP Cave' in France, where true bathyal and bathyo-abyssal organisms are able to thrive due to abnormally low and constant temperatures (Harmelin & Vacelet, 1997, and references therein).

In recent decades, systematic surveys of dark littoral submarine caves have received particular attention from the scientific community (e.g. Bakran-Petricioli et al., 2007; Bianchi, Cattaneo-Vietti, Cinelli, Morri & Pansini, 1996; Bussotti, Denitto, Guidetti & Belmonte, 2002; Boxshall & Jaume, 2000; Chevaldonné & Lejeusne, 2003; Harmelin & Vacelet, 1997; Hart Jr., Manning & Iliffe, 1985; Iliffe, Hart & Manning, 1985; Vacelet & Boury-Esnault, 1995; Ereskovsky, Kovtun & Pronin, 2015). The particular environmental conditions of these habitats, including the absence of light, oligotrophy, and reduced hydrodynamic action, make dark submarine caves enclave mesocosms of the deep aphotic zone in shallow coastal areas (Harmelin et al., 1985). In this respect, marine caves mimic the deep sea. Marine caves therefore conveniently serve as natural laboratories, and render unique opportunities for researchers to access organisms and processes that are otherwise very difficult to study (Bakran-Petricioli et al., 2007; Calado, Chevaldonné & dos Santos, 2004; Harmelin & Vacelet, 1997; Janssen, Chevaldonné & Arbizu, 2013; Vacelet, Boury-Esnault & Harmelin, 1994). Furthermore, marine caves harbour rare species that are unique to such habitats. Due to their relatively small size and ease of accessibility, environmental stability, and presence of communities of endemic and specialized species (Harmelin et al., 1985), dark submarine caves are excellent model habitats to address important ecological and evolutionary questions such as the influence of life cycle and habitat fragmentation on gene flow (Chevaldonné, Rastorgueff, Arslan & Lejeusne, 2014; Lejeusne & Chevaldonné, 2005, 2006; Rastorgueff, Chevaldonné, Arslan, Verna & Lejeusne, 2014). In addition, the information gathered on such habitats can be interpreted in the context of global climate change and can help increase awareness of the related pertinent issues (Chevaldonné & Lejeusne, 2003; Glover et al., 2010). Overall, therefore, Mediterranean marine caves are of high ecological, scientific and conservation importance, yet the available information on cave ecosystems and their component species and conservation status is limited, which hinders effective monitoring and management.

The Maltese Islands lie at the centre of the Mediterranean Sea, south of Sicily and north of Libya, and close to the geographical division between the western and eastern basins of the Mediterranean. From the point of view of biodiversity research, the location of the Maltese Islands is strategic as they lie astride the connection between the western basin, which has generally been very well studied, and the eastern one, for which there are only fragmented data. Located close to the narrowest part of the channel between Africa and Europe, the Maltese Archipelago occupies a key location for the study of movement of flora and fauna between the western and eastern Mediterranean. Moreover, the archipelago lies on the main route of the westward range extension of Erythraean (= Lessepsian) immigrants and of thermophilic indigenous Mediterranean species (Lejeusne, Chevaldonné, Pergent-Martini, Boudouresque & Pérez, 2010), and that of the eastward extension of species entering from the Atlantic (Sciberras & Schembri, 2007). Consequently, the Islands are ideally situated for understanding the processes underlying the evolution of Mediterranean biodiversity at different spatial and temporal scales and for monitoring of the changing biogeography of the central Mediterranean. The latter is necessary as surface hydrographical conditions change, such as for example the ongoing northward displacement of the '15 °C divide' that is allowing west to east and east to west passage of thermophilic species (Bianchi et al., 2012).

The Maltese Islands, being almost entirely composed of limestones of Oligo-Miocene age, have an abundance of partially submerged (hereafter 'emergent') and submerged marine caves with different geomorphological characteristics. Caves may arise by the direct action of the sea on the limestone rock at sea-level, where the force of the waves develops fissures in the rock into clefts, which eventually become caves and tunnels. This effect is enhanced if the water carries abrasive suspended material. Other caves originated on land due to karst-fluvial processes and then became totally or partially submerged due to changes in sea-level or due to tectonic movement. Some such caves continue above sea-level as terrestrial caves, and some may have freshwater seepages that give rise to a distinct halocline inside them. Caves in the Maltese Islands may also be formed by a combination of processes, both terrestrial and marine (Borg, Knittweis & Schembri, 2013).

A map of the location of marine caves in the Maltese Islands was recently published in the Maltese Marine Strategy Framework Directive (MSFD) Benthic Habitats Initial Assessment, based on surveys carried out by Thibaut (2011), and information published in diving and snorkelling guides (MEPA (2014); Fig. 1). The best-known submerged marine caves are those located within a water depth range of between 10 m and 40 m, which are accessible to divers. These include caves around Gozo, at Dwejra, Wied il-Ghasri, Reqqa Point, Hondoq ir-Rummien and Mgarr ix-Xini; around the Santa Marija area and on the western coast of Comino; and around Malta, at Anchor Bay, Qawra and along the south-western coast of Malta. The cave at Reqqa Point in Gozo is the only cave known locally from waters that are deeper than 40 m; however, it is likely that others located at such water depths may be present along the south-western coast of Malta and Gozo. Martineau (1965) studied marine terraces in Malta and found concentrations of these features at depths of ca 9.5 m, 17.5 m, 25 m and 33.5 m, which were interpreted as the results of past sea level lowstands; caves were reported associated with these terraces, but were not studied. Indeed, there have been no systematic studies on these habitats and their associated species. The little information that is available is incidental, mostly generated in the frame of studies that form part of assessments of environmental impacts, and which may not be easily accessible to the scientific community. There is even less information on the relationships between cave biota and environmental factors.

Given the lack of dedicated scientific surveys on this marine habitat in Malta, and the fact that European Union Member States are required to designate 'Special Areas of Conservation' (SACs) to safeguard this habitat under the 'Habitats Directive' (Council Directive 92/43/EEC, 1992), there is therefore an urgent need for enhancing knowledge of the diversity of marine caves. The latter is particularly important in relation to different ecological conditions, especially with respect to the effects of natural and human-induced perturbations. Additionally, it would be particularly useful to study and monitor species found in submarine cave biotopes that are 'indicators' of ongoing changes in the Mediterranean marine environment; for example, 'tropicalisation', 'meridionalisation', and invasion by non-indigenous species (Bianchi et al., 2012). Due to the high susceptibility of cave biotic communities to such phenomena, any change is exacerbated and should be more easily detected than in the external environment (Chevaldonné & Lejeusne, 2003). More generally, data collected from cave studies in Malta would also contribute to the knowledge of evolutionary biodiversity in the central parts of the Mediterranean Sea.

The main aim of the present work is to review present knowledge of the biodiversity of marine caves around the Maltese Islands to serve as a baseline for future studies. Information on the biotic assemblages and physical characteristics identified in previous surveys of marine caves is compiled and synthesised for the first time, and presented together with the results of a preliminary survey of a few example caves found in Gozo, which was carried out in 2012.

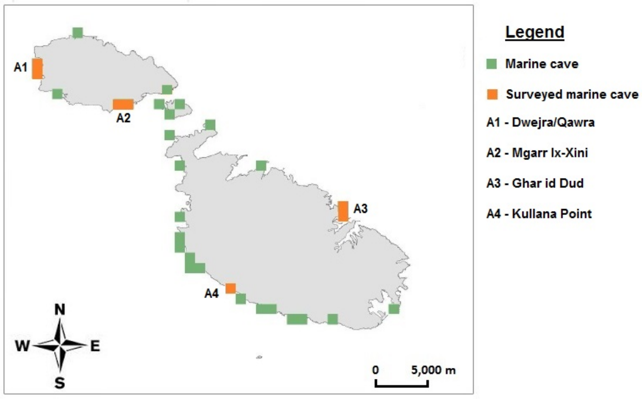


**Figure 1:** Location of known emergent and submerged caves in the Maltese Islands (Source: MEPA (2014)), including caves for which information on biotic communities is provided in the present article.

## 2 Method

In order to synthesise all information available on emergent and submerged caves in the Maltese Islands, a literature review was combined with a preliminary survey using SCUBA diving. Marine caves were taken to refer to either fully submerged caves or the submerged part of emergent caves, while the terrestrial and supralittoral to mediolittoral component of emergent caves was not considered. Moreover, only true marine caves were considered; cave-like environments such as tunnels (effectively caves which are open at both ends), deep overhangs, deep rock fissures and spaces between boulders were not considered, despite the fact these are important habitats for sciaphilic assemblages.

### 2.1 Literature Review

A comprehensive literature review of scientific articles and grey literature related to marine caves in the Maltese Islands was made. The focus of the review was on caves for which information on biotic communities was available. Where possible, information on the physical characteristics of the caves was also retrieved.

The following constituted the main sources of available information:

1. Crossett and Larkum (1965) studied the distribution of biota in a small cave below Kullana Point as part of a study on the ecology of benthic marine algae on submarine cliff faces in Malta;
2. Whilst monitoring marine infralittoral benthic communities following beach rehabilitation work in 2002, two caves at the mouth of the Mgarr Ix-Xini inlet in Gozo were surveyed by Borg and Schembri (2002);
3. Following an application for a full development permit for the construction of a car park and commercial outlets at the Sliema promenade in the

**Table 1:** Details on three cave surveys conducted in Gozo in September 2012 to assess the biogeographical and biodiversity interest of Maltese underwater caves.

| | Coral Cave, Dwejra | Ta' Barba Cave, Dwejra | Mgarr Ix-Xini |
|---|---|---|---|
| **Survey Date** | 11.09.2012 | 12.09.2012 | 14.09.2012 |
| **Water Temperature** | 25–27 °C | 25–27 °C | 25–27 °C |
| **Maximum Depth** | 29 m | 25 m | 14 m |

Chalet area, the Malta Environment Planning Authority (MEPA) requested baseline surveys. Borg and Schembri (2003) studied the biota of a number of sea-caves along the Ghar id-Dud shoreline in Sliema, Malta, as part of this project.

4. Borg, Micallef, Pirotta and Schembri (1997), and Borg, Dimech and Schembri (2004) recorded five submerged caves and six emergent caves as part of two marine benthic surveys carried out in the Dwejra/Qawra area in Gozo.

### 2.2 Preliminary Survey of Marine Caves

In order to gather additional new information on the species assemblages associated with marine caves of the Maltese Islands, three dives were conducted in September 2012 on the north-western and southern shores of Gozo, targeting caves of various topologies and depths. These include 'Coral Cave' and 'Ta' Barba Cave' located within the Qawra/Dwejra area below Ghar Ta' Barba at Dwejra, and two smaller and shallower caves on the western side of Mgarr Ix-Xini Bay in Gozo. During the dives, data on the physical characteristics of the caves as well as on their biological characteristics were recorded.

### 2.3 Biological Characteristics

In order to synthesise information about the species recorded during the preliminary surveys conducted in Gozo in 2012, as well as that available from published literature, species were classified into four survey areas (Table 2). For the purpose of the present article, species which were recorded at two or more of these surveyed areas were considered to be species characteristic of local caves. It is important to note that some of these species may also be found in other similar Mediterranean 'dark habitats' such as overhangs, rock crevices and spaces between boulders.

## 3 Results and Discussion

### 3.1 Physical Characteristics

A review of the available scientific and grey literature revealed that whilst several reports include some information, there is a lack of dedicated and detailed scientific studies of Maltese marine caves. In particular, the information available on physical characteristics is to a large extent only based on observations (Table 3); detailed measurements of cave dimensions such as depth (relative to sea-level), wall height, floor width, wall bearings measured across the floor and measures of cross-section at pre-determined points are not available to date. One notable exception is the cave at Kullana Point, for which Crossett and Larkum (1965) constructed an isometric diagram including roof profiles.

Cave size is likely to increase as a result of erosion, and decrease as a result of wall collapse and sedimentation on the cave floor. Both phenomena occur regularly in the Maltese Islands due to the widespread abundance of soft rocks and active erosion. Since there is no baseline information on the physical dimensions of marine caves at this point it is not possible to monitor whether there are changes in the size, volume or physiognomy of individual marine caves. Without such baseline information on the physical characteristics of marine caves the rel-

**Table 2:** Area codes used to classify species characteristic of local caves.

| Area | Cave Name | Reference |
|---|---|---|
| A1 | Coral Cave, Dwejra | Present study |
| | Ta' Barba Cave, Dwejra | Present study |
| | Dwejra/Qawra Area | Borg, Micallef, Pirotta and Schembri (1997, 2004) |
| A2 | Mgarr Ix-Xini Cave 1 | Present study |
| | Mgarr Ix-Xini Cave 2 | Present study |
| | Mgarr Ix-Xini Caves 1 & 2 | Borg and Schembri (2002) |
| A3 | Ghar id-Dud, Sliema | Borg and Schembri (2003) |
| | Ghar il-Lembi, Sliema | Borg, Dimech and Schembri (2004) |
| A4 | Kullana Cave, Siggiewi | Crossett and Larkum (1965) |

**Table 3:** Physical characteristics of marine caves in the Maltese Islands. Cave type S refers to submerged caves, type E to emergent caves; cave depth refers to approximate depth of cave entrance; S: south, SW: south-west, W: west, N: north.

| Cave Name | Cave Type | Cave Depth | Physical Characteristics | Reference |
|---|---|---|---|---|
| Coral Cave, Dwejra | S | 27–30 m | ∼ 20–25 m wide/∼ 10 m high opening oriented to the SW; cave narrows as horizontal penetration increases; small dark chamber with low ceiling opens to W ∼ 50 m from entrance; sandy floor with organic detritus at cave entrance, fine mud at inner part of cave. | Present study |
| Ta' Barba Cave, Dwejra | E | 25 m | Large vertical fault rising from the seafloor to the surface; deep end of the cave is ∼ 10 m wide, gradually narrowing towards the end; only dark in corners/cracks or below overhangs; bottom partly sandy with ripple marks at entrance and bedrock/large collapsed blocks further inside. | Present study |
| Mgarr Ix-Xini Cave 1 | S | 10 m | Muddy-sand bottom at entrance quickly replaced by bedrock; ∼ 3 m large entrance which narrows at the rear; several turns in the main passage act as a barrier to water movement and light penetration. | Present study |
| Mgarr Ix-Xini Cave 2 | S | 16 m | Sandy bottom at cave entrance; complex series of overhangs, ledges and smaller darker chambers at ∼ 10–12 m. | Present study |
| Ghar id-Dud | E | 2–2.5 m | Ghar id-Dud N: shape of an half-inverted U with a length of ∼ 18–20 m, extending west under the Sliema promenade; Ghar id-Dud S: extends west for the first ∼ 4–5 m and thereafter to the southwest for ∼ 27–28 m; accumulations of boulders/a mixture of cobbles and small boulders on the cave floor; rocky floor at innermost reaches of Ghar id-Dud N. | Borg and Schembri (2003) |
| Ghar il-Lembi | E | 3 m | Length of ∼ 36–38 m; trickles of freshwater seeping through rock forming roof; part of roof collapsed. Thin layer of *Posidonia oceanica* debris present on cave floor; accumulation of stones and cobbles at entrance of cave. | Borg and Schembri (2003) |
| Kullana Cave | S | 33 m | Maximum horizontal penetration ∼ 25 m; sandy floor; sides and ceiling of cave made of deeply dissected rock. | Crossett and Larkum (1965) |

evant Maltese authorities are thus not in a position to assess the 'Favourable Conservation Status' of marine caves in the Maltese Islands, as is required under Article 1 of the Habitats Directive.

The physical characteristics of caves result in pronounced environmental gradients, in particular with regards to light intensity and the degree of water movement as one proceeds from the cave mouth inwards. For instance, Pérès and Picard (1964) described horizontal zonation patterns in caves, distinguishing between parts of caves that receive some light that support the 'semi-dark cave biocoenosis', and completely dark parts of caves with the 'dark cave biocoenosis'.

Physiographic features, including depth below sea-level of the cave, the aspect of the cave entrance, size and configuration of the entrance, and degree of penetration into the rock of the cave, will determine the spatial extent of relatively well lit/semi-dark/completely dark sections of marine caves, hence determining the type of biotic communities that are present. This was particularly evident at Cave 1 surveyed in Mgarr Ix-Xini, where turns in the main passage blocked light after a short distance, creating two very distinct environments within the cave. Other factors that may also determine microhabitats, and hence the type of biotic assemblages found in a cave, include the micro-topography of cave walls and other geomorphological features (e.g. deeply dissected cave sides at Kullana Cave), sea temperature, the presence of haloclines, as well as the presence of side-chambers (e.g. Coral Cave, Ghar id-Dud), or overhangs and ledges (e.g. Mgarr Ix-Xini Cave 2) in the cave. Moreover, the nature of the cave floor may be bedrock, consist of cobbles or small boulders, or may be covered with sediment; the nature of the cave floor may also change along its length. Sediment in turn can vary from coarse sand to very fine mud, as was evident by the gradient in sediment grain size at Coral Cave in Dwejra. The floor of local partially submerged caves tends to be strewn with pebbles, cobbles and small boulders, which can be the result of roof-falls such as those recorded by Borg and Schembri (2003) at Ghar il-Lembi. It is also the result of more intense water movements in such caves.

A further distinction can be made between cave biotopes which contain short-lived species (e.g. pioneering species such as some serpulids and ascidians), and biotopes which contain long-lived species. The former will be found in caves subject to scouring (by suspended sediment), which are often smaller caves still in the process of being formed, whilst the latter will be found in cave systems which have remained undisturbed for extended periods. Due to the generally soft limestone rocks found in the Maltese Islands the natural excavation of submerged caves will be an ongoing process at sites where suspended sediment is present and wave action is common. In the present survey, large ripple marks present on the sandy sediment at the entrance of Ta' Barba Cave, Dwejra were an indication that water movement in the cave can be considerable.

A further cause of disturbance in some of the surveyed caves is anthropogenic impact from frequent visits by divers. This is of particular importance in areas A1 and A2, which are popular dive sites in the Maltese Islands since the caves are large enough for divers to enter.

### 3.2 Biological Characteristics

The complexity of local cave habitats outlined above was reflected in the variety of biotopes which were present. The most common species, defined as those present in two or more of the surveyed areas and which can thus be considered to be characteristic of marine caves in the Maltese Islands, are listed in Table 4.

Species characteristic of caves in the Maltese Islands are in agreement with ones recorded from marine caves located on the Salento Peninsula of southern Italy: all species of sessile benthos reported in Table 4, with the exception of just two species (*Zonaria tournefortii* and *Fasciospongia* sp.), were identified by Bussotti et al. (2006). During a study of fish species Bussotti and Guidetti (2009) found that the cardinal fish *Apogon imberbis* was by far the most common fish species recorded both at cave entrances and inside caves; Denitto, Moscatello and Belmonte (2009) found the boxer shrimp *Stenopus spinosus* and the majid crab *Herbstia condyliata* on rocky walls of caves in spring/summer and winter/spring respectively. *Plesionika narval* may seasonally form large swarms in some marine caves during the day, with up to thousands of individuals covering cave walls (Ott & Svoboda, 1976; Wirtz & Debelius, 2003).

Cave dwelling mysids have been extensively studied in recent years (Chevaldonné & Lejeusne, 2003; Lejeusne & Chevaldonné, 2005; Lejeusne, Pérez, Sarrazin & Chevaldonné, 2006; Lejeusne & Chevaldonné, 2006; Rastorgueff et al., 2014; Chevaldonné et al., 2014). *Hemimysis* is the dominant genus of mysids found in Mediterranean marine caves, but other species belonging to the genera *Siriella* and *Harmelinella* are also common (Ledoyer, 1989). Only *Hemimysis margalefi* had previously been reported from the Maltese Islands (Rastorgueff et al., 2014). The 2012 cave surveys reported in the present study provided the first records for the Maltese Islands of two other mysid species, *Harmelinella mariannae* (Chevaldonné et al., 2014) and *Siriella gracilipes*. All three are amongst the five most common species of cave-dwelling mysids in the north-western Mediterranean Sea (Rastorgueff, Harmelin-Vivien, Richard & Chevaldonné, 2011). Mysids have been shown to form dense swarms of over 10 million individuals in a single cave (Coma, Carola, Riera & Zabala, 1997; Passelaigue & Bourdillon, 1986) and recent research has shown that they are important vectors of organic matter from the outside euphotic zone to the various areas inside caves, since some of these organisms frequently migrate outside caves during the night (Rastorgueff et al., 2011).

With regards to species zonation in marine caves of the Maltese Islands, as expected, three distinct zones could generally be discerned: (i) an outer section where some light penetrates and allows the growth of assemblages of sciaphilic algae at the mouth; (ii) a middle section dominated by sessile invertebrates such as sponges, corals, tubicolous polychaetes, bryozoans, hydroids, brachiopods, and foraminifera; (iii) and a completely dark inner section or dark side chambers mostly devoid of sessile organisms. This is in line with patterns previously recorded in other parts of the Mediterranean, where it has been shown that species richness, biological cover and biomass tend to decrease towards the inner reaches of marine caves (e.g. Bianchi et al., 1996; Laborel & Vacelet, 1958; Riedl, 1966). Besides lower levels of light penetration this pattern has also been attributed to a decrease in water circulation and renewal in the innermost parts of caves, leading to oligo-

**Table 4:** Species recorded in two or more of the areas where biological characteristics of marine caves in the Maltese Islands have been surveyed to date. A1: Dwejra/Qawra; A2: Mgarr Ix-Xini; A3: Sliema Caves; A4: Kullana Point.

| Phylum | Class | Species Name | A1 | A2 | A3 | A4 |
|---|---|---|---|---|---|---|
| Ochrophyta | Phaeophyceae | *Halopteris filicina* | – | – | X | X |
| | | *Zonaria tournefortii* | X | X | – | – |
| Rhodophyta | Florideophyceae | *Lithophyllum stictaeforme* | X | X | – | – |
| | | *Lithophyllum* sp. | – | – | X | X |
| | | *Peyssonnelia squamaria* | – | X | X | X |
| Porifera | Calcarea | *Petrobiona massiliana* | X | X | – | – |
| | Demospongiae | *Agelas oroides* | X | X | – | – |
| | | *Chondrosia reniformis* | X | X | – | – |
| | | *Crambe crambe* | X | X | – | – |
| | | *Fasciospongia* sp. | X | – | X | – |
| | | *Ircinia* sp. | X | X | – | – |
| | | *Phorbas* sp. | X | X | – | – |
| | | *Petrosia ficiformis* | X | X | – | – |
| | Homoscleromorpha | *Oscarella tuberculata* | X | X | – | – |
| Arthropoda | Malacostraca | *Herbstia condyliata* | X | X | – | – |
| | | *Plesionika narval* | X | X | – | – |
| | | *Stenopus spinosus* | X | X | – | – |
| | | *Harmelinella mariannae* | X | X | – | – |
| | | *Hemimysis margalefi* | X | X | – | – |
| | | *Siriella gracilipes* | X | X | – | – |
| Bryozoa | Gymnolaemata | *Myriapora truncata* | X | X | – | – |
| | | *Reteporella* spp. | X | X | – | – |
| Chordata | Ascidiacea | *Halocynthia papillosa* | X | X | – | – |
| | Actinopterygii | *Apogon imberbis* | X | X | – | – |

trophic conditions (Buss & Jackson, 1981; Fichez, 1990; Garrabou & Flos, 1995).

In the Maltese Islands, assemblages of sciaphilic algae at the mouth and entrance of caves where the substratum is hard (i.e. consists of bedrock or large boulders) and light is present are characterised by species such as the chlorophytes *Palmophyllum crassum*, *Cladophora prolifera* and *Flabellia petiolata*. Common sciaphilic brown algae found in cave environments are *Zonaria tourneforti* and *Halopteris filicina*. Crossett and Larkum (1965) found *Halopteris filicina* together with *Dictyota linearis* and *Zonaria flava*; the authors considered this community to be specific to the cave environment at the surveyed depth ($\sim 30\,\mathrm{m}$). The most common type of flora found in cave environments are however red algae (Rhodophyta). The most abundant species are *Peyssonnelia squamaria* and *Lithophyllum* sp. Other species of red algae recorded from cave entrances of marine caves in the Maltese Islands to date are *Lithophyllum stictaeforme*, *Corallina elongata*, *Haliptilon virgatum*, *Heterosiphonia wurdemannii*, *Jania rubens* and *Phymatolithon* sp.

The most abundant macroinvertebrates found at the entrance of caves included sciaphilic species of sponges such as *Agelas oroides*, *Crambe crambe*, *Petrosia ficiformis*, *Chondrosia reniformis*, *Ircinia* sp. and *Phorbas* sp.; the sipunculan *Phascolosoma granulatum*; species of the polychaetes families Nereidae, Sabellidae, Syllidae, and the errant amphinomid *Hermodice carunculata*; the echinoderms *Ophidiaster ophidianus* and *Hacelia attenuata*; the cnidarians *Astroides calycularis*; and the ascidian *Halocynthia papillosa*. Crustacean species recorded from the mouth of caves are several species of hermit crabs (e.g. *Calcinus tubularis* and *Dardanus callidus*); the Mediterranean locust lobster *Scyllarides latus* and the crawfish *Palinurus elephas*; species belonging to the marine isopod families Janiridae and Sphaeromatidae; as well as the tanaeids *Apseudes* sp. and *Leptochelia savignyi*. Individuals of the gastropod *Gibbula* cf. *varia* and of the exotic crab *Percnon gibbesi* were abundant below the boulders and larger cobbles at the shallow caves Ghar id-Dud/Ghar il-Lembi.

Biotic assemblages found on hard substrata in the semi-dark, outer parts of caves just beyond the cave mouth where dim light was still present included sparse patches of coralline red algae such as *Lithophyllum* sp., and *Cruoria cruoriaeformis*. The macrofauna present in this zone was more abundant and diverse than the macroflora, consisting of species such as the tube-anemone *Cerianthus membranacea*, the scleractinians *Madracis pharensis* and *Leptopsammia pruvoti*; the long-spined sea urchin *Centrostephanus longispinus* and the Medi-

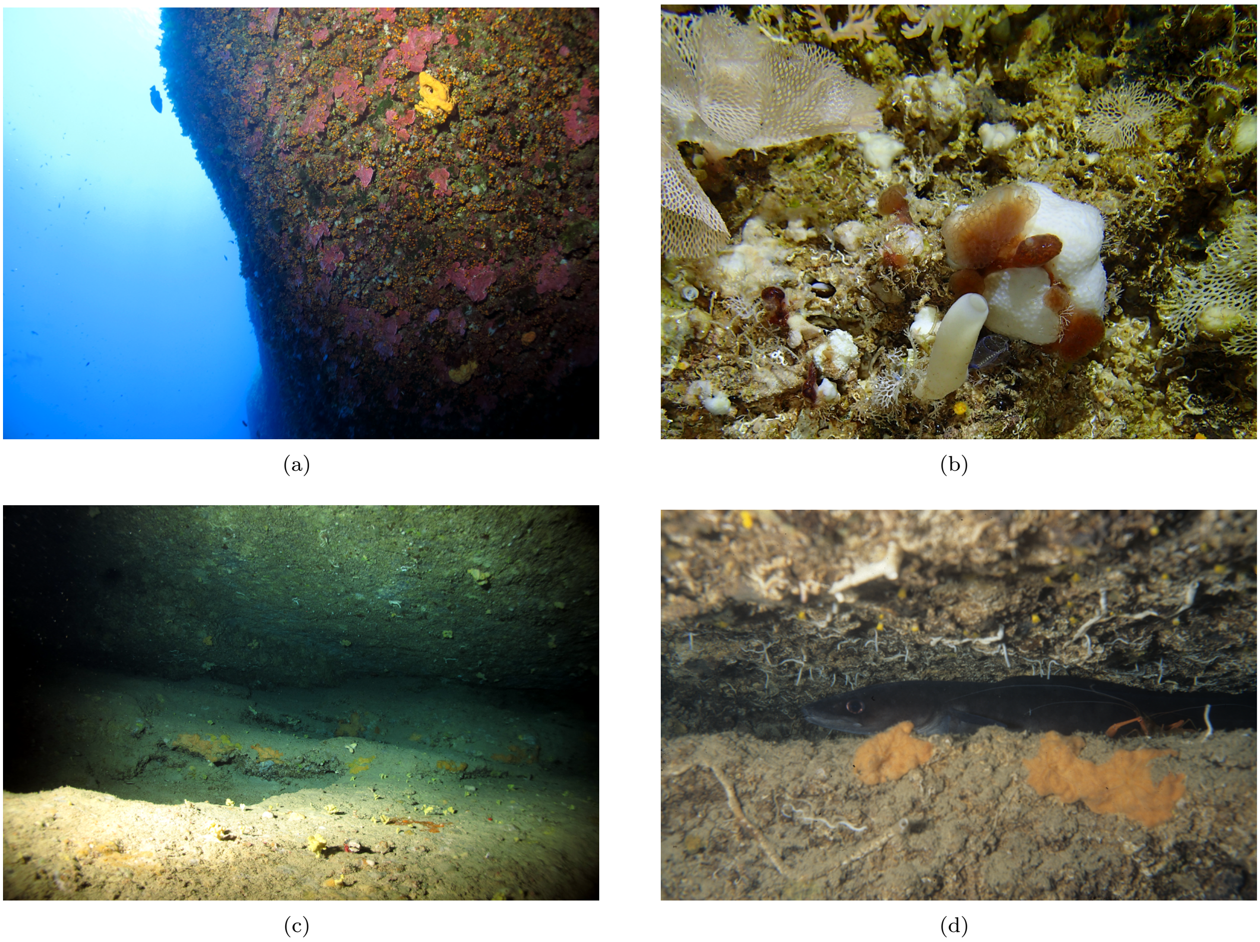


**Figure 2:** Typical biocoenotic characteristics of marine caves found in the Maltese Islands: **a.** Cave entrances where light penetrates and allows for the growth of algae (photo: T. Perez); **b.** Semi-dark cave middle sections which are dominated by massive and erect sessile invertebrates (photo: P. Chevaldonné); **c.** Completely dark cave parts which are mostly devoid of sessile macrofauna (photo: T. Perez); **d.** Example of mobile macrofauna together with sessile fauna (photo: J.A. Borg).

terranean featherstar *Antedon mediterranea.* A large diversity of sponges was identified from the eight caves for which data on biological characteristics was reviewed, including *Petrobiona massiliana*, *Oscarella* sp., *Geodia* sp., *Pleraplysilla spinifera*, *Sycon* sp., *Cinachyrella* sp. and the boring sponge *Cliona* sp. At the second cave (Cave 2) surveyed in Mgarr Ix-Xini, the very rare demosponge *Euryspongia raouchensis* was identified, which has previously only been found in Lebanese caves (Vacelet, Bitar, Carteron, Zibrowius & Perez, 2007). Several species of bryozoans are common in the semi-dark parts of caves of the Maltese Islands, including *Myriapora truncata* and *Reteporella* sp. A particularly rich bryozoan facies was found at caves in Dwejra, where species such as *Reptadeonella violacea*, *Reteporella elegans*, *Smittina cervicornis*, *Adeonella calveti*, *Schizoporella* sp., and *Buskea dichotoma* have been identified. The most common species of crustaceans recorded include the shrimps *Stenopus spinosus* and *Plesionika narval*, the majid crab *Herbstia condyliata*, numerous red cave copepods *Ridgewayia* sp., as well as the mysids *Hemimysis margalefi* and the cryptic, rare species *Harmelinella mariannae. P. narval* formed large swarms at Coral Cave in Dwejra, and as a consequence only few cave mysids were found at this location. The red cave copepods of the genus *Ridgewayia* were identified for the first time in the Maltese Islands. Brachiopods living in the semi-dark parts were not collected or identified as part of the present study, but Logan and Noble (1983) obtained three species of living brachiopods from a cave at Wied iz-Zurrieq at 25 m depth: the megathyridids *Argyrotheca cuneata*, *Argyrotheca cordata*, and *Megathiris detruncata.*

Species found in totally dark parts of inner caves or side pockets and chambers included macrofauna such as occasional individuals of the sponge *Fasciospongia* sp., sabellarid and serpulid polychaetes and crustaceans such as *Palaemon serratus*, the mysid *Siriella gracilipes*, decapods of the genus *Dromia*, and ostracods. Moreover, several of the more mobile species found in the semi-dark zone (mainly crustaceans) listed above are frequently also encountered in totally dark inner parts of caves.

Large mobile fauna frequently associated with marine caves in the Maltese Islands are species of grouper such as *Epinephelus marginatus* and *Mycteroperca rubra*, the conger eel *Conger conger*, the cardinalfish *Apogon imberbis*, the forkbeard *Phycis phycis*, and the brown meagre *Sciaena umbra*.

Several of the species listed above are protected by national and international legislation, such as for example the long-spined sea urchin *Centrostephanus longispinus*, the Mediterranean orange star coral *Astroides calycularis* and the violet starfish *Ophidiaster ophidianus* (Government of Malta Legal Notice 322, 2013; Council Directive 92/43/EEC, 1992). Moreover the dusky grouper *Epinephelus marginatus* has recently been classified as threatened by the International Union for the Conservation of Nature (IUCN) due to severe overexploitation by commercial and recreational fisheries, and is subject to a Species Action Plan (SAP) in the Maltese Islands (MEPA, 2011). In addition to being protected habitats *per se*, marine caves thus harbour sensitive and protected species.

Overall it is clear that many of the more common species recorded in marine caves of the Maltese Islands are characteristic of cave communities as they are known from the northwestern Mediterranean Sea and southern Italy. Southern, more thermophilic species are also present, although not exclusive of cave communities. The best examples of this thermophilic component are the swarms of *Plesionika narval* as well as the common occurrence of the coral *Astroides calycularis* on the walls of the studied caves.

Several species which had not been previously recorded from the Maltese Islands were identified during the preliminary survey of marine caves carried out as part of the present study, which demonstrates the dearth of current knowledge on this protected habitat. Given the abundance, diversity and complexity of cave systems present in the Maltese Archipelago it is likely that more detailed surveys would uncover numerous additional species hitherto not recorded locally. Moreover, it is important to note that the species mentioned above constitute the more conspicuous flora and fauna associated with biocoenoses found in marine caves. Undoubtedly, a much higher associated biodiversity is actually present since many of the associated animals are small macrofauna ($<$ 4 cm in size) or fall within the meiofauna ($<$ 0.5 mm) category, including species of molluscs, polychaetes, crustaceans and echinoderms that are less conspicuous and were hence not spotted in the surveys from which the information presented here was extracted. In order to address the current lack of detailed information, particular taxocenes as well as the numerous microhabitats present in caves should be studied in detail, in order to discover the main spatial and temporal patterns of species and assemblage diversity in both submerged and emergent caves of the Maltese Archipelago. Such data could then be used to assess the similarities and differences between Maltese caves and those found in other parts of the Mediterranean Sea.

Besides the obvious scientific importance of the above information, such data are required to guide cave habitat monitoring and management initiatives. The main source of anthropogenic pressure on submerged caves in the Maltese Islands is from SCUBA diving, which may cause mechanical damage to erect benthic species growing in caves, as well as damage to species growing on cave ceilings from trapped air bubbles generated by divers (Schembri, 1995). An example of such damage is the destruction of fragile bryozoan colonies in caves located in the Dwejra/Qawra area, which was reported by Borg et al. (1997), and which continues to the present day.

Although the present work does not constitute an in-depth study on marine caves around the Maltese Islands, it can be considered a prelude to more detailed surveys on this important and protected habitat, which are planned to be carried out in the near future.

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