Multivariate Analysis of Remains of Molluscan Foods Consumed by Latest Pleistocene and Holocene Humans in Nerja Cave, Málaga, Spain

Francisco Serrano, Antonio Guerra-Merchañ, Carmen Lozano-Francisco, and José Luis Vera-Peláez
Departamento de Geología, Universidad de Málaga, Campus de Teatinos s/n, E-29071 Málaga, Spain

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Nerja Cave is a karstic cavity used by humans from Late Paleolithic to post-Chalcolithic times. Remains of molluscan foods in the uppermost Pleistocene and Holocene sediments were studied with cluster analysis and principal components analysis, in both Q and R modes. The results from cluster analysis distinguished interval groups mainly in accordance with chronology and distinguished assemblages of species mainly according to habitat. Significant changes in the shellfish diet through time were revealed. In the Late Magdalenian, most molluscs consumed consisted of pulmonate gastropods and species from sandy sea bottoms. The Epipaleolithic diet was more varied and included species from rocky shorelines. From the Neolithic onward most molluscs consumed were from rocky shorelines. From the principal components analysis in Q mode, the first factor reflected mainly changes in the predominant capture environment, probably because of major paleogeographic changes. The second factor may reflect selective capture along rocky coastlines during certain times. The third factor correlated well with the sea-surface temperature curve in the western Mediterranean (Alboran Sea) during the late Quaternary.

INTRODUCTION

Nerja Cave is located in southern Spain near the coastal town of Maro in the extreme east of Málaga Province (sheet 1055 of the Mapa Topográfico Nacional de España, scale 1:50,000, Fig. 1). The cave is a karstic cavity in mid-Triassic dolomitic marbles (Delgado et al., 1981; Andreo et al., 1993) that form extensive outcrops in the southern slopes of the Almijara Mountains. The marbles form part of the Almijara Nappe (Sanz de Galdeano, 1986, 1989), an intermediate tectonic unit of the Alpujarride Complex in the central sector of the Internal Zones of the Betic Cordillera. Since its discovery in 1959, Nerja Cave has been extensively investigated, most studies appearing in geological (Carrasco Cantos, 1993), archeological (Jordá Pardo, 1986a), and zoological monographs (Pellicer and Morales, 1995).

Radiometric dating of speleothems inside the cave (Durán et al., 1993) has yielded ages ranging from 800,000 to 66,000 yr B.P., suggesting that stalagmite and stalactite growth occurred essentially during the Middle and Late Pleistocene. Early Pliocene marine sediments are present near the cave (Guerra-Merchañ and Serrano, 1993), but not inside it. These features suggest that the cave began to form in the Late Pliocene or Early Pleistocene.

Sedimentation inside Nerja Cave comprises a continuous record going back to the latest Pleistocene that contains abundant remains of human activity. The chronology (Table 1) was established on the basis of 14 C dating of 22 samples of plant remains from the sediments (Pellicer and Acosta, 1986; Jordá Pardo, 1986b). The lithostratigraphic characteristics of the Quaternary infilling (Jordá Pardo, 1986b; Pellicer and Acosta, 1986, 1995) are summarized in Figure 2 from the most comprehensive sequences. In the “Sala de la Mina” (Mine Hall), section NM-80A exposes Quaternary sediments 2.6 m thick, but does not reach the base of the sequence. On the basis of lithological and cultural features, Pellicer and Acosta (1995) have distinguished eight chronostratigraphic intervals from the Late Magdalenian to the Chalcolithic/Neolithic Transition. Section NM-80B, measuring 2.7 m thick, exposes the entire sequence of Quaternary sediments; the lowest interval lies on marble rock and the highest is covered by stalagmitic crust. In this section, 10 lithological-cultural intervals have been distinguished from the Early Neolithic to the Late Chalcolithic (Pellicer and Acosta, 1995). In the “Sala de la Torca” (Doline Hall), section NT-82 is 2.15 m thick and does not reach the base of the Quaternary sediments. Pellicer and Acosta (1986, 1995) have distinguished 13 lithological-cultural intervals from the Late Magdalenian to the Post-Chalcolithic.

The taxonomy of the malacofaunal remains accumulated in the cave has been studied by Jordá Pardo (1981, 1982, 1983, 1984–1985, 1986c), González-Tablas et al. (1984), and Serrano et al. (1995). In this study we tested the ability of multivariate analysis to distinguish periods of time on the basis of the molluscan foods consumed by humans who inhabited Nerja Cave. Cluster analysis in Q mode was used to group intervals with similar fauna. The relationships between different time periods and shellfish assemblages were
explored by Q and R mode cluster analysis. In addition, we used principal component analyses to obtain a minimum number of variables that yielded as much information as possible. These new, “fictitious” variables normally represent the principal factors that regulate variance. We therefore also examined the chronological, paleogeographical, ethological, and paleoceanographical significance of these factors. The study is based on the malacological data published by Serrano et al. (1995) for the sections mentioned above.

METHODS

The malacological material was collected during archaeological excavations of the sections. All molluscan remains found in each lithological—cultural interval were collected. The data base used for multivariate analysis was obtained by identifying and counting all malacological material collected (Table 2). Fifty-three species were identified: 31 gastropods and 22 bivalves (Serrano et al., 1995). Incomplete bivalve specimens were counted as individuals if the umbo was present and the species could be identified. Fragmented patellids were counted if the apical zone was present. Other incomplete gastropods were counted if the last whorl was present. Most fragmented specimens belonged to Stramonita haemastoma, probably because the shell was broken to obtain the soft flesh.

To obviate spurious correlations between species that were poorly represented, we excluded species that accounted for less than 5% of the total sample in any interval. This left 12 species of gastropods and 3 species of bivalves in the statistical analysis. Because of the number of variables (15 species), sampling error was reduced by considering only intervals that provided more than 100 individuals (Table 2). Thus, data from all three sections provided information on all periods except the post-Chalcolithic.

Multivariate analyses were done with the NTSYS-pc program (Rohlf, 1993). Cluster analyses in Q mode were done with partial matrices for each section and with the global matrix. Similarity relations were established on the basis of the d coefficient (average taxonomic distance) between intervals (Sneath and Sokal, 1973; Davis, 1986). To avoid the effects of the size factor, the data base was normalized by rows. Cluster analysis in R mode was done with the global matrix by calculating the r coefficient (correlation) between species.
TABLE 1
Chronology of the Cultural Periods Based on 14C Dating of Plant Remains in Quaternary Sediments in Nerja Cave
(from Pellicer and Acosta, 1986; Jorda Pardo, 1986c)

<table>
<thead>
<tr>
<th>Cultural periods</th>
<th>Samples</th>
<th>Sections/Intervals</th>
<th>Dated material</th>
<th>Age (yr B.P.)</th>
<th>Uncalibrated</th>
<th>Calibrated</th>
<th>Adopted limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postchalcolithic</td>
<td>UGRA-17</td>
<td>NM-80B/2</td>
<td>Cereals</td>
<td>4295 ± 90</td>
<td>4295–3780</td>
<td>3750</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8960</td>
<td>NT-79/2</td>
<td>Charcoal</td>
<td>4810 ± 220</td>
<td>4250</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>UGRA-14</td>
<td>NT-82/6</td>
<td>Charcoal</td>
<td>4810 ± 210</td>
<td>4750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition</td>
<td>UGRA-15</td>
<td>NT-82/6</td>
<td>Charcoal</td>
<td>4810 ± 210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Neolithic</td>
<td>GRN-GAK-8969</td>
<td>V-60/3</td>
<td>Cereals</td>
<td>5065 ± 40</td>
<td>5860–5725</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NM-79/2</td>
<td>Charcoal</td>
<td>5790 ± 140</td>
<td>6875–6475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Neolithic</td>
<td>GAK-8959</td>
<td>NT-79/3</td>
<td>Charcoal</td>
<td>6480 ± 180</td>
<td>6000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8972</td>
<td>NM-79/3</td>
<td>Charcoal</td>
<td>9900 ± 180</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Neolithic</td>
<td>UGRA-261</td>
<td>NT-82/9</td>
<td>Charcoal</td>
<td>6200 ± 100</td>
<td>7310–6875</td>
<td>6250–6500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8975</td>
<td>NM-79/4</td>
<td>Charcoal</td>
<td>7130 ± 150</td>
<td>8225–7575</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8973</td>
<td>NM-79/4</td>
<td>Acorns</td>
<td>7160 ± 180</td>
<td>8265–7575</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8963</td>
<td>NT-79/4</td>
<td>Charcoal</td>
<td>7160 ± 150</td>
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<td></td>
<td>GAK-8961</td>
<td>NT-79/4</td>
<td>Charcoal</td>
<td>11,570 ± 320</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition</td>
<td>GAK-8974</td>
<td>NM-79/5</td>
<td>Charcoal</td>
<td>7890 ± 170</td>
<td>7750</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>UGRA-16</td>
<td>NM-80A/5</td>
<td>Charcoal</td>
<td>7890 ± 170</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8962</td>
<td>NT-79/5</td>
<td>Charcoal</td>
<td>7960 ± 200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epipaleolithic</td>
<td>GAK-8964</td>
<td>NT-79/6</td>
<td>Charcoal</td>
<td>10,580 ± 350</td>
<td>8000–10,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Paleolithic</td>
<td>UGRA-147</td>
<td>NM-J/16</td>
<td>Charcoal</td>
<td>12,060 ± 150</td>
<td>11,000–12,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>UGRA-98</td>
<td>NM-J/16</td>
<td>Charcoal</td>
<td>12,270 ± 220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8976</td>
<td>NM-79/7</td>
<td>Charcoal</td>
<td>13,330 ± 270</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8966</td>
<td>NT-79/8</td>
<td>Charcoal</td>
<td>13,780 ± 340</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAK-8965</td>
<td>NM-79/8</td>
<td>Charcoal</td>
<td>16,520 ± 540</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Anomalous data, which have not been considered for establishing the chronological limits between cultural periods.

Intervals and species were ranked with the UPGMA agglomerative sequence method (Sneath and Sokal, 1973).

Principal components analyses were done with the correlation semimatrix in Q and R modes. To scale the lengths of the eigenvectors we used the code SQRT(LAMBDA): length = square root of the eigenvector.

RESULTS

Most of the 53 species identified were marine gastropods and bivalves, although two species (Cerastoderma glaucum and Tapes decussatus) can also inhabit brackish waters in continental areas (Parenzan, 1970; Poppe and Goto, 1991, 1993). Six species were pulmonate gastropods from continental terrestrial environments: Rumina decollata, Sphincterochila hispanica, Iberus alonensis, Iberus marmoratus, Otala lactea, and Caracollina lenticula (Gasull, 1975); only one species was fluvial (Melanopsis laevigata).

Marine species were from rocky coasts and sandy infralittoral environments. Rocky coast species were mainly represented by limpets (Patella caerulea, Patella ferruginea, Patella intermedia, Patella nigra, Patella rustica, and Patella ulyssepionensis), trochids (Gibbula richardi and Monodonta turbinata), the murex S. haemastoma, the divasibranchian Siphonaria pectinata, and the mussel Mytilus edulis. Also included in this group were a few species of prosobranchian gastropods from infralittoral zones, e.g., Columbella rustica and Conus mediterraneus. Sandy infralittoral species were mainly represented by the veneroid bivalves Cerastoderma edule, C. glaucum, and T. decussatus and by a few specimens of Bolinus brandaris, Hexaplex trunculus, Chlamys varia, Spondylus gaederopus, Venus nux, and Callista chione.

The molluscan remains in the sediments represented specimens captured for food (Serrano et al., 1995). Only the small pulmonate gastropods C. lenticula and R. decollata may have inhabited the cave or been transported to the cave in plant material collected for food.

Regardless of the usefulness of certain species as food, their shells were also frequently used for personal ornamentation. Perforated specimens of Patella sp., Glycymeris sp.,
Cerastoderma sp., and others were common, and highly polished specimens of S. gaederopus were also found, together with worked and polished cuttlebones. No worked shells were recovered from intervals preceding the Neolithic.

Cluster Analysis

Results obtained from analyses in Q mode were plotted as dendrograms (Fig. 3). In section NM-80A (Fig. 3A) we
## TABLE 2
Species of Molluscs and Numbers of Individuals Identified per Interval

<table>
<thead>
<tr>
<th>Sections:</th>
<th>NM-80A</th>
<th>NM-80B</th>
<th>NT-82</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervals:</td>
<td>1A 2A 3A 4A 5A 6A 7A 8A</td>
<td>1B 2B 3B 5B</td>
<td>7B 8B 9B 10B</td>
</tr>
<tr>
<td><strong>Gastropods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patella coruscata (Linne, 1758)</td>
<td>47 176 6 29 90</td>
<td>15 18 3 185 763 34 355 115 84 44 77</td>
<td>4 6 51 50 37 206 226 32 79 58 47 8</td>
</tr>
<tr>
<td>Patella forficata (Gmelin, 1791)</td>
<td>2 2</td>
<td>2</td>
<td>83 44 4</td>
</tr>
<tr>
<td>Patella intermedia (Knapp in Murray, 1857)</td>
<td>25 14 9 33</td>
<td>65 19</td>
<td>20</td>
</tr>
<tr>
<td>Patella nigrum (Da Costa, 1771)</td>
<td>6 7</td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td>Patella rustic (Linne, 1758)</td>
<td>10 56</td>
<td>13 20</td>
<td>40</td>
</tr>
<tr>
<td>Patella sinuosa (Gmelin, 1791)</td>
<td>23 62 9 13 36</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Gibbula richardi (Payraudeau, 1826)</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Bivalves</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arca illecebra (Linne, 1758)</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>182</td>
<td>390</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Systematic order according to Vaught (1989). Intervals and species included in the data base are shown in boldface.
found clusters with a close chronological relationship between intervals 1A and 2A (Chalcolithic/Neolithic Transition and Upper Neolithic), 5A and 6A (Neolithic/Epipaleolithic Transition and Epipaleolithic), and 7A and 8A (Upper Magdalenian). The Magdalenian group was clearly separated from the rest \((d = 0.146)\), and groups 1A–2A and 5A–6A were closer to each other \((d = 0.096)\) than to interval 4A \((d = 0.118)\), which was located chronologically between these two clusters.

Intervals in section NM-80B fell into two clearly distinguishable clusters separated by \(d > 0.1\) (Fig. 3B). One group comprised the Chalcolithic sequence \((1B–5B)\), together with an older interval \((9B from the lower part of the Middle Neolithic)\). Internal rank in this group showed no strictly chronological tendency, but we noted that all distances were small. The other group consisted of the intervals located between the Chalcolithic/Neolithic Transition and the Middle Neolithic \((6B–8B)\).

Intervals in section NT-82 were ranked according to chronostratigraphic sequence (Fig. 3C). The dendrogram shows three clusters separated by \(d > 0.1\). One comprises intervals 3T, 4T, and 5T, which represent the entire Chalcolithic sequence. Another is formed by intervals 6T to 11T, which include the Chalcolithic/Neolithic Transition to the Neolithic/Epipaleolithic Transition. Within this group the interval containing the Neolithic/Epipaleolithic Transition \((11T)\) was relatively well separated from the other intervals \((d = 0.076)\). The third cluster comprised interval 13T from the Upper Magdalenian and was clearly separated from the other two clusters \((d = 0.138)\).

Cluster analysis of the global matrix allowed correlation between sections. Figure 3D shows the groups that could be distinguished with a distance of \(d = 0.1\). One group was formed of all Chalcolithic intervals \((1B, 2B, 3B,\) and 5B in section NM-80B; 3T, 4T, and 5T in section NT-82) together with 4A from the Lower Neolithic and 9B from the lower part of the Middle Neolithic.

Another group comprised the intervals representing the Chalcolithic/Neolithic Transition to the Neolithic \((1A and 2A in section NM-80A, 6B–8B in section NM-80B, and 6T–10T in section NT-82)\). Also within this group but somewhat separated from the intervals named above were intervals 11T, 5A, and 6A of the Neolithic/Epipaleolithic Transition and the Epipaleolithic.

A final group contained the Upper Magdalenian intervals \((7A, 8A,\) and 13T). This group was clearly separated from the other two \((d = 0.149)\) and its intervals were separated by relatively large distances \((0.074 and 0.097)\).

These results show that the intervals were grouped according to chronostratigraphy in a manner independent of the section to which they belonged. Thus, good agreement was found between the correlation by cluster analysis and the lithological—archaeological correlation (Pellicer and Acosta, 1986).

Analyses of the interval clusters suggested that malacofaunal composition differed between different chronostrati-
graphic intervals. The dendrogram of the correlation semimatrix for species (Fig. 4) shows two large, inversely correlated clusters ($r = -0.34$). Each cluster could in turn be divided into two groups with a correlation close to zero. We established four groups of species, designated assemblages: (1) *P. caerulea*, *P. nigra*, and *P. ulyssiponensis*; (2) *P. ferruginea*, *P. rustica*, *M. turbinata*, and *S. haemastoma*; (3) *P. intermedia* and *M. edulis*; (4) *G. richardi*, *S. hispanica*, *T. decussatus*, *I. alonensis*, *O. lactea*, and *C. edule*. Assemblages 1 to 3 consisted exclusively of species that inhabit rocky shores. Two species in assemblage 1, *P. nigra* and *P. ulyssiponensis*, showed a high correlation ($r = 0.80$) above the 99% level of confidence of Snedecor ($r = 0.62$). The correlation ($r = 0.52$) between the two most abundant species in assemblage 2, *M. rustica* and *M. turbinata*, was higher than the 95% level of significance ($r = 0.623$). The correlation ($r = 0.497$) in assemblage 3, *P. intermedia* and *M. edulis* showed a low correlation ($r = 0.27$) below the 95% level of significance.

Assemblage 4 comprised continental and infralittoral species with only one species typical of rocky shores (*G. richardi*). The correlations between these species were highly significant at the 99% level, except for the correlation between *C. edule* and the other components ($r = 0.58$), which was above the 95% level of significance.

A composite plot of assemblage and interval dendrograms together with the proportions of each species per interval (Fig. 5) illustrated the relative weight of each assemblage in the interval groups (González Donoso et al., 1991). In group 1 intervals (Chalcolithic with some intervals of the older intervals and the remaining intervals (Figs. 6C and 6D). Chalcolithic and Neolithic intervals fell within the area of high positive values, and Paleolithic intervals were restricted to the area of negative values. Assemblage 4 was poorly represented; *S. hispanica* and *T. decussatus* were completely absent, and *G. richardi* and *O. lactea* were rarely found.

Neolithic intervals in group 2 (including the Chalcolithic/Neolithic Transition) were characterized by the predominance of assemblage 1 (mainly *P. caerulea*, and to a lesser extent *P. ulyssiponensis*). As in group 1, members of assemblage 4 were scarce, only *I. alonensis* appearing regularly, albeit in low numbers.

Relatively well-separated intervals in group 2, belonging to the Neolithic/Epipaleolithic Transition and the Epipaleolithic, showed signs of changes. Assemblages 3 (particularly *M. edulis*) and 4 were better represented than in Chalcolithic and Neolithic groups, whereas assemblage 1 was less common than in Neolithic intervals.

In group 3 intervals (Upper Magdalenian) the changes were more evident. Assemblages 1 and 2 were much less frequent, and assemblage 4 clearly predominated. Especially abundant was *T. decussatus*, a species that was practically absent from Chalcolithic and Neolithic intervals.

**Principal Components Analysis**

In the principal components analysis of intervals (*Q* mode), the first three components explained 85% of the variance (Fig. 6A), whereas the fourth component accounted for less of the variance than expected from the broken stick model (Jolliffe, 1986). The first three components ranked intervals according to chronology and produced a semiheliodal distribution (Fig. 6B).

Individually, component 1 distinguished well between older intervals and the remaining intervals (Figs. 6C and 6D). Chalcolithic and Neolithic intervals fell within the area of high positive values, and Paleolithic intervals were restricted to the area of negative values. Epipaleolithic intervals (including the Neolithic/Epipaleolithic Transition) tended to occupy intermediate positions, although they were not clearly distinguished from the set of modern inter-
FIG. 5. Integration of the dendrograms obtained with Q and R mode analyses, with relative frequencies of species in each interval. Neolithic includes the Chalcolithic/Neolithic Transition; Epipaleolithic includes the Neolithic/Epipaleolithic Transition.

Component 2 (Fig. 6C) distinguished well between Chalcolithic and Neolithic intervals (the latter including the Chalcolithic/Neolithic Transition), placing the former within the area of negative values and the latter in that of positive values, particularly those of the Neolithic/Epipaleolithic Transition.
values. Epipaleolithic and Paleolithic intervals were assigned mainly to low positive values.

Component 3 (Fig. 6D) placed Late Paleolithic intervals in the region of high positive values, Epipaleolithic intervals in the area of intermediate positive values, and Neolithic and Chalcolithic intervals in the area of low values. Chalcolithic
FIG. 7. Results of principal components analysis in R mode. (A) Variance explained by the first 10 components, compared with the expected distribution according to the broken stick model. (B) Three-dimensional distribution of species according to the first three principal components. (C) Distribution of intervals according to components 1 and 2. (D) Distribution of intervals according to components 1 and 3. In C and D, species are shown according to habitat.

intervals showed a slight tendency toward positive values, and Neolithic intervals tended toward negative areas.

In the principal components analysis of species (R mode), the first three components explained 71.2% of the variance. The first component was the only one that accounted for a clearly larger proportion of variance (42.6%) than the corresponding component obtained with the broken stick model (Fig. 7A). This component grouped species closely related by habitat (Figs. 7C and 7D): assemblages 1 and 2 were located in the area of positive values, assem-
DISCUSSION AND CONCLUSIONS

Cluster analyses for sections generally grouped the different intervals chronologically. Global cluster analysis showed good concordance with the chronostratigraphic (lithological–archaeological) correlation. The intervals were ranked in three chronostratigraphic groups, which showed good correspondence with the Chalcolithic, Neolithic–Epipaleolithic (including the Chalcolithic/Neolithic Transition), and Late Paleolithic (Late Magdalenian) cultural periods. Intervals from the lower part of the Neolithic (4A and 9B) associated with Chalcolithic intervals suggested a brief period approximately to the Middle Neolithic/Early Neolithic boundary that is distinguishable from the rest of the Neolithic.

Principal components analysis in $Q$ mode showed that component 1 most effectively distinguished Late Paleolithic intervals, where continental and sandy infralittoral species predominated. Epipaleolithic intervals, containing species frequent in all three capture environments (rocky coast, sandy infralittoral, and continental), were also slightly separated. In Neolithic and Chalcolithic levels, rocky shore species were clearly predominant and formed a compact group. This suggests that component 1 detected changes in the capture environment that were most likely conditioned by changes in the coastline as a result of sea-level rising during deglaciation.

Component 2 distinguished well between Chalcolithic and Neolithic intervals. In this component, $M.\ turbinata$ predominated (loading factor $= -0.86$), and considerable influence was also exerted by $P.\ ulyssiponensis$ (0.71) and $P.\ caerulea$ (0.57), which correlated inversely with $M.\ turbinata$ ($-0.38$ and $-0.42$, respectively). All three species occupied the same rocky intertidal habitat; therefore, the discrimination cannot be explained on the basis of climatic or paleogeographic factors. Component 2 may represent a selective capture factor. Chalcolithic intervals contained remains of $M.\ turbinata$ in sufficient numbers to suggest that this species was a major component of the shellfish diet. In contrast, Neolithic humans may have been less selective, or may have preferred patellids.

The behavior of component 3 was similar to that of component 1, classifying the intervals into three groups according to age: Late Paleolithic, Epipaleolithic, and Neolithic + Chalcolithic. In the third group there was a slight separation between Neolithic and Chalcolithic intervals.

The loading factors of the components per interval in chronological order were correlated with changes in sea-

![FIG. 8. Comparison of the curves obtained with the loading factors for the first three factors in the principal components analysis in Q mode with the sea-surface temperature (SST) curve for the Alboran Sea. In component 3 positive values are on the left to facilitate visual comparisons with the SST curve.](image-url)
surface temperature (SST) in the Alboran Sea (Fig. 8). The SST curve was calculated from the transfer function by Kipp (1976) based on assemblages of planktonic foraminifera (González Donoso et al., 1991). This plot shows that components 1 and 3 generally paralleled the temperature curve. However, a closer look showed that component 3 was a more sensitive indicator of temperature changes.

In conclusion, molluscan remains from Quaternary sediments identified in Nerja Cave show significant variations through time. In the Upper Paleolithic, remains from terrestrial environments (I. alonensis, S. hispanica) and sandy sea bottoms in the infralittoral zone (T. decussatus, C. edule) are common. These findings suggest that part of the continental shelf was exposed. Seismic profiles (Hernández Molina et al., 1994) reveal that during late Pleistocene time the Alboran continental shelf in the Málaga area consisted of a low subsident ramp. At the start of the last transgression 14,000 yr ago (Stanley et al., 1970; Bartolini et al., 1972; Caralp, 1988), sea level in this area was 90 m lower than at present. The emerged platform, exposing reworked sands and gravels, may have been as much as several kilometers wide (Hernández Molina et al., 1994). Under these conditions the coastal environment consisted mainly of beaches, and marine molluscs were therefore gathered mainly from the infralittoral zone.

Epipaleolithic molluscan remains are more diverse, reflecting an increase in captures from rocky coastal habitats. During this period (11,500–7750 yr B.P.) the coastline may have reached mountainous areas as a result of rising sea level, leading to the formation of rocky coastlines. The seismic reflector at the base of the sediments from the last Pleistocene and Holocene displays a rupture 73 m below the current surface. Above this level the topography of the reflector is irregular, with a general increase in slope, suggesting that the coastline may have reached mountainous areas. According to Hernández Molina et al. (1994), sea level would have reached this point 12,500 yr ago, but would have receded during the Younger Dryas interval approximately 11,000–10,000 yr ago (Bard et al., 1987; Kudrass et al., 1991; Troelstra and van Hinte, 1995).

In the Neolithic and Chalcolithic intervals (7750–3750 yr B.P., ages not calibrated) the predominant species were from rocky coasts (patellids and trochids). During this time, sea level rose to its highest recorded point 6500–6000 yr ago, when it was 2–3 m above the current level (Hoffman and Schulz, 1987), and the coastline advanced toward higher altitudes. Between this maximum eustatic level and the present, changes in sea level were less than 2 m. Accordingly, the coastline during the Neolithic and Chalcolithic was probably similar to its current configuration. The predominance of rocky environments would have favored captures from these habitats.

The molluscan remains of post-Chalcolithic time are inconclusive; this interval was not included in the data matrix because of the low numbers of specimens recovered. However, the predominant malacofauna consists of species from rocky coastlines, with smaller numbers of pulmonate gastropods. This assemblage is similar to that representing the Chalcolithic and Neolithic intervals.

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