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# A matter of taste? Mode and periodicity of marine mollusc exploitation on the Mediterranean island of Favignana (Ègadi Islands, Italy) during its isolation in the early Holocene

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ABSTRACT: The exploitation of marine molluscs by Mediterranean hunter-gatherers increased from the Upper Palaeolithic onwards, although their role in subsistence has rarely been investigated fully. An ideal area to address this issue is the archipelago of the Ègadi Islands, most of which were isolated by Post-Glacial sea level rise. Here we report on the results of the study of the mollusc assemblage recovered during the 1972 excavations at Grotta d'Oriente, a cave on Favignana, occupied from the Late Pleistocene to the middle Holocene. Marine molluscs, including principally rocky shore intertidal gastropods (*Patella* and *Osilinus*), were taken to the cave for consumption throughout its occupation, sporadically in the early Mesolithic, but more frequently and throughout the year in the late Mesolithic and early Neolithic. Progressive isolation resulted in intensification of shellfish exploitation, but not, however, in long-term over-exploitation of all intertidal marine gastropods, despite their vulnerability to human predation. The archaeozoological and isotopic data suggest that shellfish were a useful source of protein for the occupants of Grotta d'Oriente, but that the main role of marine molluscs was probably to provide nutrients not readily available in the terrestrial foods which constituted the bulk of the diet.

KEYWORDS: GROTTA D'ORIENTE, FAVIGNANA, SICILY, MESOLITHIC, MARINE MOLLUSCS, Ox YGEN ISOTOPE ANALYSIS, SEASONALITY

RESUMEN: La explotación de los moluscos marinos por parte de las sociedades cazadoras mediterráneas se incrementó a partir del Paleolítico Superior, si bien el papel desempeñado por este recurso raramente ha sido investigado en profundidad. Un marco ideal para abordar tal cuestión es el archipiélago de las Egadi, la mayoría de cuyas islas quedaron definidas como tal durante el Holoceno como resultado de la subida del nivel del mar. En este trabajo presentamos los resultados del análisis de las colecciones malacológicas recuperadas en las excavaciones de 1972 en Grotta d'Oriente, una cueva en la isla de Favignana ocupada entre el final del Pleistoceno y primera mitad del Holoceno. Los moluscos marinos, especialmente los caracoles marinos de litoral rocoso (*Patella* y *Osilinus*), fueron transportados para su consumo a lo largo de toda la ocupación, esporádicamente en el Mesolítico temprano pero de forma más intensa y a lo largo de todo el año durante el Mesolítico tardío y el Neolítico. El aislamiento progresivo de la zona generó una mayor intensidad de marisqueo aunque no una sobrexplotación a largo plazo de todos los gasterópodos de la línea de costa, a pesar de la vulnerabilidad de estos moluscos a la depredación por parte del hombre. Los datos arqueozoológicos e isotópicos sugieren que el marisco constituyó una útil fuente de proteínas para los ocupantes de la Grotta d'Oriente, si bien el papel principal de los moluscos marinos seguramente fue el de proveer nutrientes no siempre disponibles en las fuentes alimentarias de origen terrestre que constituyeron en todo momento el elemento principal de la dieta.

PALABRAS CLAVE: SICILIA, MESOLÍTICO, MOLUSCOS MARINOS, ANÁLISIS DE ISÓTOPOS DE Ox ÍGENO, ESTACIONALIDAD

## INTRODUCTION

The exploitation of coastal resources, including marine molluscs, has traditionally been thought to have intensified during the Post-Glacial, a view distorted by ethnographic and archaeological biases that have affected our interpretation of the role of such foods in human subsistence (Bailey & Flemming, 2008). In the Mediterranean Basin, humans have been consuming shellfish since at least the Middle Palaeolithic and, as shown in a recent review (Colonese *et al*., 2011a), the consumption of these resources increased from the late Upper Palaeolithic, during the Late Glacial. Most of the mollusc assemblages that have been studied are from cave sites, generally associated with rocky shores, and their interpretation has frequently been based on models proposed for oceanic coastal regions of Europe (Mannino, 2010). These models are not appropriate for Mediterranean coastal environments, which are characterized by narrow intertidal ranges and low primary productivity, resulting in lower secondary biomass, compared to analogous oceanic habitats (Fa, 2008). In order to propose models pertinent to the Mediterranean Basin, it is, thus, essential to undertake studies on prehistoric mollusc assemblages, including investigations on the taphonomy, biometry and seasonality of collection of the exploited shellfish. This should allow us to address questions important for our understanding of the role of coastal resources in hunter-gatherer subsistence (Mannino & Thomas, 2008), such as (i) whether environmental changes affected the exploitation of marine molluscs, (ii) whether over-exploitation by human foragers and/or culturally-driven changes caused shifts in species exploited and (iii) whether shellfish exploitation was independent of or subsidiary to terrestrial-based hunting and gathering. An ideal area of the Mediterranean Basin to investigate all these issues is the archipelago of the Ègadi Islands, off the western coast of Sicily, because two of its largest islands (Levanzo and Favignana) were isolated in the early Holocene as a result of sea level rise (Antonioli, 1997; Lambeck *et al*., 2004). Until then, this protrusion of north-western Sicily was inhabited by human groups that subsisted mainly by hunting and gathering and left behind traces of their activities in the deposits of numerous caves (Tusa, 1999).

## GROTTA D'ORIENTE: THE SITE AND ITS SETTING

Favignana, the largest of the Ègadi Islands, was connected to the mainland till the around 7 ka cal BP, when it became isolated by Post-Glacial sea level rise (Figure 1). The territory of the present-day island was inhabited by Upper Palaeolithic and Mesolithic hunter-gatherers from the last few millennia of the Pleistocene to the early Holocene (Martini *et al*., 2007; Mannino *et al*., 2012b). Numerous cave sites occupied by these groups have been discovered around Montagna Grossa (Bovio Marconi, 1952; Tusa, 1999), a limestone hill that divides Favignana into eastern and western parts. Grotta d'Oriente, a cave on the north-eastern slopes of Montagna Grossa, has been extensively excavated initially in 1972 (Mannino, 2004) and then in 2005 (Martini *et al*., 2007).The 1972 campaign, conducted by Giovanni Mannino (2004), explored prehistoric deposits assignable on archaeological and stratigraphic grounds to the closing stages of the Late Pleistocene (Upper Palaeolithic) and early-to-mid Holocene (Mesolithic, Neolithic and later). AMS radiocarbon dates have subsequently been obtained on shells of *Osilinus turbinatus*, as part of the research presented here, from the Mesolithic and early Neolithic levels of the sequence (Table 1). These dates confirm that the deposits excavated in

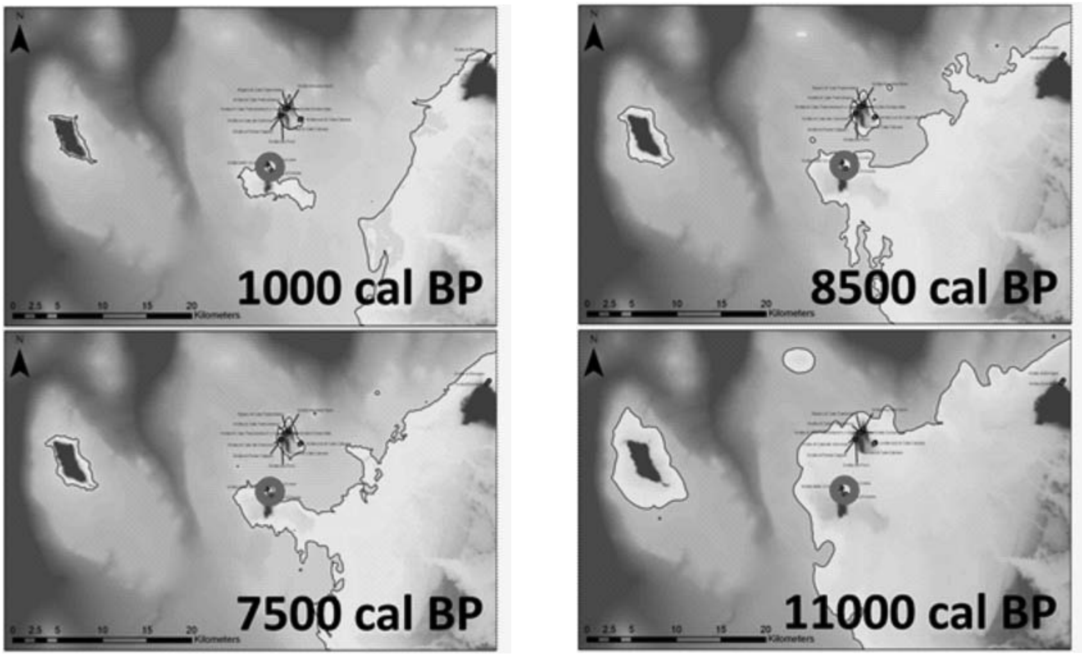


FIGURE 1

Maps showing the changes in shorelines produced by rising sea levels in the early Holocene. The palaeo-coastline has been retrieved from a 100 meter resolution submarine DEM (digital elevation model) generated from the interpolation of a batymethric map (Istituto Idrografico della Marina, 1995, Litorale da Trapani a Marsala e Isole Egadi 1:50,000, Genova) using the Topo to Raster (ANUDEM) interpolation algorithm of ArcGIS 9.0 and the sea level curve published by Lambeck *et al*. (2004).

| Radiocarbon laboratory number | Stratigraphic unit | Radiocarbon date (BP) | Calendar age cal. BC (2σ) | Calendar age cal. BP (2σ) |
|---|---|---|---|---|
| OxA-15562 | B40/60 | 6955 ± 36 | 5570 (p. 95.4%) 5310 | 7510 (p. 95.4%) 7260 |
| OxA-14256 | B100/114 | 8159 ± 37 | 6790 (p. 95.4%) 6440 | 8740 (p. 95.4%) 8390 |

TABLE 1

AMS radiocarbon dates from shells of the marine intertidal gastropod *Osilinus turbinatus* recovered in stratigraphic units 40-60 cm and 100-114 cm of Trench B (Grotta d'Oriente). The dates were calibrated with Oxcal 4.1. (Bronk Ramsey, 2009) using the Marine09 calibration curve (Reimer *et al*., 2009).

1972 accumulated in the early Holocene and that the Mesolithic occupation of the cave, or the Mesolithic-Neolithic transition, lasted until around 7500 cal. BP. This chronological framework is fully in line with results of radiocarbon dating undertaken on charcoal fragments recovered from the campaign of 2005, which was conducted at Grotta d'Oriente using state of the art excavation techniques (Colonese *et al*., 2011b). In the course of the 1972 excavations two prehistoric burials ('Oriente A' and 'Oriente B') were unearthed by Mannino (2004) at the base of the Mesolithic deposits. These burials were attributed on stratigraphic and archaeological grounds to a period potentially extending from the closing stages of the Late Pleistocene to the beginning of the Holocene (Di Salvo *et al*., in press). The main reason of interest in this site for the study of human subsistence lies in its temporal coincidence with a period of dramatic environmental changes (Figure 1), which led to the progressive isolation of the Ègadi Islands (with the exception of Marettimo that was probably isolated). The lithic material culture and the faunal food refuse recovered at the site constitute, therefore, a record of how humans adapted their subsistence to the changes which transformed Favignana in a marginal terrestrial environment, with coastal morphologies progressively characterized by rocky shores to the detriment of lagoonal and freshwater habitats (Mannino & Thomas, 2004; Martini *et al*., 2007). The faunal remains are mainly bones of terrestrial mammals and shells of molluscs. The skeletal remains of vertebrates include those of birds and fish, which are, however, not particularly numerous. The molluscs are mainly marine, although terrestrial taxa are also present. Here we present the results of archaeozoological and isotopic investigations on the marine molluscs from Grotta d'Oriente with the aim of characterizing the role and seasonality of their exploitation within the subsistence of the early Holocene hunter-gatherers of Favignana.

## FAUNAL ASSEMBLAGE

The fauna recovered at Grotta d'Oriente from the 1972 excavations was studied in detail by Mannino & Thomas (2004). The assemblage includes both vertebrates, mainly terrestrial mammals, and invertebrates, almost exclusively molluscs. The vertebrate remains amount to 739 specimens of which 265 were identifiable. The early Mesolithic deposits contained the remains of mammals such as the European wild ass (*Equus hydruntinus*), aurochs (*Bos primigenius*), red deer (*Cervus elaphus*), wild boar (*Sus scrofa*) and red fox (*Vulpes vulpes*). The herbivores and the *S. scrofa* were brought to the cave by humans who consumed their meat, the most frequent prey being *C. elaphus* followed by *E. hydruntinus*. The subsistence base broadened in the closing stages of the Mesolithic, when it included freshwater (*Emys orbicularis*) and marine turtles (*Caretta caretta*), marine fish of coastal habitats (e.g. *Epinephelus marginatus*, *Muraena helena*, *Pagrus pagrus*) and, possibly, birds (Mannino & Thomas, 2004). At this time, or just after, domestic ovicaprids were introduced and became an important component of the animal-based economy of the human groups that populated Favignana. Shells of terrestrial and marine molluscs occur throughout the sequence at Grotta d'Oriente. *Eobania vermiculata* is the most abundant terrestrial species (90% of the 279 land snails constituting the assemblage from the 1972 excavations) and is represented almost exclusively by adult individuals. On the basis of the available evidence it is not possible to ascertain whether the *E. vermiculata* shells were introduced into the cave by humans or not, as discussed also by Colonese *et al*. (2011b: 78) in relation to specimens recovered during the excavations of 2005 and as is the case at most contemporary sites where similar snails are recovered (Girod, 2011). If, however, the occupants discarded these shells after consuming the snails, this would have at most constituted a minor contribution to human subsistence. The contribution of marine molluscs to human subsistence will be discussed below, firstly by synthesizing the archaeozoological data obtained by Mannino & Thomas (2004) and secondly by presenting the results of the oxygen isotope analyses on the intertidal marine gastropod *Osilinus turbinatus* undertaken for this study.

## MARINE MOLLUSCS

The marine molluscs recovered during the excavations of 1972 at Grotta d'Oriente, reported by Mannino and Thomas (2004), include: (i) intertidal rocky shore species of the genera *Patella* and *Osilinus*, (ii) taxa from the subtidal zone of hard and secondary hard substrates (*Hexaplex trunculus*, *Thais haemastoma*, *Luria lurida*, *Cerithium vulgatum*, *Cymatium corrugatum*, *Conus mediterraneus*, *Spondylus gaederopus*, *Ostrea* sp.) and soft-bottom shore taxa (*Pinna nobilis*, *Cerastoderma glaucum*). The taphonomy of the shells and the changes in their proportions through the sequence will be discussed in the following sections, in order to interpret the use of marine molluscs by the occupants of the cave.

## NATURAL AND ANTHROPOGENIC TAPHONOMY

The taphonomy of the shells indicates that the bivalves and subtidal gastropod taxa, with the exception of the muricids that might have been consumed, were not collected when the animals were alive (Mannino & Thomas, 2004). The assemblage is overwhelmingly dominated by intertidal rocky shore taxa, the shells of which are largely intact, as they were collected for dietary purposes. The damages around the edges of many *Patella* are compatible with those produced by humans when detaching these gastropods from the rocks. Most of the *Osilinus* are intact or almost intact, but lacking the apex (Table 2). Observations on these specimens suggest that the apex was removed intentionally, probably using a lithic tool or possibly even a stone, in order to break the muscle ligament attaching the animal to the shell. Of the *Osilinus turbinatus* shells, 69% lack the apex, a percentage that decreases from the bottom to the top of the sequence. A higher proportion of *Osilinus articulatus* shells (84%) lack the apex and, in this case too, the number decreases through the sequence. This might imply that through time the extraction of mollusc flesh, perhaps following boiling, became more effective, possibly because a more efficient tool was available for this purpose in the late Mesolithic or early Neolithic. Based on our experience, flesh extraction from *Osilinus* shells is easier in larger specimens. As shown below, the size of *Osilinus* increased through time, a trend which might explain the lower number of shells devoid of apex in the upper part of the sequence. In this case it can be concluded that, while extraction techniques did not change through time, it is likely that the animals were cooked by boiling before being removed from their shells.

Among the marine molluscs from Grotta d'Oriente are shells with perforations (Mannino & Thomas, 2004). Most of the perforated shells were recovered from burials Oriente A (8 *Luria lurida* and 2 valves of *Ostrea edulis*) and Oriente B (5 *Luria lurida*, 1 *Conus mediterraneus* and 2 *Spondylus gaederopus*). Some other perforated shells were found within the deposit, including 2 *Luria lurida*, which on the basis of their stratigraphic position might have been associated with burial Oriente B, and a few *Patella*. All the shells with holes were perforated artificially, mainly through direct percussion. Two specimens of *L. lurida* from burial Oriente A and one of the *S. gaederopus* valves from burial Oriente B, on the other hand, have holes made by abrasion, probably with a sawlike (*sciage*) movement. The perforations on the shells have traces of wear, suggesting that they were worn in life as ornaments. The position of the *L. lurida*, *Ostrea* and *Spondylus* shells in the burials of Oriente A and B, between the clavicles and sternum, was interpreted by the excavator (Mannino, 2004) as indicating their use as beads and pendants, possibly in necklaces such as the one illustrated by Mannino & Thomas (2008: 43, fig. 8).

| Trench & stratigraphic unit | *Osilinus turbinatus* | | *Osilinus articulatus* | |
|---|---|---|---|---|
| | with / without apex | % without apex | with / without apex | % without apex |
| A cm 0-20 | 22/28 | 56 | 2/5 | 71 |
| A cm 20-80 | 36/83 | 70 | 6/27 | 82 |
| A cm 80-114 | 28/87 | 76 | 27/125 | 82 |
| *Total A* | *86/198* | *70* | *35/157* | *82* |
| B cm 20-40 | 41/38 | 48 | 3/4 | 57 |
| B cm 40-60 | 120/270 | 69 | 9/51 | 85 |
| B cm 60-80 | 151/575 | 79 | 60/313 | 84 |
| B cm 80-100 | 1/5 | 83 | 2/2 | 50 |
| B cm 100-114 | 6/6 | 50 | 1/3 | 75 |
| *Total B* | *319/894* | *74* | *75/373* | *83* |
| C cm 0-14 | 19/13 | 41 | 0/3 | 100 |
| C cm 14-40 | 254/324 | 56 | 14/64 | 82 |
| C cm 40-75 | 148/388 | 72 | 109/616 | 85 |
| C cm 75-110 | 3/8 | 73 | 1/10 | 91 |
| *Total C* | *424/733* | *63* | *124/693* | *85* |
| ***Total*** | ***829/1825*** | ***69*** | ***234/1223*** | ***84*** |

TABLE 2

Number of *Osilinus* shells with and without apices from the three trenches, including the percentage of individuals lacking the apex.

## SHELLFISH Ex PLOITATION AND CHANGING ENVIRONMENTS

The taphonomy and abundance of the marine shells recovered from Grotta d'Oriente during the 1972 excavations (total MNI = 8747) excludes the possibility that agents other than humans were responsible for their introduction into the site. In all three trenches (Figure 2), the MNI rise from the early to the late Mesolithic, dropping after the early Neolithic (Mannino & Thomas, 2004: 45, tab. 2, 3 and 4). As mentioned above, the majority of these specimens belong to rocky shore intertidal taxa of the genera *Patella* and *Osilinus* (Figure 2), the latter being more numerous in the early Mesolithic, while the former in the late Mesolithic and early Neolithic. The consistency in the trends observed in the three trenches confirm the substantial integrity of the deposits explored in the 1972 excavations, as seen in Figure 2. Amongst the limpets, the most represented species is *Patella caerulea*, followed by *Patella rustica*, *Patella ulyssiponensis* and then *Patella ferruginea*. The latter is the largest of the species collected for food and was exploited throughout the occupation of the cave, albeit in low numbers, and therefore its contribution to human diets was probably limited. *P. rustica*, on the other hand, is the smallest of the limpet species and its numbers increase from the early to the late Mesolithic, possibly attesting that the exploitation of *Patella* had become more intensive. The drop in the representation of *Osilinus* is mainly attributable to the marked reduction in the

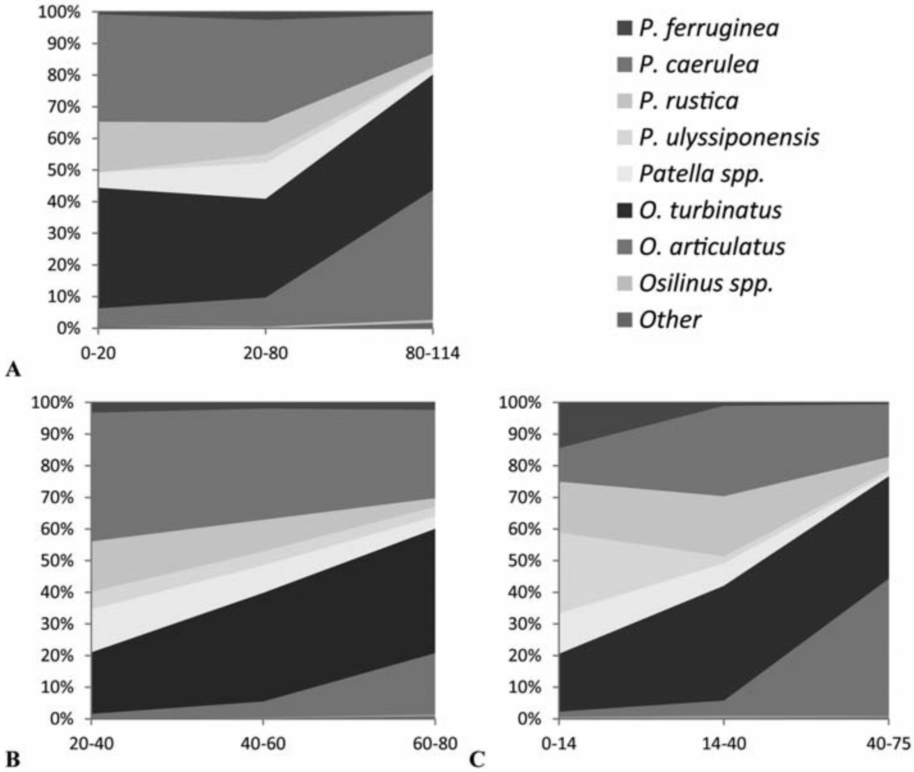


FIGURE 2

Graphs of the MNI percentages of the main species from the late Mesolithic, Mesolithic-Neolithic transition and later prehistoric phases of the three Trenches (A, B, C) excavated at Grotta d'Oriente in the 1972 campaign. The stratigraphic units of Trench A contained respectively 144 (0-20 cm), 404 (20-80 cm) and 408 (80-114 cm) individuals for a total for the trench of 957, including one specimen from the lower units. The stratigraphic units of Trench B contained respectively 433 (20-40 cm), 1306 (40-60 cm) and 1994 (60-80 cm) individuals for a total for the trench of 3820, including 87 specimens from the lower units. The stratigraphic units of Trench C contained respectively 180 (0-14 cm), 1857 (14-40 cm) and 1867 (40-75 cm) individuals for a total for the trench of 3970, including 66 specimens from the lower units. The complete MNI data have been published by Mannino & Thomas (2004: 45, tables 2, 3, 4).

numbers of *Osilinus articulatus*, while the variations in the numbers of *Osilinus turbinatus* mirror those of the *Patella* species, increasing through the Mesolithic and decreasing thereafter.

A biometric study was undertaken on shells of *P. ferruginea* and on both *Osilinus* species to verify whether the changes in species representation were linked to increased human exploitation or to environmental changes in the coastal habitats of Favignana. The statistical significance of the differences in the size distributions between stratigraphically contiguous samples with more than 5 measurable specimens was verified with the Mann-Whitney U test using SPSS 20. The results of the biometric study and of the statistical tests are shown in Table 3. The low numbers of measurable *P. ferruginea* makes it difficult to evaluate whether there was a progressive decrease in the size of specimens of this species through time (Table 3), as would be expected for over-exploited populations (Mannino, 2010). The only indication of this might be the significant reduction in size between the lowermost (0/14 cm) and uppermost (75/110 cm) units in Trench C. The mean sizes of the *Osilinus* species do not decrease progressively through the sequences of the three trenches (Table 3), which excludes the possibility that human predation was intensive enough to produce a lasting impact on their populations. Statistically significant differences have been recorded between contiguous samples both for *O. turbinatus* (A 20/80 – 80/114, A 0/20 – 80/114; B 40/60 – 60/80; C 0/14 – 14/40, C 14/40 – 40/75) and *O. articulatus* (B 40/60 – 60/80; C 14/40 – 40/75), although in all these cases increases rather than decreases in size occurred (Table 3). On the basis of this evidence, it can be concluded that *Osilinus* species were not subject to a long-term over-exploitation by the hunter-gatherers of Grotta d'Oriente, while this possibility cannot be ruled out for *P. ferruginea*.

| **Species Statistics** | **Trench A (unit in cm)** | | | **Trench B (unit in cm)** | | | | | **Trench C (unit in cm)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0<br>20** | **20<br>80** | **80<br>114** | **20<br>40** | **40<br>60** | **60<br>80** | **80<br>100** | **100<br>114** | **0<br>14** | **14<br>40** | **40<br>75** | **75<br>110** |
| *O. turbinatus* | | | | | | | | | | | | |
| number | *50* | *119* | *115* | *79* | *387* | *722* | *6* | *12* | *30* | *578* | *536* | *11* |
| mean | 22.8 | 22.5 | 21.2 | 22.5 | 22.9 | 22.3 | 21.9 | 22.5 | 24.0 | 22.3 | 21.6 | 22.4 |
| variance | 4.3 | 4.1 | 4.0 | 5.5 | 4.6 | 4.9 | 5.5 | 3.3 | 7.2 | 4.7 | 4.4 | 2.5 |
| maximum | 27.6 | 27.6 | 26.5 | 27.8 | 29.1 | 29.3 | 25.1 | 25.6 | 28.3 | 30.0 | 28.0 | 24.6 |
| minimum | 17.2 | 17.8 | 17.1 | 16.3 | 16.1 | 16.5 | 18.3 | 19.1 | 18.3 | 16.7 | 17.0 | 20.1 |
| probability | 0.494 | 0.000 | 0.000 | 0.113 | 0.000 | 0.718 | 0.553 | 0.949 | 0.000 | 0.000 | 0.208 | 0.054 |
| *O. articulatus* | | | | | | | | | | | | |
| number | *7* | *33* | *152* | *7* | *60* | *373* | *4* | *4* | *3* | *78* | *725* | *11* |
| mean | 19.6 | 20.3 | 19.3 | 21.8 | 20.6 | 19.9 | 20.5 | 18.9 | 20.1 | 20.3 | 19.0 | 18.8 |
| variance | 3.2 | 4.3 | 3.9 | 3.3 | 2.3 | 3.6 | 6.5 | 5.3 | 3.4 | 2.5 | 3.6 | 3.7 |
| maximum | 21.9 | 25.1 | 25.6 | 23.6 | 24.5 | 27.5 | 24.0 | 21.6 | 21.5 | 25.2 | 25.1 | 21.5 |
| minimum | 16.6 | 16.2 | 14.7 | 18.4 | 17.4 | 15.4 | 18.0 | 16.0 | 18.0 | 16.1 | 14.0 | 15.4 |
| probability | 0.626 | 0.080 | 0.554 | 0.050 | 0.001 | - | - | - | - | 0.000 | 0.902 | - |
| *P. ferruginea* | | | | | | | | | | | | |
| number | *6* | - | *1* | *9* | *10* | *24* | *2* | *4* | *20* | *8* | *4* | *11* |
| mean | 43.9 | - | 43.2 | 48.7 | 42.8 | 46.1 | 46.9 | 61.0 | 48.3 | 42.3 | 47.5 | 57.5 |
| variance | 5.8 | - | - | 109.7 | 12.5 | 31.8 | 37.0 | 21.5 | 56.2 | 23.7 | 236.2 | 49.2 |
| maximum | 54.2 | - | - | 71.4 | 46.0 | 55.4 | 51.2 | 65.4 | 62.5 | 48.8 | 66.6 | 68.2 |
| minimum | 38.9 | - | - | 38.3 | 34.6 | 33.1 | 42.6 | 55.1 | 35.4 | 36.7 | 34.6 | 43.5 |
| probability | - | - | - | 0.182 | 0.093 | - | - | - | 0.037 | - | - | 0.004 |

TABLE 3

Biometric data for the two *Osilinus* species (diameter in mm) and *Patella ferruginea* (length in mm). In order to test whether each set of samples from one stratigraphic unit has significantly different values from the unit that is immediately below it we adopted the Mann-Whitney U test. In the case of the samples from the lowermost units the test was carried out with the samples from the uppermost units (e.g. A80/114 and A0/20). The test was performed between samples with more than 5 specimens using SPSS 20 and the probability that the null hypothesis can be rejected or retained is shown for each species in the rows entitled 'probability'.

The archaeozoological study of the marine molluscs from the 1972 excavations at Grotta d'Oriente suggests that these resources were not collected intensively during the early Mesolithic (Mannino & Thomas, 2008), when exploitation was similar to that attested for the late Upper Palaeolithic at the site (Martini *et al*., 2007). In the course of the Mesolithic, however, there was an increase in the reliance on marine molluscs, which did not result in the over-exploitation of the *Osilinus* species, but might have impacted upon *P. ferruginea*, albeit not enough to cause its extirpation on the shores of Favignana during prehistory. Intensified predation on marine molluscs is also attested by the increased reliance on species such as *P. caerulea* and *P. rustica*, both of which are generally smaller in size than *P. ferruginea*. In fact, the increase in collection of *P. rustica* (which as mentioned above is the smallest of Mediterranean limpets), around the Mesolithic-Neolithic transition, might in itself be indicative of the over-exploitation of *Patella*. It should, however, be pointed out that even though humans might have been impacting upon the local populations of rocky shore intertidal molluscs on the island of Favignana, it is unlikely that these resources constituted more than useful dietary supplements, given that, as shown by Fa (2008) and discussed by Colonese *et al*. (2011a), the intertidal zones of Mediterranean rocky shores support a limited secondary biomass.

The inversion in the proportional representation of *Patella* and *Osilinus* is analogous to that which occurred at Grotta dell'Uzzo, also between the late Mesolithic and early Neolithic, which was attributed to a change in dietary preference (Compagnoni, 1993).This might also be the case for Grotta d'Oriente, although part of the shift in this case reflects the marked decrease in the numbers of *O. articulatus*, probably caused by changes in coastal morphology produced by rising sea levels. *O. articulatus* occupies a specific niche on rocky shores, preferring large rock pools, which are generally present on gently-shelving coasts (Menzies *et al*., 1992). *O. turbinatus*, on the other hand, prefers the more open, seaward side, of rocky shores. The rising sea levels of the early Holocene submerged gently-shelving coasts, making shores progressively more similar to their present state and, hence, increasingly more suitable for *O. turbinatus*.

## METHODS AND MATERIALS

To gain a fuller understanding of the subsistence strategies linked to the exploitation of marine molluscs it is useful to estimate the seasonality of their collection. In the context of the Mediterranean Basin, the method most commonly used to achieve this has been oxygen isotope analyses of shell carbonates (Mannino, 2010), although this has only been successfully applied to one intertidal gastropod species, namely *O. turbinatus* (e.g. Mannino *et al*., 2007, 2011b, 2012a; Colonese *et al*., 2009). The oxygen isotope ($\delta^{18}O$) composition of the exoskeletons of marine organisms is a proxy for sea surface temperature (SST) experienced during growth, when shell carbonates are secreted in so-called equilibrium with seawater. In this case, the $\delta^{18}O$ values of shell carbonates will be negatively correlated to SST (e.g. Wefer & Berger, 1991).

Mannino *et al*. (2008) demonstrated that *O. turbinatus* carbonates are reliable archives of SST during shell growth, provided that shells to be analyzed are carefully selected and that large/old specimens are avoided, given that they grow less through the year and stop growing for longer at times of physiological stress. In particular, for archaeological purposes, the oxygen isotope composition of the edge of the shell is a record of SST during the season when the mollusc died and, therefore, serves as a proxy for the estimation of the seasonality of collection.

The present isotope-based seasonality study has been conducted following the sampling strategy proposed by Mannino *et al*. (2007) for the investigation of shells from the Mesolithic site of Grotta dell'Uzzo in NW Sicily. This strategy was devised to estimate the seasonality of collection by undertaking the lowest number of isotope analyses to achieve a sufficient degree of precision, as shown by its results on shells of living animals collected monthly at different localities (Mannino *et al*., 2008). For the Grotta d'Oriente study, two shells of *O. turbinatus* were selected to obtain long sequences of determinations, to establish the yearly isotopic/temperature ranges during the early Mesolithic (specimen A, Trench C/75-110 cm) and late Mesolithic – early Neolithic (specimen A, Trench B/40-60 cm). Forty-two shells, listed in Tables 4 and 5, were selected for determining the seasons of mollusc collection during the accumulation of three stratigraphic units of Trench B (40-

| Specimen | Diameter (mm) | 3rd sample $\delta^{18}O$(‰) | 2nd sample $\delta^{18}O$(‰) | edge sample $\delta^{18}O$(‰) | % quartile | Trend | Overall trend | Season of death |
|---|---|---|---|---|---|---|---|---|
| A | 24.3 | 1.31 | 1.89 | 2.38 | >75% | ↑↑ | ↑ | Winter |
| B | 22.0 | 1.31 | 1.73 | 1.96 | >75% | ↑↑ | ↑ | Winter |
| C | 21.2 | 2.07 | 2.07 | 2.13 | >75% | =↑ | ↑n.s. | Winter |
| D | 21.3 | - | - | 2.19 | >75% | - | - | Winter |
| E | 24.5 | 1.91 | 2.02 | 2.23 | >75% | ↑↑ | ↑ | Winter |
| F | 20.3 | 2.46 | 2.64 | 2.52 | >75% | ↑↓ | ↑n.s. | Winter |
| G | 22.6 | 0.67 | - | 0.39 | 25-75% | - | ↓ | late Spring-Summer |

TABLE 4

Results of the oxygen isotope analyses on shell carbonates of O. *turbinatus* from Trench C, stratigraphic unit 75-110 cm, excavated at Grotta d'Oriente in 1972 and attribution of each specimen to its respective season of death/collection.The $\delta^{18}O$ values were obtained from the 'growing' edge ('edge sample') of all shells, while the second and third δ18O values correspond respectively to the first and second sample back from the edge sample. The '% quartile' column shows in what quartile the edge value falls into. The 'Trend' column shows the variation in the $\delta^{18}O$ values from the third to the second samples and from the second to the edge sample. The 'Overall trend' column shows whether there is an increase (↑ = up or 'cooling') or a decrease (↓= down or 'warming') in the $\delta^{18}O$ values from the third to the edge samples. In a few cases consecutive values are equal (=). In two cases the overall difference between the third and the edge samples is not greater than the measurement error (2 σ) and, therefore, not significant (= n.s.).

60 cm, 60-80 cm and 100-114 cm) and one of Trench C (75-110 cm). Most of the shells selected for analysis had diameters smaller than 23.0 mm, because, as mentioned above, these faster-growing specimens record temperature-related isotopic variability more accurately. Ten larger specimens were also analyzed to increase sample size, given that Mannino *et al*. (2008) showed that shells with diameters greater than 23.0mm can be used to estimate SST, provided that they do not have numerous closely-spaced growth checks near the aperture.

## RESULTS

The shells sampled for long series of isotope values show, as expected, cycles of high and low $\delta^{18}O$ values (Figure 3), which reflect annual temperature variations in the same way as recorded by modern shells (Mannino *et al*., 2008). As in previous studies of *O. turbinatus* from prehistoric cave sites (e.g. Mannino *et al*., 2007, 2011b, 2012), the highest and lowest values from the sequence are used to define the range of values that could, in theory, be recorded from edge samples of any shell depending on when in the year it was collected (Figure 4). In order to attribute a shell to a season, the annual isotope range is divided into quartiles, which should correspond to the coolest phase of the year (winter), to the warmest part of the year (summer) or to intermediate phases (autumn or spring). For shells which fall between the 25% and the 75% percentiles it is possible to distinguish between spring or autumn collection by inspecting the trend in $\delta^{18}O$ values in the three samples taken from the edge backwards along the axis of maximum growth.

As shown in Tables 4 and 5, all the molluscs from the early Mesolithic (Trench B/100-114 cm and Trench C/75-110 cm), except one (G from Trench C/75-110 cm), had $\delta^{18}O$ edge values which fall in the upper quartile and, therefore, were collected during the coldest part of the year between the late autumn and early spring, but most probably in the winter. No shells were collected in the warmest part of the year, while one was collected in late spring (G specimen from Trench C/75-110 cm).The difference between the edge values of shells from Trench C/75-110 cm is 2.1‰, which goes down to 0.5‰ if one excludes the outlying value of specimen G. All the shells from Trench B/100-114 cm have edge values which are within 0.5‰, comparable to what has been attested for shells recovered in roughly contemporary levels from the 2005 excavations (Colonese *et al*., 2009). This indicates that all the specimens from the lower, early Mesolithic, layers were collected in a time interval during which the temperature varied

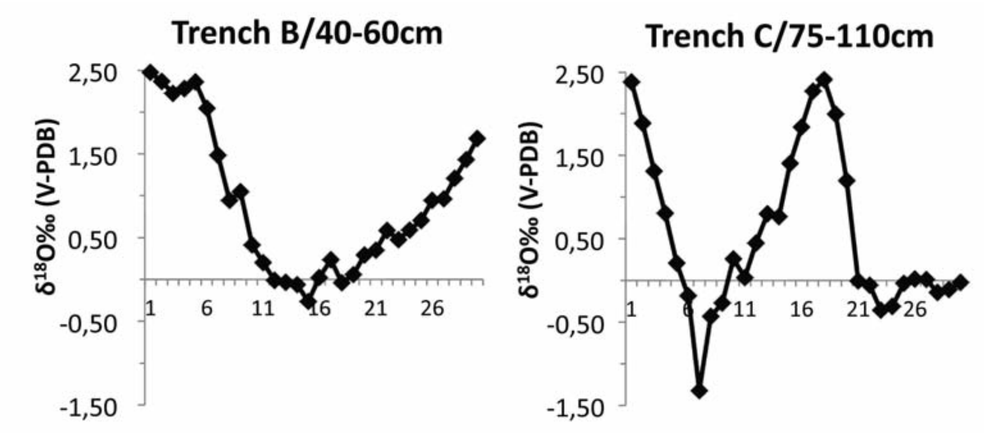


FIGURE 3

Oxygen isotope values of sequences of 30 samples taken back from the 'growing edge' (= sample 1) of shells of *O. turbinatus* from the early Neolithic – late Mesolithic (specimen A, Trench B/40-60 cm) and early Mesolithic (specimen A, Trench C/75-110 cm) deposits at Grotta d'Oriente.

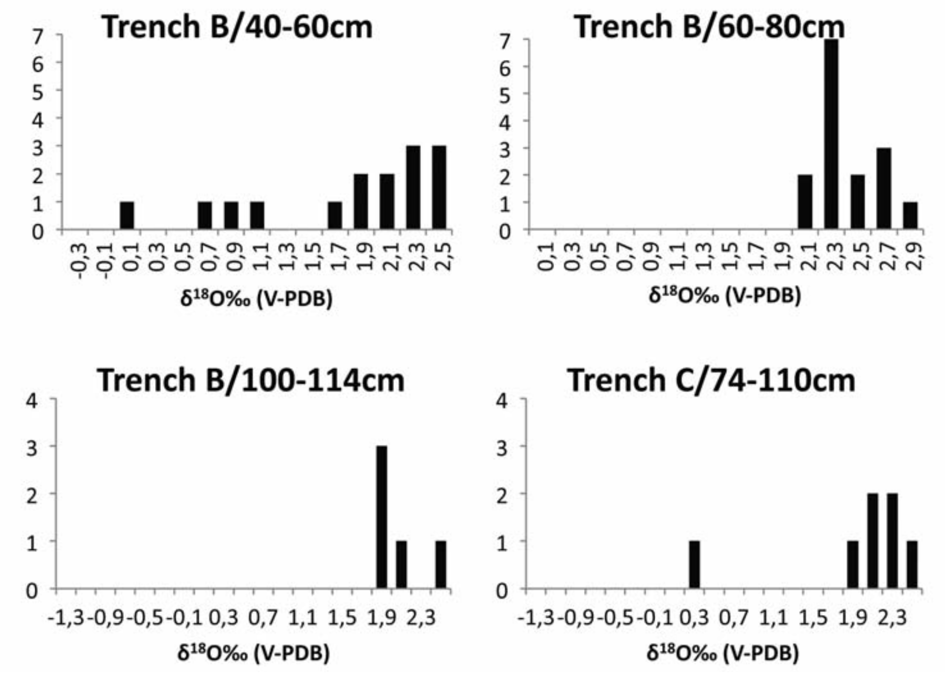


FIGURE 4

Oxygen isotope values of edge samples from shells of *O. turbinatus* from late Mesolithic – early Neolithic (Trench B/40-60 cm), late Mesolithic (Trench B/60-80 cm) and early Mesolithic (Trench B/100-114 cm; Trench C/74-110 cm) stratigraphic units at Grotta d'Oriente. The number of analyzed specimens falling into the classes of isotope values represented in the x-axis (each of which is equivalent to slightly less than 1.0 °C in SST [= 0.23‰]) is reported in the y-axis.

by around 2.0°C, a narrow range compatible with very few collection episodes. The specimens sampled from stratigraphic unit Trench B/60-80 cm (Table 5) were also collected during a restricted period of the year, given that they have a relatively narrow (= 0.8‰) range of $\delta^{18}$O edge values.

| Stratigraphic unit / Specimen | Diameter (mm) | 3rd sample δ18O(‰) | 2nd sample δ18O(‰) | edge sample δ18O(‰) | % quartile | Trend | Overall trend | Season of death |
|---|---|---|---|---|---|---|---|---|
| cm 40-60 | | | | | | | | |
| A | 23.7 | 2.22 | 2.37 | 2.48 | >75% | ↑↑ | ↑ | Winter |
| B | 22.4 | 1.72 | 1.90 | 1.94 | >75% | ↑↑ | ↑ | Winter |
| C | 19.2 | 2.23 | 2.08 | 2.32 | >75% | ↓↑ | ↑n.s. | Winter |
| D | 21.6 | 1.94 | 2.12 | 2.48 | >75% | ↑↑ | ↑ | Winter |
| E | 22.6 | 0.23 | 0.64 | 1.07 | 25-75% | ↑↑ | ↑ | Autumn |
| F | 22.2 | 2.13 | 2.38 | 2.33 | >75% | ↑↓ | ↑ | Winter |
| G | 23.8 | 0.04 | 0.27 | 0.64 | 25-75% | ↑↑ | ↑ | Autumn |
| H | 22.6 | 2.22 | 2.17 | 2.44 | >75% | ↓↑ | ↑ | Winter |
| I | 19.9 | -0.16 | -0.22 | 0.00 | <25% | ↓↑ | ↑n.s. | Summer |
| J | 20.0 | 2.25 | 2.30 | 2.10 | >75% | ↑↓ | ↓n.s. | Winter |
| K | 21.9 | -1.76 | 0.16 | 0.94 | 25-75% | ↑↑ | ↑ | Autumn |
| L | 21.3 | 1.42 | 1.55 | 2.03 | >75% | ↑↑ | ↑ | Winter |
| M | 20.7 | 1.12 | 2.00 | 2.30 | >75% | ↑↑ | ↑ | Winter |
| N | 23.2 | 2.00 | 2.20 | 1.89 | >75% | ↑↓ | ↓n.s. | Winter |
| O | 23.1 | 1.56 | 1.59 | 1.64 | 25-75% | ↑↑ | ↑n.s. | Autumn |
| cm 60-80 | | | | | | | | |
| A | 23.8 | 0.60 | 1.61 | 2.28 | >75% | ↑↑ | ↑ | Winter |
| B | 25.0 | 2.21 | 2.65 | 2.65 | >75% | ↑= | ↑ | Winter |
| C | 22.8 | 2.45 | 2.79 | 2.38 | >75% | ↑↓ | ↓n.s. | Winter |
| D | 23.1 | 1.79 | 1.95 | 2.10 | >75% | ↑↑ | ↑ | Winter |
| E | 22.6 | 2.85 | 1.37 | 2.67 | >75% | ↓↑ | ↓ | Winter |
| F | 22.3 | 2.04 | 2.42 | 2.46 | >75% | ↑↑ | ↑ | Winter |
| G | 19.2 | 2.39 | 2.79 | 2.27 | >75% | ↑↓ | ↓n.s. | Winter |
| H | 20.0 | 2.04 | 2.62 | 2.34 | >75% | ↑↓ | ↓ | Winter |
| I | 19.7 | 2.50 | 2.30 | 2.06 | 25-75% | ↓↓ | ↓ | Spring |
| J | 17.0 | 2.05 | 2.08 | 2.24 | >75% | ↑↑ | ↑ | Winter |
| K | 19.2 | 1.70 | 2.09 | 2.23 | >75% | ↑↑ | ↑ | Winter |
| L | 18.9 | 2.43 | 2.29 | 2.28 | >75% | ↓↓ | ↓n.s. | Winter |
| M | 21.7 | 1.79 | 2.12 | 2.43 | >75% | ↑↑ | ↑ | Winter |
| N | 22.3 | 2.77 | 2.69 | 2.88 | >75% | ↓↑ | ↑n.s. | Winter |
| O | 20.6 | 2.33 | 2.33 | 2.70 | >75% | =↑ | ↑ | Winter |
| cm 100-114 | | | | | | | | |
| A | 23.4 | 2.14 | 2.10 | 2.10 | >75% | ↓= | ↓n.s. | Winter |
| B | 22.4 | 1.01 | 1.53 | 1.95 | >75% | ↑↑ | ↑ | Winter |
| C | 22.7 | 2.39 | 2.25 | 2.41 | >75% | ↓↑ | ↑n.s. | Winter |
| D | 21.8 | 1.89 | 2.02 | 1.94 | >75% | ↑↓ | ↑n.s. | Winter |
| E | 19.7 | 1.69 | 1.92 | 1.99 | >75% | ↑↑ | ↑ | Winter |

TABLE 5

Results of the oxygen isotope analyses on shell carbonates of O. *turbinatus* from Trench B excavated at Grotta d'Oriente in 1972 and attribution of each specimen to its respective season of death/collection. The $\delta^{18}O$ values were obtained from the 'growing' edge ('edge sample') of all shells, while the second and third $\delta^{18}O$ values correspond respectively to the first and second sample back from the edge sample. The '% quartile' column shows in what quartile the edge value falls into. The 'Trend' column shows the variation in the $\delta^{18}O$ values from the third to the second samples and from the second to the edge sample. The 'Overall trend' column shows whether there is an increase (↑ = up or 'cooling') or a decrease (↓ = down or 'warming') in the $\delta^{18}O$ values from the third to the edge samples. In a few cases consecutive values are equal (=). In twelve cases the overall difference between the third and the edge samples is not greater than the measurement error (2 σ) and, therefore, not significant (= n.s.).

Fourteen of these shells were collected between the late autumn and the early spring, albeit more likely in the winter, while one was collected during the spring. The narrow ranges of $\delta^{18}O$ edge values recorded in individuals from the bulk of the Mesolithic deposits at Grotta d'Oriente attest that these were likely to have been subject to little or no bioturbation and were probably *in situ*.

The shells from the late Mesolithic – early Neolithic deposits (Trench B/40-60 cm) have $\delta^{18}O$ edge values ranging from 0 to 2.5‰ (Table 5), a range that covers most of the yearly variation recorded in the long sequence of isotope values in specimen A from the same stratigraphic unit (Figure 3). Taking into account the three values available for the fifteen specimens sampled from this unit (Table 5), ten shells (specimens A, B, C, D, F, H, J, L, M, N) can be interpreted as having been collected in the interval between late autumn and early spring. However, all of these were probably collected during winter, with the possible exception of J and N in which the edge values are significantly lower than those of the second sample, and which might thus represent an early spring collection. The remaining five shells sampled were collected mainly in autumn (E, G, K, O), with only a single specimen (I) collected in summer (Table 5). Specimen K has a particularly low $\delta^{18}O$ value for the third sample (= -1.8‰), probably attesting that this shell might have originated from a different layer. Overall, the results for unit Trench B/40-60 cm demonstrate that in the transitional phase between the Mesolithic and the Neolithic marine mollusc exploitation occurred throughout the year.

## DISCUSSION

The archaeozoological and isotopic studies of the marine molluscs recovered during the 1972 excavations at Grotta d'Oriente have allowed us to establish the behaviours linked to shellfish exploitation during the early Holocene, from the early Mesolithic to the Neolithic. These can be summarized, in chronological order, as follows: (i) marine molluscs were collected sporadically and in small numbers during the early Mesolithic, (ii) their exploitation was more intensive in the late Mesolithic although it continued to be strongly seasonal, (iii) in the transition to the early Neolithic, exploitation continued to be intensive and occurred in most seasons, while (iv) mollusc consumption, and probably cave occupation, became sporadic again after this.

The restricted mollusc exploitation during the early Mesolithic is probably indicative of the site's sporadic occupation, which at this time might have been linked to its use for funerary rituals (Di Salvo *et al*., in press). Comparable isotopic results have been obtained by Colonese *et al*. (2009) from shells recovered in early Mesolithic levels during the 2005 excavations at Grotta d'Oriente. Later on in the Mesolithic molluscs were also exploited during the coldest time of the year, but probably over longer periods of time, as has been attested at contemporary levels at Grotta dell'Uzzo (Mannino *et al*., 2007), but also more generally for early Holocene occupation deposits in NW Sicily (Mannino & Thomas, 2009). Colonese *et al*. (2009) have suggested that this strong bias in the seasonality of marine mollusc exploitation was the result of it being subsidiary to red deer (*Cervus elaphus*) hunting, the subsistence activity which provided most of the dietary protein to the Late Pleistocene and early Holocene hunter-gatherers of Sicily (Mannino *et al*., 2011a, 2011b). This seasonal pattern lasted till the late stages of the Mesolithic, as shown by Colonese *et al*. (2009), after which there was a dramatic expansion in the periodicity of shellfish collection at Grotta d'Oriente, as attested here by the Mesolithic – Neolithic samples of Trench B/40-60cm. At this time (ca. 7500 cal BP) Favignana was 'hanging by a thread' to the mainland (Figure 1), but, in spite of this increasing marginality, the reliance on marine molluscs by the hunter-gatherers living on this strip of land appears to have been analogous to that documented for contemporary groups in NW Sicily (Mannino *et al*., 2007, 2011b). Had Grotta d'Oriente represented a central place, then it could have been argued that the over-representation within its deposits of low-ranked food taxa, such as rocky shore intertidal gastropods, compared to higher-ranked taxa, such as marine molluscs from soft-bottom shores, was linked to strategies of optimal foraging (Bird & Bliege Bird, 1997). However, it is unlikely that Grotta d'Oriente ever represented a central place, not only due to its difficult access, but also to the restricted seasonality of shellfish exploitation from it, which has been attested both in this study and by Colonese *et al*. (2009), and to the few remains of food refuse recovered within it (Mannino, 2004; Mannino & Thomas, 2004; Martini *et al*., 2007). The dearth of evidence for the exploitation of molluscs from lagoons and wetlands at Grotta d'Oriente during the early Holocene can, in our view, be taken as evidence of absence of this subsistence activity. In fact, these habitats were becoming rarer during the isolation of Favignana, as the shoreline became more rocky and similar to its present state, and there is little evidence for the consumption of taxa from such habitats at sites on the Ègadi Islands (Cassoli & Tagliacozzo, 1982; Mannino & Thomas, 2004, 2010; Martini *et al*., 2007). Overall, the hunter-gatherers of Grotta d'Oriente do not appear to have adapted their subsistence and diet specifically to cope with the dramatic changes in the geography of their seascape and landscape, as also attested by carbon and nitrogen isotope analyses on the bone collagen of humans buried at this site (Mannino *et al*., 2012b). Further research is needed to clarify the role of coastal resources in the subsistence of the Favignana hunter-gatherers, but presently available data suggests that they relied on shellfish, fish and other marine taxa at similar levels to contemporary groups living in mainland Sicily, such as those that occupied Grotta dell'Uzzo (Tagliacozzo, 1993). In summary, analogously to what has been documented for foragers worldwide (e.g. Meehan, 1982), the frequency of marine mollusc gathering from Grotta d'Oriente probably changed through time as a result of changes in three inter-related factors: (i) its distance from the coast, (ii) the seasonal cycle and (iii) ceremonial obligations, which in the case in question might have included activities connected to the periodic use of the cave as a burial site.

The mollusc assemblage from Grotta d'Oriente offers a unique opportunity to test the role of rocky shore intertidal gastropods in the subsistence of Mediterranean foragers, given that with isolation the hunter-gatherers of Favignana might have been forced to exploit increasingly low-return coastal taxa. In a very different environment, such as Arnhem Land in the Northern Territory (Australia), shellfish played many different roles in the diet of the Anbarra people; they were staple foods, subsidiary foods, snacks or alternative foods when foraging for other resources failed (Meehan, 1982). The hunter-gatherers of Grotta d'Oriente used marine molluscs as subsidiary and alternative foods and as sources of micronutrients difficult to obtain from the terrestrial resources that constituted the bulk of the diet (Mannino *et al*., 2012b). The consumption of marine molluscs might essentially have been mainly a 'matter of taste', given that the vitamins, minerals and omega-3 fatty acids confer to them a distinctive flavour and that they were a source of fresh food available at any time. Shellfish are sometimes consumed for similar motivations by foragers, as documented by Meehan (1982), and this has also been the case for their consumption in Sicily, where it has traditionally been recognized that shellfish are a meagre source of food. A local proverb (*Pateddi, rizzi e granci, spenni assai e nenti manci*) sums it up: «to collect limpets, sea urchins and crabs, one spends a lot but eats little».

## CONCLUSIONS

The marine molluscs from Grotta d'Oriente provide useful insights into their potential role as food in the diets of prehistoric people in the Mediterranean. These resources were probably important for the hunter-gatherers of Favignana in terms of their dependability and of their nutritional composition. The present study, however, supports the hypothesis of Colonese *et al*. (2011a) that marine molluscs, and in particular rocky shore intertidal gastropods, were only a minor source of protein for human foragers in Mediterranean coastal environments. We think this is likely to be true for the whole Mediterranean Basin, although it should be tested further through approaches similar to those adopted here, particularly along the coasts of the Alboran Sea, where available shellfish biomass might be slightly higher (Fa, 2008).

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