Shellfish Meet Otoliths in Shell Midden Archaeology of the Gulf of California, Mexico

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Abstract

Despite a long tradition of shell midden archaeology in Baja California, most archaeologists excavating at coastal sites have ignored the presence of otoliths. This article investigates the fish resources accessible to the prehistoric groups by focusing on taxonomic identification, abundance, and diversity of otoliths recovered in six late prehistoric period deposits. Furthermore, analysis of the Caro’s Cave rockshelter demonstrates that when otolith data are integrated with mollusk data, together they can convey relevant information and open new questions on the interaction that existed between man and the coastal ecology. This article also emphasizes that in the Gulf of California otoliths open a new field in which archaeologists can meet ecologists to study the past roles of endemic species.

Introduction

The ears of bony fish possess three kinds of mineralized structures (utriculith, formerly termed lapillus; sacculith, formerly sagitta; and lagenar, formerly asteriscus) known as otoliths (literally, “ear stones”), whose functions are linked to fish movement, orientation, and hearing (VanderKooy and Guidon-Tisdel 2009). In any one species the sacculiths are the largest otoliths, ranging in size from millimeters to centimeters (Pannella 1980), and thus the potential for their archaeological recovery is greater than for utriculiths and lagenars. All otolith data generated for this study refer to sacculiths.

Their mineralogical composition, as with the other otoliths, is calcium carbonate (aragonite), a product of biomineralization that occurs in equilibrium with the environment (Kalish 1991; Thorrold et al. 1997). The concentric accretion of these structures makes it possible to distinguish annual growth bands based on transulence (opaque if the fish was growing, but translucent if it was not growing). Sacculiths are widely used to determine some of the characteristics of fish communities, including age, growth, migration, and the differentiation of stocks (Campana 1999).

Although the proposal for their use in archaeological studies is not new (Casteel 1976), the visual technique that has sometimes been used to infer annual seasons based on the transulence of the otolith’s final band continues to be a subject of debate (Andrews et al. 2003). Studies demonstrating greater reliability have corroborated visual assessment with isotopic ($\delta^{18}O$) analysis of the final growth band formed in the sacculith, thus supporting inferences concerning seasonality and the use of fish resources among prehistoric human groups (Hufthammer et al. 2010).

The study of these materials related to a single faunistic group becomes relevant in geographical areas where endemic species are known to exist, such as occurs in the north of the Gulf of California. Although fish bones can get into archaeological deposits by means of the stomach contents of other fish and marine mammals, and in the stomach contents and
droppings of birds and scavenging land animals, the sacculiths of totoaba (Totoaba macdonaldi), shortfin corvina (Cynoscion parvipinnis), gulf croaker (Micropogonias megalops) and gulf corvina (Cynoscion othonopterus) found in clear archaeological contexts do provide robust evidence for the prehistoric exploitation of these resources by human groups (Table 1).

Materials and Methods

Recovery

The archaeological sites discussed in this article are located on the northeastern coast of Baja California (Figure 1) and were excavated in July and

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<th>Cynoscion othonopterus</th>
<th>Sacculith</th>
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<td><strong>Gulf Corvina</strong></td>
<td>This fish is endemic to the Gulf of California. Its habits are coastal, and it reaches a total length of 70–100 cm. It uses the mouth of the Colorado River to hatch between the months of February and April. It is of great commercial importance and, unfortunately, its hatching period coincides with the intensification of its fishing (Rowell et al. 2005).</td>
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<th>Cynoscion parvipinnis</th>
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<td><strong>Shortfin Corvina</strong></td>
<td>This fish reaches 40–60 cm in total length. It inhabits coastal areas where it finds sandy substrates to feed primarily on small fish (Chao 1995).</td>
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<th>Micropogonias megalops</th>
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<td><strong>Gulf Croaker</strong></td>
<td>This fish is endemic to the Gulf of California and reaches 40 cm in length. It maintains a preference for estuaries and river mouths; however, it can also be found in deep water. Its recognition as an important commercial species is recent, and its fishery was long linked to the dragging techniques in use (Chao 1995) and as a substitute during periods of low shrimp capture in the upper gulf (Aragón-Noriega et al. 2009).</td>
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<td><strong>Totoaba</strong></td>
<td>This fish is endemic to the upper Gulf of California and presently subject to protective guidelines. It reaches 200 cm in total length. It has coastal habitats and maintains a migratory pattern with life stages at different geographical points off the northern and central portion of the Baja California peninsula. Its migration extends from the mouth of the Colorado River to Bahía Concepción on the western shore of the gulf and to the mouth of the Río Fuerte on the eastern shore (Cisneros-Mata et al. 1995).</td>
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Table 1. Identification of the Dominant Fish Species in the Otolith Samples Recovered at Six Archaeological Sites on the Gulf of California.

Note: Illustrations from Chao (1995); photographs by Isidro Madueño González.
August 2010, during the first phase of a project entitled “Salvamento Arqueológico San Felipela Laguna Chapala Kms 109+340 a 117+940,” directed by Antonio Porcayo Michelini, archaeologist at the Centro INAH-Baja California. In the excavation of six late prehistoric period deposits, diverse archaeological materials were recovered, and their diversity, abundance, and stratigraphic distribution were analyzed.

In terms of total otoliths recovered in the six deposits, the Caro’s Cave rockshelter was predominant with regard to diversity and abundance of the identified fish species. Accordingly, a concerted effort was focused on the site’s units S2E3/S2E4 and S3E3/S4E4, where the excavation reached culturally sterile soil at 1.1 m. This area (2m x 2 m), excavated in 10-cm levels, was located directly in front of the entrance of the rockshelter; a total of 802 liters of sediment were recovered. Charcoal samples from depths of 80 cm (level 8) and 40 cm (level 4) gave chronological ranges of AD 1410–1455 (478 ± 28 BP / INAH-2906) and AD 1810–1920 (70 ± 23 BP / INAH-2905), respectively. These samples derived from two different hearths. Because one of the objectives was to collect otoliths, fine-mesh screen (1/16 in) was used to assure greater control of the specimens and to recover them in the field. Other faunal remains such as skull bones and vertebrae from different fish species were also recovered in the site; however, they were not included in this analysis of prehistoric fishing.

Data Analysis

Taxonomic identification of otoliths and mollusks relied principally on observations of specimen morphology. Otoliths recovered in the same season but in different sites were eventually identified using the comparative collection at the Cotsen Institute of Archaeology (UCLA). Sacculiths were divided into complete specimens and fragments. For the biological identification and counts of fragments by taxon, a classification based on the following diagnostic
parts was used: posterior section, anterior section, and medial section (Figure 2). The medial section included specimens whose orientation (right or left) could not be determined, but whose taxonomic affiliation could be determined. Adding the frequencies of the three above-mentioned sections with the number of complete specimens made it possible to obtain the number of identified specimens (NISP) by species and provenience. The minimum number of individuals (MNI) per taxon was derived from the preceding information, taking into account the size correspondence between pairs of otoliths in complete specimens.

Among the mollusks the classes of pelecypods, gastropods, and chitons were identified using primary sources (Keen 1971; Keen and Coan 1974; Abbott 1974). Number of identified specimens (NISP) and minimum number of individuals (MNI) were determined for samples from each excavation level.

On the basis of the mollusks’ habitats, species were divided into two groups: (1) those that live on rocky substrates; and (2) those from sandy substrates. If it is assumed that prehistoric groups focused their efforts on the environments with greater available resources, the ecological provenience of the recovered specimens acts as an indicator of variation through time in the coastal exploitation habits among human groups.

Results

Identified Fish Species

Of the sacculiths, 99.3 percent MNI belong to the Sciaenidae family and predominantly to three species that are endemic to the Gulf of California (Table 1). The exception to endemism was *Cynoscion parvipinnis* which was also the less frequent identified species in the samples (Figure 3). The corvina *Cynoscion othonopterus* was the most abundant followed by *Micropogonias megalops* and *Totoaba macdonaldi*. These three fish share in common their coastal habitat. According to recent studies that used the oxygen isotopic signal of both archaeological and modern otoliths, *C. othonopterus* and *T. macdonaldi* return to the Colorado River estuary on a transient basis over the course of their life, just as they did in the past (Rowell et al., 2005, 2008).

Species Distribution

*C. othonopterus* had a marked importance in the Caro’s Cave and El Regino sites based on the greater number of recovered otoliths; in Caro’s Cave (70.3 percent MNI); in El Regino (55 percent MNI) (Figures 4 and 5). *M. megalops* occurred at four of the six sites and was the second most abundant species after *C. othonopterus*. Otoliths of *C. parvipinnis* were also distributed at four sites; however, a comparatively

Figure 2. Division of the structure of a left sacculith of *Cynoscion parvipinnis* in its sections (from left to right: posterior, medial, and anterior), used for classifying the fragments in this study.
Seven genera and 12 species of mollusks were identified at Caro’s Cave Rock Shelter. Of the specimens, 90 percent were distributed in seven taxa: three gastropods (Collisella dalliana, Tegula rugosa, and Turbo cf. fluctuosus), two bivalves (Protothaca grata and Cardita affinis), and two chitons (Acanthochitona cf. exquisita and Chiton cf. virgulatus) (Figure 6). In the analysis, significant differences were found in the MNI distribution of the species within the three strata ($H = 14.92, df = 2, P = 0.001$) as well as in the preferred habitats of the mollusks throughout the deposit ($H = 7.74, df = 1, P = 0.005$) (Figure 7).

Among the fish, gulf corvina (C. othonopterus) was most abundant, but there were no significant differences in the MNI distributions of the species by stratum ($H = 5.31, df = 2, P = 0.07$) (Figure 8). Variation in the abundance of MNI mollusks and MNI otoliths presented a low correlation throughout the archaeological deposit ($r_p = 0.41$) (Figure 9).

**Discussion**

The analysis of sacculith samples from six archaeological deposits confirms that endemic fish constituted a food resource of the Native communities that were settled in the northeast of the Baja California peninsula during the late prehistoric period. The bones and lithic materials recovered by the project have only
Figure 5. Percent distributions of the four fish species identified by otoliths at the six analyzed archaeological sites. The data correspond to MNI of each species by site (n.id. = unidentified specimens).

Figure 6. Abundances of the predominant mollusk species at Caro’s Cave rockshelter.
been analyzed in a preliminary manner, and accordingly, before the following arguments are accepted, they need to be confirmed through the future integration of all the materials in the interpretation of each of the sites.

The results show that exploitation was focused on a family of fish (Sciaenidae) whose habitats are coastal. Presently, it is not possible to suggest that fishing at a distance from the coastline occurred during the late prehistoric period. On the other hand, it was observed that *C. othonopterus* and *M. megalops* were the species available for a greater number of localities in the study area, which calls attention to the fact that the current commercial value of these species in the upper gulf was reached only at the start of the twentieth century after the decline in the taking of totoaba and shrimp (Encinas 2008; Aragón-Noriega et al. 2009).

Figure 7. Distributions of the predominant mollusks by stratum (above) and by habitat (below) at Caro’s Cave rockshelter.
Figure 8. Abundance of fish species (above) and their distribution by stratum (below) at Caro’s Cave rockshelter.
With regard to totoaba, at present the combined responsibility of overfishing and habitat loss for the alteration of this species’ natural condition in the upper gulf has been demonstrated (Rowell et al. 2008). However, little is known concerning its past abundance, because this is the first time that the recovery of totoaba otoliths has been reported on the basis of systematic excavations designed to reveal the interaction between coastal resources and the prehistoric human communities of northeastern Baja California. Recently, ecological and paleoenvironmental studies in the upper gulf have used the isotopic composition ($\delta^{18}O$) of modern and archaeological otoliths to document the degree of alteration that this habitat has presented for several endemic species (Rowell et al. 2005, 2008). The preceding supposes that otoliths are archaeological materials that can serve as indicators of the paleoenvironment as well as indicators of the biological characteristics of those species with which prehistoric man maintained ecological interaction.

This study is not able to explain the fact that totoaba (T. macdonaldi) showed a low presence in all the analyzed deposits. According to what is known concerning the seasonal migration of this species from the upper gulf toward the south of the peninsula, the area where the archaeological sites are located corresponds to a passageway, both for juveniles that have completed at least two years of feeding in the estuary zone at the mouth of the Colorado River and for adults that have completed their single reproductive cycle for the year (Cisneros-Mata et al. 1995). Presently, no information exists concerning behavior in its passage along the littoral that extends from Puertecitos to the area enclosed between the continental zone and the islands of El Muerto and San Luis, where the study area is located (Figure 1). In contrast, gulf corvina (C.
othonopterus) are currently distributed in this area known as “Las Encantadas,” where its commercial exploitation, while not important in comparison with the area close to the delta, can be achieved in deep zones between 16 m and 33 m using line fishing (piola de mano y cimbra) (Encinas 2008). The discussion concerning the importance that these and other fish species had as resources for human consumption during prehistory will be enriched by archaeozoological studies and the inclusion of otoliths recovered from a greater variety of geographical areas within the Baja California peninsula.

The exercise carried out at Caro’s Cave to analyze the distribution of mollusks and sacculiths throughout the archaeological deposit is far from complete. Still needed are studies of Caro’s Cave as a time-averaging deposit. To refine the chronological and spatial resolution of the samples collected requires consideration of circumstances such as the repeated usage of the cave and the reworking of activity material traces by both natural and anthropogenic phenomena.

What the data do make possible to propose is the hypothesis that Caro’s Cave was a semipermanent camp focused on fishing (mainly of a single species, *Cynoscion othonopterus*) and shellfish gathering from the two coastal settings with easy access, the rocky shores and the sandy shores. It is evident that two distinct environments were exploited during the beginning of the occupation in contrast to a later time when efforts were focused on the rocky environment. This is deduced from the decrease in bivalve shells pertaining to sandy substrates. However, not ruled out is the possibility that instead of abandoning the soft substrates, the prehistoric groups were able to optimize their exploitation of bivalves, thus resulting in the absence of evidence of this exploitation in the archaeological record. On this point it is important to mention that the distance of the site from the coast (ca. 2 km) is an argument in favor of the possibility that the prehistoric groups were exploiting mollusks whose shells were not necessarily transported inland to the site. This argument derives from the observed behavior of present-day collectors, among whom a high degree of specialization involves resource maximization using collection strategies in which a lower investment of time intervenes between the pursuit and the extraction of the resource; in return there is a greater energy profit for each unit collected (Bird et al. 2004). With a more detailed analysis it will be important to indicate the effect that the site’s distance from the coast had for defining the types of exploitation that characterized the malacological resources of Caro’s Cave. Equally, it will be important not to neglect analysis of the mollusks based on their ecological role, because some of the predominant species at the site constitute opportunistic communities that customarily appear during stages of ecological succession in the intertidal zone that occur naturally or from anthropogenic causes.

**Conclusions**

Otoliths, whose mineralogical composition is lasting, provide information about the fish communities exploited, and in their biochemical composition they represent, equally with mollusks, the characteristics of the natural environment in which these communities developed. Therefore, archaeological otoliths can contribute ecological and paleoenvironmental information for the interpretation of the prehistoric coastal sites on the peninsula of Baja California.

Although we still do not know the proportional importance of each subsistence activity at each site, the analysis of faunal remains at Caro’s Cave suggests that either fishing or shellfish gathering was the subsistence basis that accounts for site formation. Additionally, the mollusk habitats point out the variation in the exploitation of two coastal environments (rocky shore and sandy shore) during formation of the deposit.

Three fish species endemic to the upper Gulf of California were important subsistence fare for the
prehistoric communities that occupied the northeast coast of Baja California.

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