Holocene coastal change and intertidal mollusc exploitation in the central mediterranean: variations in shell size and morphology at Grotta d'Oriente (Sicily)

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ABSTRACT: Grotta d'Oriente, on the island of Favignana (NW Sicily, Italy), preserves evidence of the human exploitation of marine resources dating back to the early Holocene (Mesolithic and Mesolithic-Neolithic transition), at the time of dramatic coastal changes in the area during the isolation of Favignana from Sicily. Mesolithic and Meso-Neolithic deposits contained abundant intertidal mollusc remains, offering the opportunity to explore potential effects of human collection and coastal environmental changes on size and shape of some target species (e.g. *Patella caerulea*/*ulyssiponensis* and *Osilinus turbinatus*). Morphometric analysis reveals a significant reduction in the size of *P. caerulea*/*ulyssiponensis* shells between Mesolithic and Meso-Neolithic phases, corresponding with the interval of more intense shellfish exploitation. In the case of *O. turbinatus*, there is a significant change in shell shape, with slender Mesolithic shells being replaced by squatter forms in the Meso-Neolithic. These differences suggest the concomitance of environmental factors and exploitation pressure in the case of *P. caerulea*/*ulyssiponensis*, whereas the differences in shape of *O. turbinatus* seems more consistent with collection shifting from sheltered shores in the Mesolithic to exposed rocky shores in the Meso-Neolithic.

KEYWORDS: EARLY HOLOCENE, CENTRAL MEDITERRANEAN, SICILY, MESOLITHIC AND MESOLITHIC-NEOLITHIC TRANSITION, INTERTIDAL EXPLOITATION, SHELL SIZE VARIABILITY

RESUMEN: Grotta d'Oriente, en la isla de Favignana (NW Italia, Sicilia), presenta evidencias de la explotación humana de los recursos marinos en el periodo cronológico correspondiente al Holoceno antiguo (Mesolítico y transición Mesolítico-Neolítico). Este hecho, se corresponde con el registro de cambios importantes en la costa, ocurridos durante el aislamiento de Favignana de Sicilia. Los depósitos mesolíticos y meso-neolíticos contienen abundantes restos de moluscos intermareales, que ofrecen la oportunidad de explorar los posibles efectos de la explotación humana y de los cambios ambientales en los tamaños de los principales taxones recolectados (*Patella caerulea*/*ulyssiponensis* y *Osilinus turbinatus*). Los resultados morfométricos revelan una disminución significativa en los tamaños de *P. caerulea*/*ulyssiponensis* entre la fase Mesolítica y Meso-neolítica, en relación con el momento de mayor explotación. Los datos de *O. turbinatus*, por el contrario, indican un cambio significativo en la forma que se refleja con conchas más altas y más bajas en el Mesolítico y Meso-Neolítico respectivamente. En el caso de *P. caerulea*/*ulyssiponensis*, las variaciones en las medidas parecen relacionadas sea con factores ambientales que con una posible intensificación de la recolección durante la

fase Meso-neolítica, mientras que las variaciones en las conchas de *O. turbinatus* probablemente reflejan un cambio en la formación de la costa, que pasa de protegida a expuesta entre el Mesolítico y Meso-Neolítico respectivamente.

PALABRAS CLAVE: HOLOCENO ANTIGUO, MEDITERRÁNEO CENTRAL, SICILIA, MESOLÍTICO Y TRAN-SICIÓN MESOLÍTICO-NEOLÍTICO, EXPLOTACIÓN INTERMAREAL, VARIABILIDAD EN EL TAMAÑO DE LAS CONCHAS

INTRODUCTION

There have been almost not studies of the impact of past societies on marine resources in the Mediterranean (e.g. Morales-Muñiz & Roselló-Izquierdo, 2004, 2008; Lotze *et al.*, 2006, 2010), even less on prehistoric times (e.g. Stiner *et al.*, 1999, 2000; Hunt *et al.*, 2011; Mannino *et al.*, 2011), in spite the worldwide interest in the topic (e.g. Mannino & Thomas, 2001; Jerardino *et al.*, 2008; Rick & Erlandson, 2008; Gutiérrez-Zugasti, 2011). This is particularly surprising given that the Mediterranean Sea, in spite of its huge biodiversity, is poorly productive (Zenetos, 2002) and the impact of human activities are proportionally stronger here than in any other sea of the world (Coll *et al.*, 2010). Although recent studies demonstrate that prehistoric pressure on Mediterranean marine resources has no measurable effect compared to historical times (e.g. Lotze *et al.*, 2006; Morales-Muñiz & Roselló-Izquierdo, 2008; Coll *et al.*, 2010), scattered evidence suggest some degree of impact on intertidal zones dating back to the Late Pleistocene and early Holocene. These evidence emerge, for instance, from the size reduction of some intensively collected intertidal mollusc species (e.g. *Patella* spp., *Osilinus turbinatus*) from the Upper Palaeolithic through the Epipaleolithic (Stiner *et al.*, 1999, 2000; Hunt *et al.*, 2011), as well as by the gradual decline of the endemic limpet species *Patella ferruginea* through the early-middle Holocene in Italian peninsula and Sicily (e.g. Durante & Settepassi, 1972; Compagnoni, 1991; Ghisotti, 1997). Such archaeological records likely represent the earliest evidence of the anthropogenic pressure on Mediterranean coastal areas, and are important in the historical assessment of human population growth and impact on Mediterranean coastal ecosystems on the whole.

Grotta d'Oriente, on the island of Favignana (NW Sicily, Italy, Figure 1A-B), preserves evidence of the human exploitation of marine resources dating back to the early Holocene, during Mesolithic and Mesolithic-Neolithic (Meso-Neolithic) occupation of the cave. These occupation episodes occurred at the time of dramatic coastal changes in the area, with the isolation of Favignana from Sicily in about less than one millennium (from ~8 to ~7 cal ka BP, using data from Antonioli *et al.*, 2002). Mesolithic and Meso-Neolithic deposits at Grotta d'Oriente, therefore, offer the exceptional opportunity to explore potential effects of human collection and coastal environmental changes on size and morphology of some of the most targeted species during the Holocene in the area. This paper presents the results of morphometric analysis of shells of intertidal species from the early Holocene succession of Grotta d'Oriente. It provides new insights into the role played by coastal resources for late hunter-gatherers in Mediterranean regions.

ENVIRONMENTAL AND ARCHAEOLOGICAL SETTING

Favignana is the largest (~20 km^2) of a group of the small islands forming the Egadi Archipelago, at about 5 km from the NW coast of Sicily, Italy (Figure 1A). It is estimated to have been isolated by rising sea levels between ~8 and ~7 cal ka BP (Agnesi *et al.*, 1993; Antonioli *et al.*, 2002). Coastal areas are mostly composed by reefs (rocky shores), but small sand beaches are also present. Vegetation includes heath, scrub, maquis and garrigue, mixed with annual dry grassland and pseudo-steppe (Rete Natura, 2000: http://www.minambiente.it/).
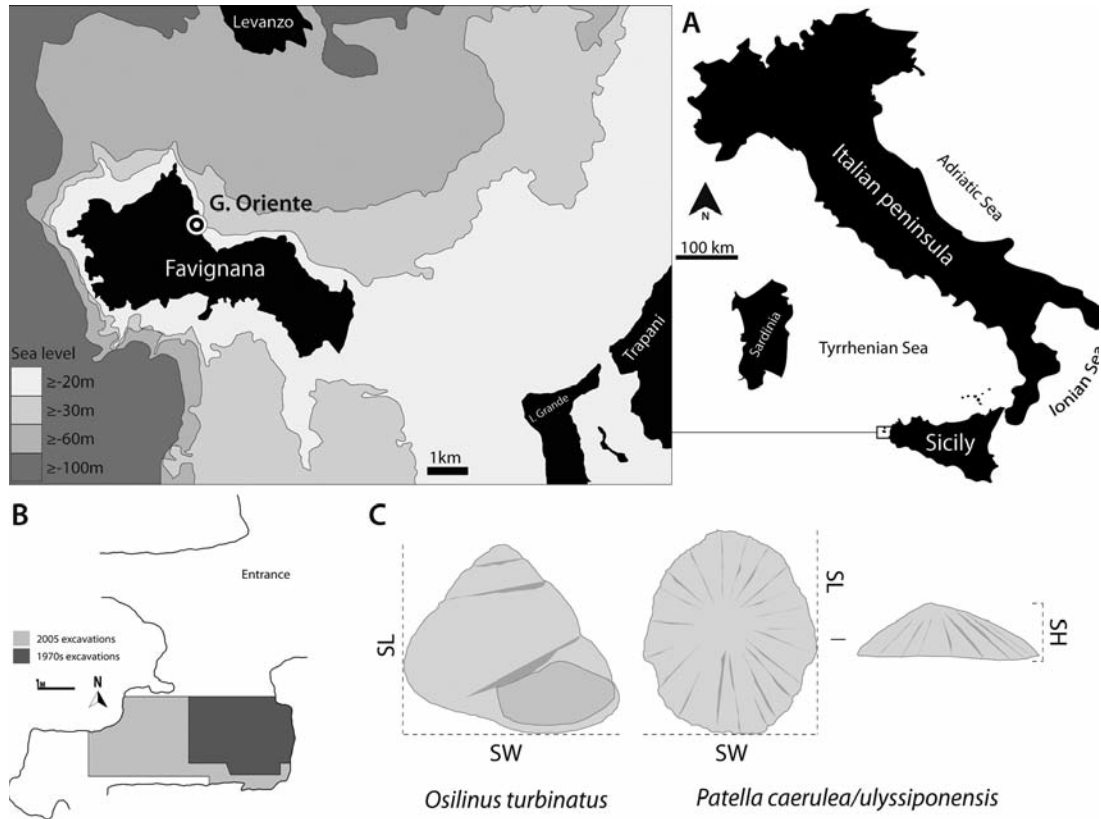
FIGURE 1

(A) Geographic position of Favignana (Sicily) showing Grotta d'Oriente (ORT). (B) Position of archaeological excavation and prove-nance of marine molluscs from ORT (2005 excavations). (C) Morphometric parameters used in this study.

Grotta d'Oriente (ORT) is a small calcareous cave located on the slope of the «Montagna Grossa», at ~40 m above sea level (a.s.l.). The cave was first excavated in the early 1970s (Mannino, 1972) and subsequently in 2005 (Martini *et al*., 2009, in press); material presented in this study was obtained during the 2005 field season (Figure 1B). The sedimentary succession (~2 m thick) provided cultural evidence spanning from the Late Glacial to the middle Holocene, represented by Upper Palaeolithic (Layers 7A - 7E), Mesolithic (Layers 6A - 6D), Mesolithic-Neolithic transition (Meso-Neolithic) or early Neolithic (Layers 5A - 5C) and Bronze Age (Layers 4 - 3) phases (Table 1; Colonese *et al*., 2009, 2011b; Martini *et al*., 2009, in press). In particular, the Meso-Neolithic deposit yielded cultural evidence relating to the end of the local Mesolithic and the beginning of the Neolithic in Sicily. The stone tools production

present some features comparable to the Castel-novian model previously recognized in early Neolithic occupations of Grotta dell'Uzzo (e.g. Tusa, 1996); pottery remains are absent, but domestic fauna have been found (Martini *et al*., in press). These cultural phases (indicated by numbers) contained occupation episodes (indicated by letters) composed by structured hearths, pits and abundant faunal remains (mostly marine). Previous isotopic analysis on shells of *O. turbinatus* revealed that some of these occupation episodes (layers 6C and 5A) occurred at very short-term scale (Colonese *et al*., 2009). A human burial was found in the Upper Palaeolithic layer 7D (Lo Vetro & Martini, 2006; Martini *et al*., 2007; Craig *et al*., 2010), and adds to two others excavated by Mannino in 1972 (Mannino, 1972, 2002; D'Amore *et al*., 2010).

Layers	^{14}C yr BP	^{14}C yr cal BP (68%)	^{14}C yr cal BP (95%)	Lab. code	Material	Cultural epoch
5A	7040±55	7870±60	7990 – 7750	LTL877A	Charcoal	Meso-Neolithic
6B	8619±65	9610±70	9750 – 9470	LTL876A	Charcoal	Mesolithic
6C	8608±65	9600±70	9740 – 9460	LTL874A	Charcoal	Mesolithic
6D	8699±60	9690±100	9890 – 9490	LTL875A	Charcoal	Mesolithic
7E	12,132±80	14,200±220	14,640 -13,760	LTL873A	Charcoal	Upper Palaeolithic

TABLE 1

Radiocarbon ages based on charcoal. ^{14}C ages are reported as conventional and calibrated BP. 1 sigma ^{14}C ages (68% probability) are reported as weighted average values along with standard deviations. 2 sigma ^{14}C ages (95% probability) are reported as range. Calibration was performed with CALPAL_A (advanced) (http://www.calpal.de; Weninger & Jöris, 2010).

A preliminary study on marine mollusc remains revealed exploitation focused mainly on intertidal taxa inhabiting rocky shores (e.g. *Patella* spp. and *Osilinus* spp.) during both Mesolithic and Meso-Neolithic occupations (Colonese, in press). Upper Palaeolithic shellfish collection was limited, compared with these subsequent phases. However both Upper Palaeolithic and Mesolithic deposit have yielded a considerable amount of shells of Cerithiidae, and in particular *Potamides conicus*, suggesting the use of transitional environments (e.g. coastal lagoons, estuaries) during the cave occupation. Abundant land snail shells are also present in this archaeological deposit (Colonese *et al*., 2011b).

MATERIALS AND METHODS

Analysed shells were recovered from bulk sediments by washing through a 1.5 mm sieve (e.g. Colonese, in press; Martini *et al*., in press). Morphometric analysis were carried out on shells of the genus *Patella* and *Osilinus*, the most abundant taxa at ORT and commonly exploited resource around the Mediterranean basin during this period (e.g. Colonese *et al*., 2011a). The genus *Patella* is present at ORT with highly variable shell morphology. It is difficult to discriminate between shells of *P. caerulea* and *P. ulyssiponensis* that display wide morphology and colour in many Italian (Cretella *et al*., 1990), but also in other Mediterranean and Atlantic coasts (Sanna *et al*., 2012). Indeed previous studies demonstrated the unreliability of their specific identification using only shell morphometric parameters, emphasizing

the necessity of genetic approaches (Mauro *et al*., 2003; Petraccioli *et al*., 2010; Sanna *et al*., 2012). Shells with the characteristics of *P. caerulea* and *P. ulyssiponensis* were identified, and are here reported, as *P. caerulea/ulyssiponensis*.

Morphometric analyses were carried out on samples of shells retrieved randomly from distinct Mesolithic (layers 6A-D) and Mesolithic-Neolithic (layers 5A-C) occupation episodes (Table 2). Shell length (SL), width (SW), height (SH; only for *P. caerulea/ulyssiponensis*) were measured using a digital calliper accurate to 0.01mm (see Figure 1C for morphometric parameters). Shell shape was investigated using SL/SW ratio (Menzie *et al*., 1992) for *O. turbinatus* and SH/SL ratio (Cabral & da Silva, 2003; Cabral, 2007) for *P. caerulea/ulyssiponensis*. A conspicuous number of shells were considerably broken or partially fragmented. In particular, shells of *O. turbinatus* exhibited a high frequency of fractures in the apex (from 63% to 86%, depending upon layer). *P. caerulea/ulyssiponensis* often had broken margins, thus quantitative data may vary substantially between some layers and morphometric parameters, which does introduce a degree of uncertainty.

The normal distribution of data was tested out using the Shapiro-Wilk test in PAST 2.13 (Hammer *et al*., 2001). Most of data are normally distributed for both *P. caerulea/ulyssiponensis* and *O. turbinatus*, but in some cases the normal distribution was rejected (Table 2). Therefore comparisons between layers and cultural phases were carried out using both a parametric test for the analysis of variance (One-way ANOVA), which assumes that samples are close to the normal distribution, along with a non-parametric test for the comparison of medians (Kruskal-Wallis). For both tests a statisti-

	Meso-Neolithic 7.870 cal BP			Mesolithic 9.600 – 9.690 cal BP				ANOVA	Kruskal Wallis
	5A	5B	5C	6A	6B	6C	6D	(p)	(p)
Median SL (mm)									
P. caerulea/ulyssiponensis	**28.0±5.2**	**28.7±5.7**	**29.4±5.6**	**32.3±5.2**	**32.2±4.9**	**32.0±6.0**	**33.0±4.9**	< 0.0001	< 0.0001
	= 0.0235	= 0.1382	= 0.0200	= 0.182	= 0.7201	= 0.0325	= 0.1748		
	(p < 0.05)	(p > 0.05)	(p < 0.05)	(p > 0.05)	(p > 0.05)	(p < 0.05)	(p > 0.05)		
	(n = 163)	(n = 146)	(n = 118)	(n = 90)	(n = 62)	(n = 39)	(n = 65)		
O. turbinatus	**19.0±2.8**	**19.4±3.3**	**19.3±3.3**	**20.0±2.7**	**21.3±3.0**	**20.0±2.2**	**21.0±3.5**	< 0.001	< 0.001
	= 0.0605	= 0.1461	= 0.627	= 0.8788	= 0.249	= 0.3231	= 0.4265		
	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)		
	(n = 61)	(n = 50)	(n = 53)	(n = 17)	(n = 56)	(n = 29)	(n = 33)		
Median SW (mm)									
P. caerulea/ulyssiponensis	**24.0±4.5**	**24.8±5.5**	**25.0±4.7**	**27.1±4.9**	**28.7±4.7**	**28.0±4.9**	**28.2±5.1**	< 0.0001	< 0.001
	= 0.0007	= 0.0010	= 0.02157	= 0.01613	= 0.047	= 0.3395	= 0.1618		
	(p < 0.05)	(p < 0.05)	(p < 0.05)	(p < 0.05)	(p < 0.05)	(p > 0.05)	(p > 0.05)		
	(n = 137)	(n = 172)	(n = 119)	(n = 90)	(n = 64)	(n = 36)	(n = 58)		
O. turbinatus	**20.5±2.5**	**21.0±2.5**	**21.0±2.6**	**22.0±2.0**	**21.0±2.2**	**20.0±2.1**	**21.0±2.4**	< 0.0001	< 0.0001
	= 0.5913	= 0.1672	= 0.8006	= 0.0644	= 0.5268	= 0.0627	= 0.7853		
	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)		
	(n = 137)	(n = 156)	(n = 144)	(n = 131)	(n = 155)	(n = 91)	(n = 121)		
Median SH/SL									
P. caerulea/ulyssiponensis	**0.330±0.05**	**0.317±0.05**	**0.308±0.05**	**0.306±0.04**	**0.299±0.04**	**0.293±0.03**	**0.288±0.03**	< 0.0001	< 0.0001
	= 0.2106	= 0.9229	= 0.9798	= 0.9911	= 0.9768	= 0.9635	= 0.9379		
	(p > 0.05)	(p < 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p < 0.05)		
	(n = 103)	(n = 114)	(n = 83)	(n = 70)	(n = 56)	(n = 31)	(n = 51)		
Median SL/SW index									
O. turbinatus	**0.952±0.05**	**0.961±0.06**	**0.971±0.07**	**1.000±0.07**	**1.000±0.05**	**0.973±0.55**	**1.000±0.06**	< 0.001	< 0.001
	= 0.0003	= 0.5312	= 0.2512	= 0.6818	= 0.27	= 0.0173	= 0.1299		
	(p < 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p > 0.05)	(p < 0.05)	(p > 0.05)		
	(n = 61)	(n = 50)	(n = 51)	(n = 17)	(n = 55)	(n = 29)	(n = 33)		

TABLE 2

Median SL, SW, SH/SL and SL/SW of *Patella caerulea/ulyssiponensis* and *Osilinus turbinatus* from Mesolithic and Meso-Neolithic occupation episodes. [14]C ages (cal BP) are also reported at 1σ (68% probability, see Table 1). Comparison of mean (ANOVA) and median (Kruskal-Wallis) of morphometric parameters between layers are also reported, along with results of the normal distribution of data (Shapiro-Wilk).

cal significance threshold of α=0.05 was assumed. Data were then grouped into quartiles (Box-plot using interpolation) combined with jitter plots (40 jitters), where each value is plotted as a dot (Hammer *et al*., 2001). Quartile distribution organizes values into four different groups of equal parts consisting with 1/4th of the data set. Lowest and highest values are grouped in the lower (lowest 25% of data) and upper quartile (upper 25% of data) respectively. Intermediate values are grouped into the interquartile range (>25% and <75%) and the horizontal line inside the box represents the median; the use of median was preferred because it is less influenced by asymmetrical distribution of data.

Although the animal age is an important parameter in shell-size analysis (e.g. Gutiérrez-Zugasti, 2011), this variable was not taken into account in the present study because reliable estimations of age structure cannot be assessed using external growth increments in both *P. caerulea/ulyssiponensis* and *O. turbinatus* (e.g. Bannister, 1975; Mannino *et al*., 2008).

RESULTS

Shell-size of *P. caerulea/ulyssiponensis* and *O. turbinatus* varies significantly between archaeological layers (Table 2, Figure 3A-F). Median SL and SW in *P. caerulea/ulyssiponensis* range from 33 mm (layer 6D) to 28 mm (layer 5A) and from 28.7 mm (layer 6B) to 24 mm (layer 5A) respectively. As concern *O. turbinatus*, median SL and SW ranges from 21.3 mm (layer 6B) to 19 mm (layer 5A) and from 28.7 mm (layer 6B) to 24 mm (layer 5A) respectively. Results from *P. caerulea/ulyssiponensis* reveal a significant reduction in both SL and SW from the Mesolithic to the Meso-Neolithic by 5 and 4 mm respectively. Although its shell height (SH) does not differ statistically through the stratigraphic succession, significant variability has been observed in the shell conicity index (SH/SL). The Mesolithic assemblages yielded the flattest shells of the sequence (e.g. 0.288 in layer 6D compared to 0.330 in layer 5A).

Size variability also occurs in shells of *O. turbinatus* but they do not follow the same trend of
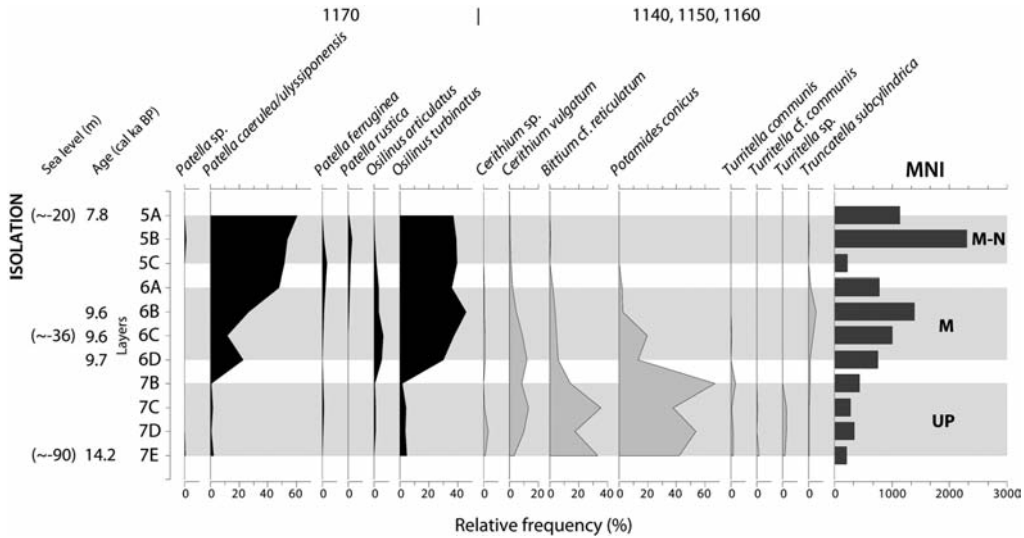
FIGURE 2

Relative frequency of selected species of marine mollusc remains from Upper Palaeolithic (UP), Mesolithic (M) and Meso-Neolithic (MN) layers at Grotta d'Oriente. The minimum numbers of individuals (MNI) are also reported on the right. Indication of sea level stands at the moment of Late Pleistocene and Holocene occupation episodes (see Antonioli *et al*., 2002) are shown alongside the ^{14}C ages at 1 sigma (68% probability, see Table 1). Habitat type codes of selected species follow the European Union Habitats Directive. (http://ec.europa.eu/environment/nature/natura2000/marine/index_en.htm). 1140: Mudflats and sandflats not covered by sea water at low tide; 1150: Coastal lagoons; 1160: Large shallow inlets and bays; 1170: Reefs.
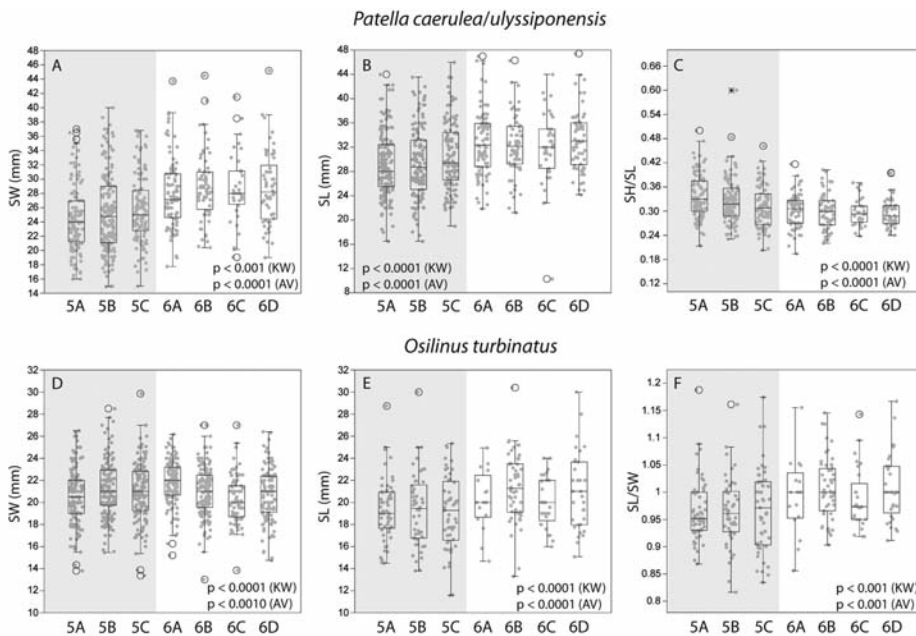

FIGURE 3

A-F. Combined box and jitter plots (grey dots) representing variations in morphometric parameters of (A-C) *Patella caerulea*/*ulyssipo-nensis* and (D-F) *Osilinus turbinatus* between Mesolithic (6A-D) and Meso-Nesolithic (5A-C) layers. Outliers are represented by circles. Results from Kruskal-Wallis (KW) and ANOVA (AV) tests between distinct layers are also reported for each parameter.

P. caerulea/ulyssiponensis. Median SL oscillate of 2 mm between Mesolithic and Meso-Neolithic occupations (i.e. SL), while the SW vary also within the same Mesolithic period. Its shell shape (SL/SW) displays significant variability between layers, ranging from 1.00 (layers 6D, 6A-B) to 0.95 (layer 5A), basically due to changes in SL. Conversely to *P. caerulea/ulyssiponensis*, results from *O. turbinatus* attest to a significant shift from slender to squatter shells between Mesolithic and Meso-Neolithic occupation respectively.

Significant differences also occur at long-time scales (Figure 4A-F). Both SL and SW in *P. caerulea/ulyssiponensis* are significantly larger at ~9.6 cal ka BP compared with shells successively collected at ~7.8 cal ka BP. The significant differences detected in the SH/SL ratio between these time intervals reflect the remarkable change from slightly conical to a more flat forms. The opposite trend is recorded in *O. turbinatus* between ~9.6 and ~7.8 cal ka BP. The decline in SL is the main responsible for changes in its shell shape, promoting squatter shells at ~7.8 cal ka BP compared with those at ~9.6 cal ka BP.

DISCUSSION AND CONCLUSIONS

The results show significant variability in shell size and shape of *P. caerulea/ulyssiponensis* and *O. turbinatus* at ORT. However, the pattern of morphometric variability between these species differs considerably. *P. caerulea/ulyssiponensis* are present with larger and more conical shells during Mesolithic occupations compared with subsequent Meso-Neolithic phases (Figure 3A-C, 4A-C). Contrarily, *O. turbinatus* shows significant changes in shell-shape between populations, with shells becoming squatter during the same time-interval. Such morphometric variability occurs at the time of enhanced exploitation of intertidal resources at ORT, but also during major environmental changes in the region (Figure 2), making it difficult to attribute these changes to anthropogenic (intensification) or natural forces (environmental changes).

Between ~9.6 and ~7.8 cal ka BP, coastal areas of the NW Sicily underwent important environmental changes. The early-middle Holocene rise
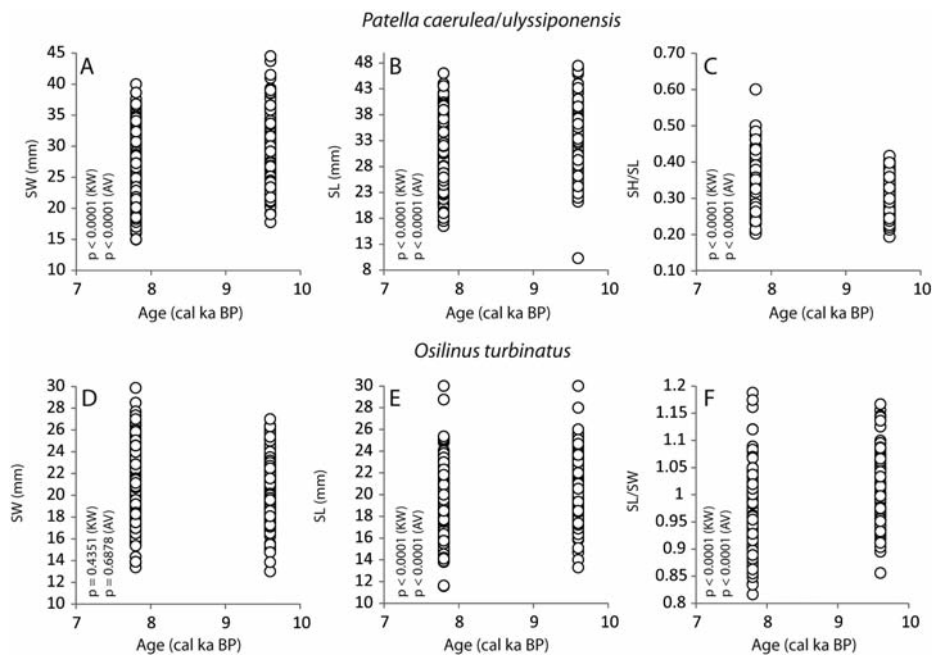

FIGURE 4

A-F. Variations in morphometric parameters of (A-C) *Patella caerulea/ulyssiponensis* and (D-F) *Osilinus turbinatus* plotted against a Holocene timescale (ka cal BP) derived from ^{14}C calibration (68% probability; Weninger and Jöris, 2010) of archaeological layers discussed in the text. Results from Kruskal-Wallis (KW) and ANOVA (AV) tests between time intervals are also reported for each parameter.

of sea level promoted a progressive coastal reorganization by isolating Favignana from the Sicily (Agnesi *et al*., 1993). Human responses to this unprecedented abrupt environmental change are attested at ORT with the enhanced incorporation of coastal resources during the Meso-Neolithic occupation, as suggested by the increase of shellfish (Figure 2) and fish remains (*ongoing study*) in these deposits. From isolation, the hunting of land mammals on the island is likely to have become progressively less sustainable, and this seems to be supported by the scarcity of land mammals in these deposits (Martini *et al*., in press). Our data suggest that coastal resources play a more crucial economic role during and after island formation; it is at this time that a significant reduction of size of *P. caerulea/ulyssiponensis* takes place at ORT. Results show an interesting correlation between increased use of coastal resources and size reduction of *P. caerulea/ulyssiponensis*, represented by a broadening of size-range of collected individuals during the Meso-Neolithic, with particular focus on smallest individuals (Figure 3A-C). This first observation suggests an anthropogenic factor in the size decline of this intertidal taxa between the Mesolithic and the Meso-Neolithic.

However size distribution in Patellidae shells are particularly complex, and may involve the interplaying of environmental factors at different spatial and temporal scales (e.g., Lewis & Bowman, 1975; Thompson, 1980; Jenkins & Hartnoll, 2001; Campbell, 2008). Differences in coastal exposure have been invoked to explain intraspecific variability in growth rate of *Patella* but data are somewhat controversial, with studies reporting the occurrence of both large (higher growth rate) and small (lower growth rate) individuals in correspondence to exposed shores (e.g. Jenkis & Hartnoll, 2001; Bailey & Craighead, 2003; Gutiérrez-Zugasti, 2011). Similar variability occurs with zonation pattern of *Patella* size classes. Previous studies have indeed observed larger animals in lower intertidal zones compared with upper areas (e.g. Thompson, 1980), but opposite examples have been also reported (e.g. Blackmore, 1969). Because the set of studied shells likely includes both *P. caerulea* and *P. ulyssiponensis*, size variations cannot be ascribed to taxonomic differences and to their different distribution on the shore (Bannister, 1975). Climatic variability seems to be excluded from observed size variations because regional marine palaeoclimatic records do not envisage substantial changes during these intervals

(e.g. Incarbona *et al*., 2010). However the different number of measured shells per layer may result in some degree of uncertainty in size comparison (Table 2).

The SH/SL of archaeological specimens does not correlate with SL (R^2 = 0.00 and 0.12 at ~9.6 and ~7.8 cal ka BP respectively) indicating that shell growth in Holocene *P. caerulea/ulyssiponensis* at ORT was isometric (e.g. Cabral, 2007). As consequence differences in shell conicity between Mesolithic and Meso-Neolithic occupations is likely to involve changes in environmental conditions (e.g. Chapman, 1995; Cabral & da Silva, 2003), complex to assess in past populations. Intraspecific variability in shell-shape has been explained in terms of phenotypic adaptation to hydrodynamic forces (e.g. Trussell *et al*., 1993; Prowse & Pile, 2005). Shell-shape variability in limpets have been observed between exposed and sheltered areas, but also between intertidal zones (e.g. Cabral & da Silva, 2003). These previous observations suggest that molluscs at ORT may have been collected in coastal areas with distinct wave exposure between ~9.6 (exposed) and ~7.8 (sheltered) cal ka BP. Alternatively Mesolithic and Meso-Neolithic groups may have adopted distinct harvesting strategies. Collections during the Mesolithic may have been focused on lower intertidal zones or in exposed shores. Conversely, Meso-Neolithic groups would have collected limpets on upper intertidal zones or in sheltered coastal areas. In anticipation of further regional studies on prehistoric *Patella* assemblages, our results suggest that variability in shell size and shape of *P. caerulea/ulyssiponensis* between Mesolithic and Meso-Neolithic deposits at ORT may have been promoted by both natural and social factors. These likely include gathering on distinct coastal areas, combined with the effect of intense collections during the Meso-Neolithic.

Shell variability in *O. turbinatus* is mostly associated with changes in SL from ~9.6 to ~7.8 cal ka BP, and this is not surprising given that SL can be the most variable parameters in *O. turbinatus* (Boucetta *et al*., 2011). Results therefore indicate that long-term variability in shells of *O. turbinatus* at ORT refers prevalently to the shape. Phenotypic adaptation to hydrodynamic forces has been reported also for *O. turbinatus*; shells from exposed rocky shores in the eastern Mediterranean have shorter and squatter forms compared with those from sheltered areas, with slender shells (Menzie *et al*., 1992). According to these previous

studies, our results would indicate that humans collected *O. turbinatus* initially on sheltered and then on exposed coastal areas at ~9.6 and ~7.8 cal ka BP respectively. These findings are clearly in contrast with results from *P. caerulea*/*ulyssiponensis*, which denote an inverse pattern of coastal exposure. It seems reasonable to propose that these taxa were not collected in the same area and that variability in shell size and shape between these time intervals were determined by the combination of coastal reorganization and human pressure. Our interpretative scenario is that the rising sea-level formed both sheltered and exposed shores, during which humans exploited these coastal environments indiscriminately and, later (at ~7.8 cal ka BP), possibly operated a certain degree of pressure on the most exploited taxa (*P. caerulea*/*ulyssiponensis*).

It appears that variations in *O. turbinatus* are likely associated to changes in coastal exposure during the island formation, rather than human collection. Similarly, Mannino *et al*. (in this volume) do not observe evidence of size reduction of *O. turbinatus* from Holocene deposits at ORT dated approximately to the same interval (1972 excavations), suggesting no evident human impact on this species. By contrast the size decline in *P. caerulea*/*ulyssiponensis* could result from intensive collection, changes in harvesting strategies and also coastal dynamics during the Meso-Neolithic occupation of the island, compared with the Mesolithic, coinciding with the time of more intense use of marine resources in NW Sicily. In spite the crucial role of land mammals to the diet of early Holocene hunter-gatherers in this region (e.g. Mannino *et al*., 2011), their remains are scarcely represented in some Mesolithic and early Neolithic archaeological records, which are dominated by marine resources (Colonese *et al*., in press; Martini *et al*., in press). Although it does not imply that the former were overall more important in the diet than the latter, as demonstrated by carbon and nitrogen isotope analysis on human bone collagen and archaeozoological studies (e.g. Mannino *et al*., 2011), regional data suggest that marine resources may have been more intensively exploited in late Mesolithic and Mesolithic-Neolithic transition than earlier on (e.g. Colonese *et al*., 2011a, b). This is further supported by recent studies revealing regional changes in the seasonal pattern of intertidal mollusc collections (from seasonal to year-round) at the end of the Mesolithic and onset of Neolithic in this region (Mannino & Thomas, 2009; Mannino *et al*., this volume). Intriguing, it is

from ~9 to ~7 cal ka BP that specie of genus *Patella* became intensively exploited also in other Italian sites (Durante & Settepassi, 1972; Compagnoni, 1991; Wilkens, 1993; Ghisotti, 1997; Colonese & Tozzi, 2010). On the whole, regional evidence seem to point out to an enhanced importance of coastal resources in late Mesolithic and Mesolithic-Neolithic transition in NW Sicily (see also Colonese *et al*., 2011a). A possible explanation for this regional economic scenario in Sicily could be the overall stress of resources on lands due to long-term human predation (Mannino & Thomas, 2009). Such effect would have been further amplified in Sicily due to the limited faunal turnover, which typically characterizes the insular realm (e.g. Masini *et al*., 2008).

In conclusion, Mesolithic and Meso-Neolithic occupations at ORT seem to provide snapshots of both human and/or environmental impact on shell size and shape of some intertidal taxa during the early Holocene in NW Sicily, at the time dramatic coastal changes in the region. Basic morphometric parameters reveal that *P. caerulea*/*ulyssiponensis* and *O. turbinatus* may have not been affected in the same way by prehistoric exploitation, emphasizing the need to use distinct taxa for assessing the impact of both human and environmental agents on intertidal populations. Results underlines the importance of carrying out morphometric analysis on different species, using multiples measurements, to obtain o more complete picture of the interplaying factors behind shell size and shape in archaeological records.

ACKNOWLEDGEMENTS

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