# Early Human Impact on Megamolluscs

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Roberto Cipriani

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# Exploitation of *loco, Concholepas concholepas* (Gastropoda: Muricidae), during the Holocene of Norte Semiárido, Chile

**PEDRO R. BÁEZ[1] & DONALD S. JACKSON[2]**

**Abstract**
This paper is a contribution to the understanding of the possible causes leading to changes in size frequency, species distribution, and abundance of *Concholepas concholepas* during the Holocene. We present a review of more than 200 archaeological sites and shell middens at Los Vilos (31º55'S, 71º32'W), Provincia de Choapa, *Norte Semiárido* of Chile spanning for approximately 10,000 years. We synthesize our current knowledge on how populations of *C. concholepas* living in this locality were affected by the pre-Hispanic human exploitation and by changes in the environment occurred since the Pleistocene. Changes in diversity and abundance of *loco* and other molluscs during this period were most probably caused by paleoclimatic changes than human behaviour. Through the Early Holocene, coastal occupation was permanent and human subsistence depended on marine resources, locals gathered a wide variety of species but intensively exploited few of them. During the Middle Holocene, humans occupied the coast only seasonally, when shellfish gathering was easy to predict and molluscs were abundant. There was intensive exploitation of some marine mollusc species as well as a greater dependence on terrestrial species. The collection of marine species in 6,500 B.P. was associated to more arid and dry climate conditions, scarcity of other resources, and changes in the sea level. During the Late Holocene, climatic conditions more similar to those present today, allowed the proliferation of coastal settlements exploiting a variety of resources. Our study suggests that marine resources were not necessarily overexploited by humans from Los Vilos, and recorded changes in shell size, abundance, and availability of *loco* were minimal both in temporal and spatial scales during the Holocene.

**Key words:** *Concholepas concholepas,* marine gastropods, Los Vilos, Chile, Holocene, shell midden, Norte Semiárido

## Introduction

*Concholepas concholepas* (Bruguière 1789) (Figure 1), commonly known as *loco* in Chile and as *chanque* or *tolina* in Perú, is the only surviving species of an odd-looking genus that appeared some 17 million years ago (mya) during the Early Miocene (DeVries 2000). *C. concholepas*, with other five species known from the fossil record, *C. unguis* (E. Miocene – M. Miocene from Perú), *C. chirotensis* (M. Miocene from Perú), *C. kieneri* (L. Miocene from Chile and Perú), *C. nodosa*, and *C. camerata* (L. Pliocene), populated the Peruvian and Magellanic Provinces in the south eastern Pacific.

The current geographic distribution of *C. concholepas* extends from the south central Perú, Callao, and Lobos de Afuera (Sánchez Romero 1973) along the entire Chilean coast to Cabo de Hornos (Stuardo 1979), and offshore to the Juan Fernández Archipelago (Manríquez et al. 2004), living along a latitudinal range extending from 7º – 55º S.

*C. concholepas* inhabits crevices in the rocky intertidal and subtidal environments of high energy shores and is commonly found in shallow waters (3 m deep, on average) (Rabí et al. 1996, Manríquez et al. 2004). Females, fertile when their shells are 8 to 10 cm long (Castilla and Cancino 1976; Durán and Castilla 1988), lay their egg-capsules all the year-round but most frequently in March, April, August, and September. They are capable of producing from 3.2 to 7.2 millions of planktonic larvae per year, a proportion of which recruits four months later in the intertidal (Martínez and Navarrete 2002) or subtidal (Arias 1991; Stotz et al. 1991) zones, measuring approximately 2 mm long (Gallardo 1979; Guisado and Castilla 1983; Rivas and Castilla 1987; Di Salvo 1988, Moreno et al. 1993; Moreno 2004). One year and one half after metamorphosis, they already measure 5 to 7 cm and weight 40 to 80 g. Three years and one half later, they measure between 10.5 and 12.0 cm in length, weight 210 to 330 g (Acuña and Stuardo 1979), and are still able to grow up to 15.0 cm long.

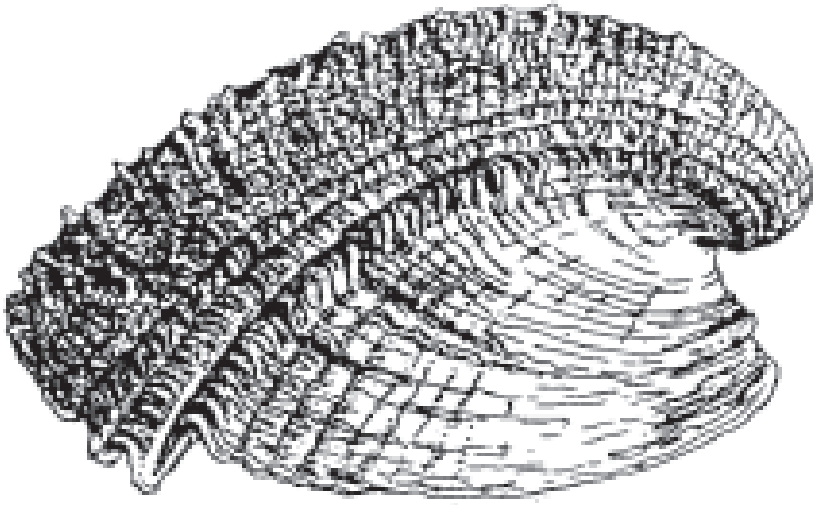
*C. concholepas* is one of the most important species of shallow benthic water communities of southern latitudes in the Eastern Pacific and exerts a strong influence in their structure, feeding preferentially upon cirripeds (*Balanus laevis*, *Austromegabalanus psittacus*, *Jehlius cirratus*, and *Chthamalus scabrosus*), ascidians (*Pyura chilensis*), and mytilids (*Perumytilus purpuratus*, *Brachidontes granulata*, and *Semimytilus algosus*) (Castilla et al. 1979; Castilla and Durán 1985).

The accessibility of humans to their habitats, their fecundity, and their size have made of *C. concholepas*

[1] Sección Hidrobiología, Museo Nacional de Historia Natural, Casilla 787, Santiago (pbaez@mnhn.cl) and Facultad de Ciencias del Mar y de Recursos Naturales, Universidad de Valparaíso, Casilla 5080 Reñaca, Chile (Pedro.Baez@uv.cl)

[2] Departamento de Antropología, Universidad de Chile, Santiago, Casilla 10115, Chile (djackson@uchile.cl)

**A)**



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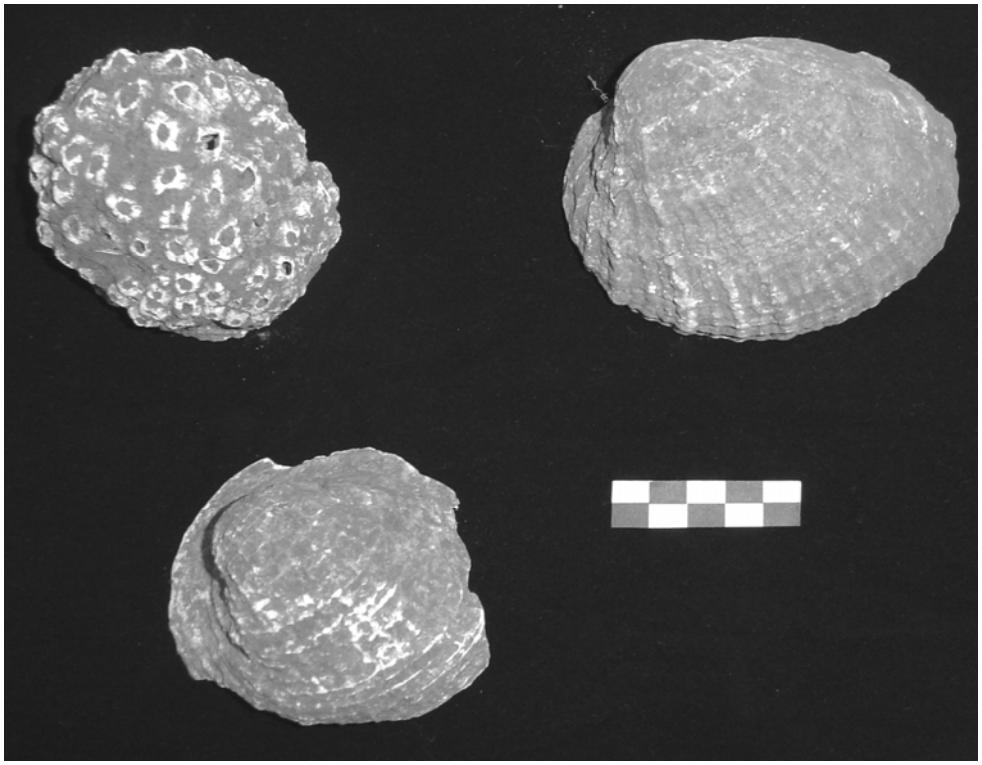


**Figure 1. A)** Shell of *loco*, *Concholepas concholepas (*Bruguière 1789) (Mollusca, Gastropoda, Muricidae) lateral view; **B)** Archaeological remnants of *loco* from Middle Holocene contexts. Scale: 5 cm.

populations a traditional source of food for human groups living along the coast. Indeed, today *loco* is intensively exploited by the Chilean and Peruvian fishermen (Leiva and Castilla 2002) for what individuals of large size are only found in the subtidal fringe (Castilla et al. 1979). In some areas, this species has been so overexploited that fisheries are banned or restricted (Moreno et al., 1986).

The exploitation of *loco* in the region *Norte Semiárido* of Chile, between Copiapó and Petorca, that occurred 10,000 to 2,000 years ago occurred at a different geographical scale but was not very much different than that happening today. Different human groups that populated the coast on those times depended on marine resources for their subsistence and *C. concholepas* was one of their main resources, as interpreted from the abundant shell remains and shell middens of this species found in many archaeological sites along the region (Jackson and Báez 2005).

This paper is a contribution to the understanding of the possible causes leading to changes in size frequency,

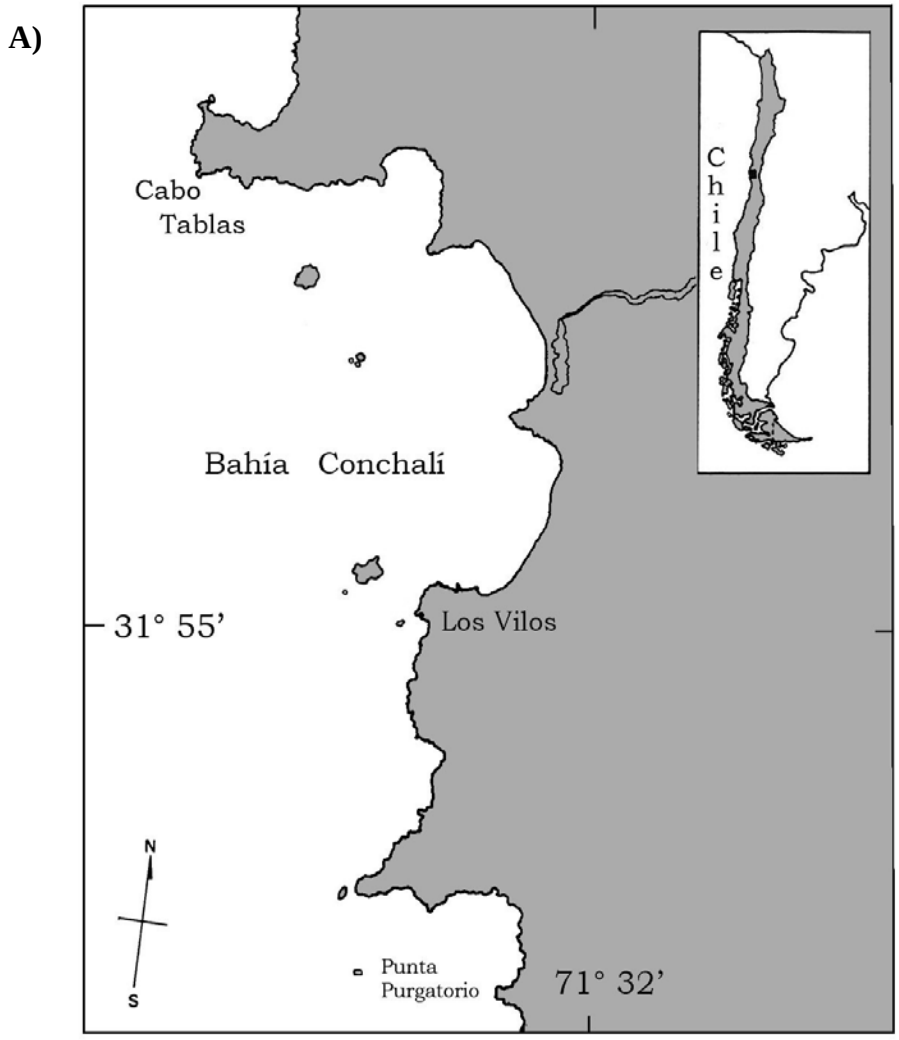





**Figure 2. A)** Sampling area in the Southern limit of the Chilean *Norte Semiárido*;
**B)** Shell midden area from Los Vilos (31º55'S, 71º32'W); **C)** coastal area of the Chilean Norte Semiárido.

species distribution, and abundance of *loco* during the Holocene. More than 200 archaeological sites and a number of *conchales* (shellmiddens) spanning for approximately 10,000 years (Jackson et al. 1995; Jackson 2002; Méndez 2004) have been intensively and systematically studied in Los Vilos (31º55'S, 71º32'W), Provincia de Choapa, *Norte Semiárido* of Chile (Figure 2) since the beginning of the 1990s. In this contribution, we synthesize our current knowledge on how populations of *C. concholepas* living in this locality were affected by the pre-Hispanic human exploitation (Jackson et al. 1996; Méndez 2002, and 2003; Báez et al. 2003; Méndez and Jackson 2004; Báez et al. 2004; Jackson et al. 2004b; Jackson and Méndez 2005; Jackson and Báez 2005) and by changes in the environment occurred since the Pleistocene (Villagrán 1982; Varela 1983; Ota and Paskoff 1993; Núñez et al. 1994; Villagrán and Varela 1990; Prieto and Jackson 2000; Maldonado and Villagrán 2002; Maldonado 2004).

**Effect of Currents and Tectonics on the Environment of *Norte Semiárido***

A number of events affected the climate of the South Eastern Pacific region during the Pleistocene and the Holocene and triggered changes in the composition of the coastal marine communities of *Norte Semiárido*.

Originating sometime between the Miocene-Pliocene (5.0 mya, Larraín 1975) and the Pliocene-Pleistocene boundaries (1.8 mya, Otlieb 1995; Villagrán 1995), the Humboldt Current System replaced a strong and warm current flowing to the South (WCS), associated to the extreme arid conditions of Northern Chile existing since the Oligocene (Galli-Olivier 1967; Camus 2001), allowing cold-temperate low-diversity faunas to replace the richer subtropical marine communities living along the Chilean coast until then (Brattstroem and Johanssen 1983).

Increasing upwelling and glacial extensions (i.e., at 73,000, 19,500, and 14,500 B.P.) during the Pleistocene and part of the Holocene of Southern Chile, and a warming trend starting in the Early Holocene (9,000 B.P.) (Salinger 1981), resulted in climatic and geophysical changes directly affecting the coastal terraces and faunal distributions of the Northern region (Villagran et al. 1983; Jerardino et al. 1992; Otlieb 1995). The raising temperature coincided with the population of the earliest-known pre-Hispanic settlements in Antofagasta (Llagostera 1979).

The Middle Holocene (5,000 B.P.) became warm and dry (Villa and Villagrán 1997), the terrestrial biota changed and the ongoing marine transgression resulted in a progressive raise of waters from 2 to 5 m above the current sea level. Most important for the faunal composition and reshuffling of the *Norte Semiárido* was the beginning of El Niño-Southern Oscillation (ENSO) (Rollins et al. 1986). At least two ENSO events have had notorious effects on the biology of the region: a cooling event occurred between 1,850 and 1,650 B.P., and a warming event, occurred between 640 and 530 B.P. (Camus 1990; Villalba 1994). The ages of the so called "Small Ice Age" and "Warm Episode" events recorded in *Mejillones del Sur* Bay, characterized by oscillations of shallow-water biological productivity and the reduction of dissolved oxygen in the sea surface (Valdés et al. 2003), are coincident with those two dates.

Finally, the influence of earthquakes on the coastal marine biota of *Norte Semiárido* is not well known. Their effects are localized to small geographical areas, as suggested by the changing zonation pattern and the massive mortality of the macroalga *Lessonia nigrescens* after the earthquake occurred in 1985, in Central Chile (Castilla 1988). However, documented evidences of abrupt changes in coastal borders related to earthquakes during the Holocene of Chile (Villagrán 1995) and Perú (Craig and Psuty 1968) are few. Drastic geographic changes with abrupt raisings occurred between 8,000 and 6,000 B.P., and the appearance of bays and the displacements of the Peruvian coastal border to the west, occurred between 4,000 and 3,000 B.P., mark the formation of the present-day coast. Beside these, there are not more evidences of the possible effects of tectonics on the faunal composition of the Chilean *Norte Semiárido*.

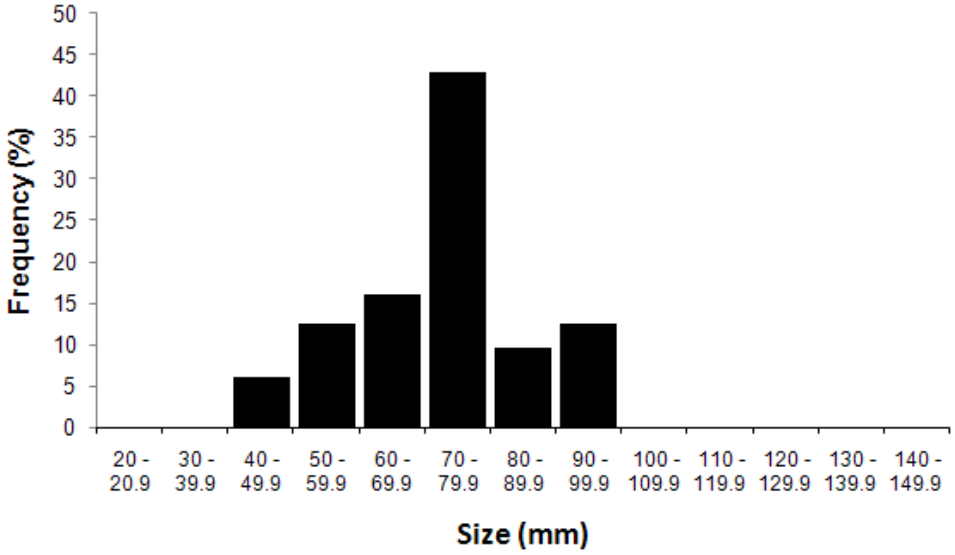
**Exploitation of *Concholepas concholepas*: Archaeological Evidence**

**Late Pleistocene**

The first humans inhabiting Chile arrived by the end of the Pleistocene (11,500 B.P.). At least two Paleoindian archaeological sites are known from Los Vilos: Quebrada de Quereo and Quebrada El Membrillo (Núñez and Santoro 1990, Jackson et al. 2004a). Quebrada de Quereo shows two main occupational events (11,600 and 11,100 B.P.) with very few molluscs remains (Montané and Bahamondes 1973; Núñez et al. 1983; 1994) suggesting to archaeologists that the areas of mollusc processing were located away from the main settlements and near to the littoral line. Quebrada El Membrillo also yields few mollusc fragments, including some of *C. concholepas* (Jackson 2003).

However, shell remains are so scarce in these two locations that it is also possible that they were incorporated to the archaeological context by non-cultural processes, such as through bird egagropiles (Jackson et al., in preparation). Indeed, until today, there are not evidences of Paleoindian groups in the South American Pacific coast using marine resources as food. Other archaeological evidence suggests that these human groups had a circum-lagoon style of life based on hunting megamammals and some other small species (Núñez et al. 1987). These evidences suggest that if molluscs actually lived in these regions but humans did not exploit them, either their habitats were not adequate for shells to be preserved in archaeological contexts or mollusc populations lasted for very short periods of time, leaving behind a very poor record.

**A) LV 098 a (11,000 B.P.)**




**B) LV 079 (10,040 B.P.)**

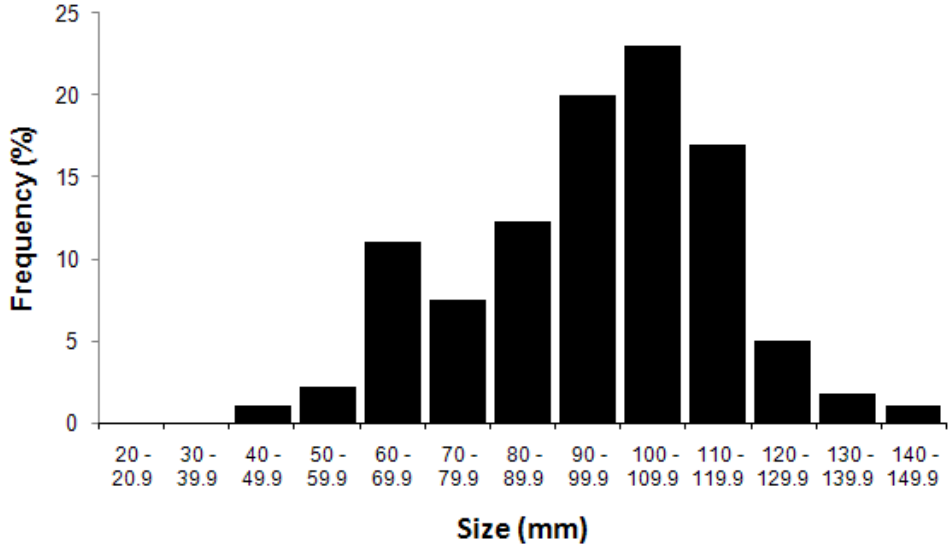


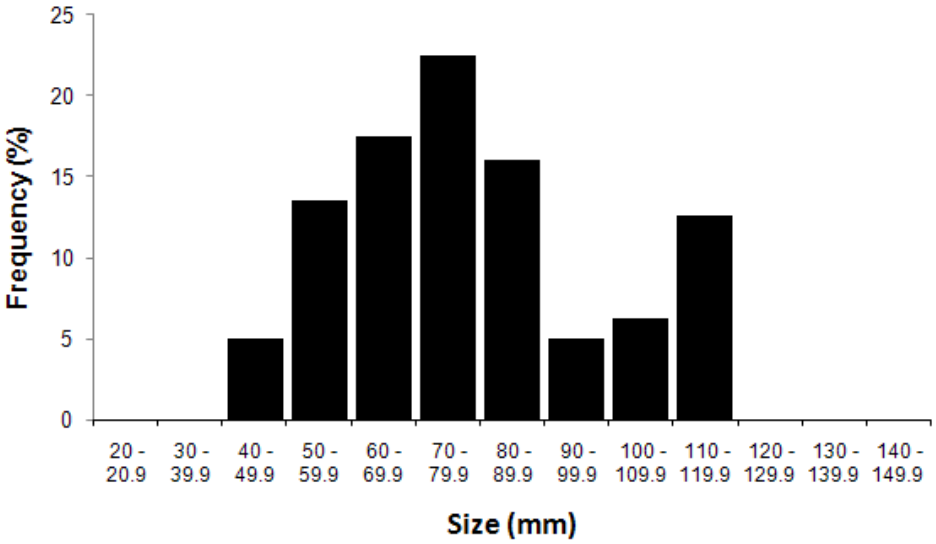

**Figure 3.** Shell size frequencies of *Concholepas concholepas* from the Early Holocene: **A)** Site LV 098 a (Punta Ñagué); **B)** Site LV 079 (Punta Purgatorio).

**Early Holocene**

Contrary to the evidence obtained from Pleistocene sites, the use of marine coastal resources is strikingly evident in archaeological contexts dating from the Pleistocene-Holocene transition, during the post glacial period, when climate changed from cold and wet to warm and dry. Several sites from the Pacific coast of South America, dating from 10,000 B.P., yield evidences of hunter-gatherer-fishermen groups intensively exploiting marine resources (Richardson III 1998; Sandweiss et al. 1998), either opportunistically or in a very well organized fashion.

In the coast close to Los Vilos, many archaeological sites from the Early Holocene have abundant remains of *loco* (Jackson et al. 1999). Among the number of gathered species found in the occupational event of the site LV098a, in Punta Ñagué, the earliest human settlement on the Chilean coast (11,000 B.P.) (Figure 3), densities of *loco* with shell sizes varying from 40.0 to 99.9 mm, reach 102 individuals/m³ (Báez et al. 2004). Furthermore, of more than 20 mollusc species found in site LV079 of Punta Purgatorio (10,000 B.P.) (Jackson et al. 1997), *C. concholepas* shells make 28.0%, with sizes from 40 to 145 mm and densities reaching up to 991 individuals/m³

**A) LV 036 (6,030 +- 80 y.B.P.)**




**B) Site LV 099 (5,480 B.P.)**

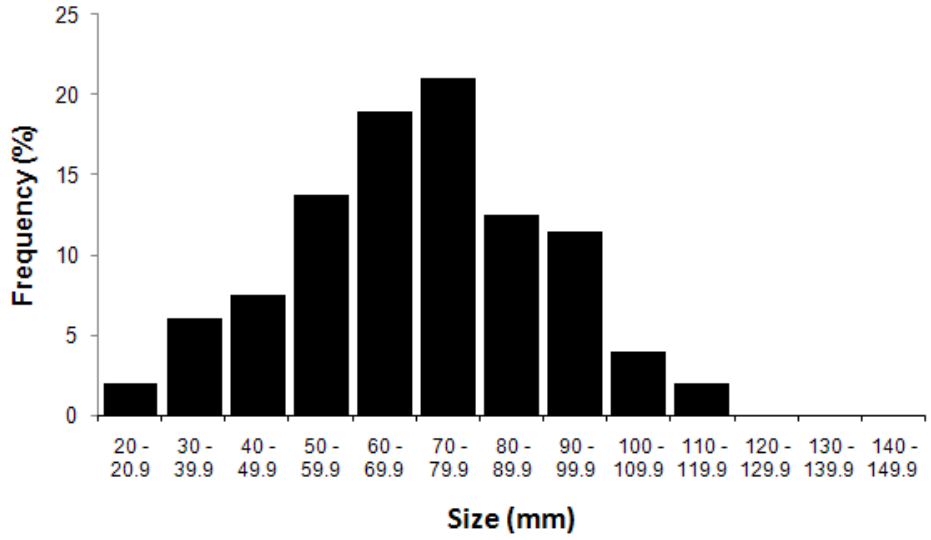
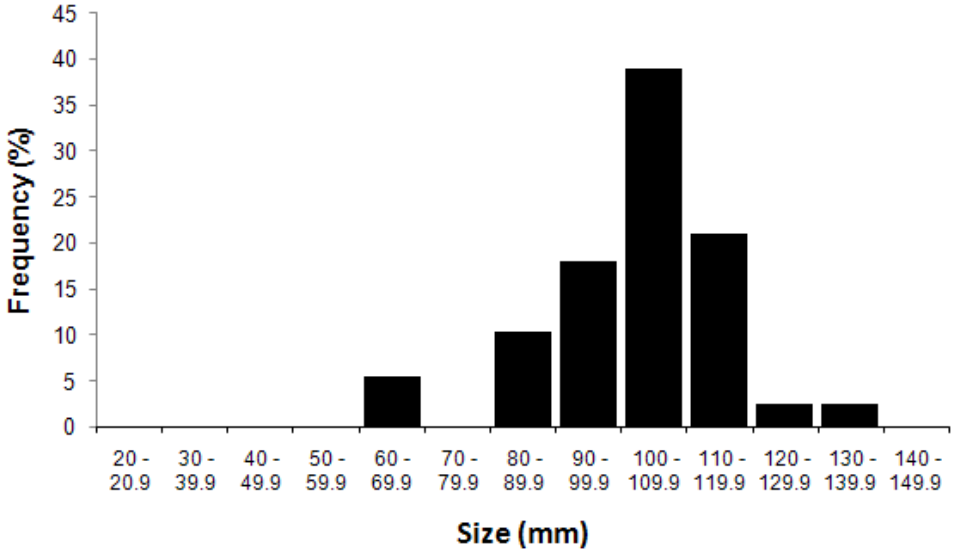



**Figure 4.** Shell size frequencies of *Concholepas concholepas* from the Middle Holocene: **A)** Site LV 036 (Quereo Norte); **B)** Site LV 099 (Fundo Agua Amarilla).

(Báez et al. 2004). In Quebrada Las Conchas (La Chimba) site of Antofagasta (10,300 and 7,100 B.P.) *loco* was the most abundant shell when compared to the other 11 species found in the site (Llagostera 1979; Llagostera et al. 2000). Also, in the oldest site of that area (8,500 B.P.), Curaumilla-1 of Punta Curaumilla, South from Los Vilos, *loco* shells are very abundant and so are a number of key-hole limpets species (*Fisurella* spp.) and polyplacophorans (*Chiton* spp.), adding up to a total of 16 species (Jerardino et al. 1992).

Large densities of *loco* found in these sites are probably related to high rates of exploitation for food purposes. But this exploitation was far from being constant throughout the region during the Early Holocene. In fact, in the site of Huentelauquén (9,400 B.P.), located 30 km North of Los Vilos and 1.5 km away from the coast, *locos* and other gastropods are surprisingly less abundant than pelecypods. Low frequencies of *loco* shells have also been found in El Obispito site (10,800 to 10,440 B.P.) (Cervellino et al. 2000). If *loco* exploitation in these sites was actually comparable to that described from Punta Ñagué and Punta Purgatorio, the only viable explanation for such low gastropod densities in Huentelauquén and El Obispito settlements is that shells were separated from their valuable meat in a gathering place, before being

**A ) Site LV 046 a (Without date)**




**B) Site LV 046 (2,270+-60 B.P.)**

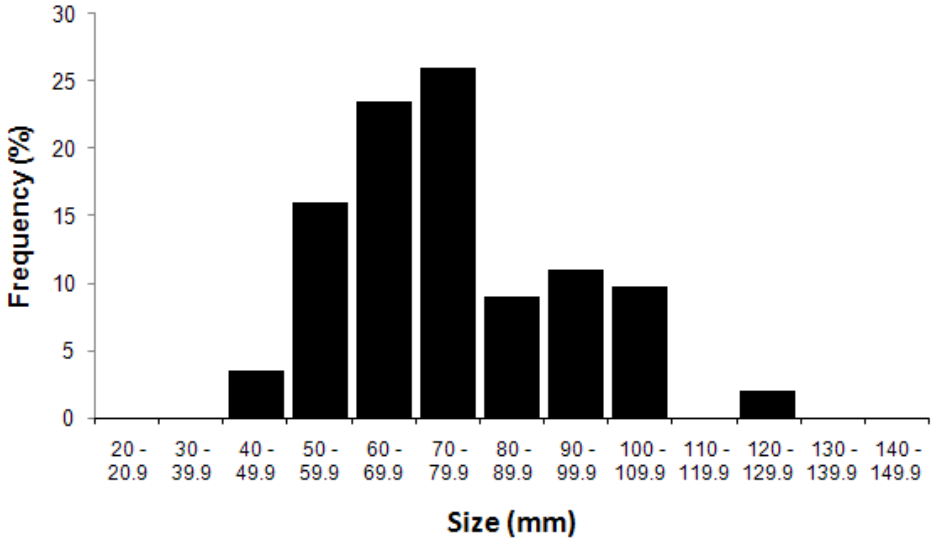



**Figure 5.** Shell size frequencies of *Concholepas concholepas* from Late Holocene:
**A)** Site LV 046 a, level 2; **B)** Site LV 046 a, level 1.

transported elsewhere, as an attempt to reduce the weight to be carried to the residential settlements (Vásquez et al. 1996). Evidences from sites in the Middle Holocene strongly support this argument.

**Middle Holocene**

Most of the 63 Middle Holocene sites, located in the coastal area of Los Vilos, date from 7,000 to 4,000 B.P. In these sites, workshop settlements in which *loco* meat was separated from shells, are located on high terraces near the tidal line. The closest residential settlements are approximately 3 km away from the coast (Jackson et al. 1996; Jackson 2002; Méndez 2002). In site LV053, *loco* shells add up to 39.6% of all shells from a total of 16 different species. The same happens in LV047 site, in which *C. concholepas*, one of 8 invertebrate species collected there, represents 61.6% of all remains. In other sites, like LV099 in Fundo Agua Amarilla, the density of *loco* shells is 24 individuals/m³ and their estimated abundance in the shellmidden amounts to 46,000 individuals. In site LV036, in Quereo Norte, the density of *loco* is 629 individuals/m³ and its shell midden´s abundance reaches up to 4,185,000 shells (Báez et al. 2004) (Figure 4). Being one of the 9 species found in site

**LV 007 (1,510 A.C.)**

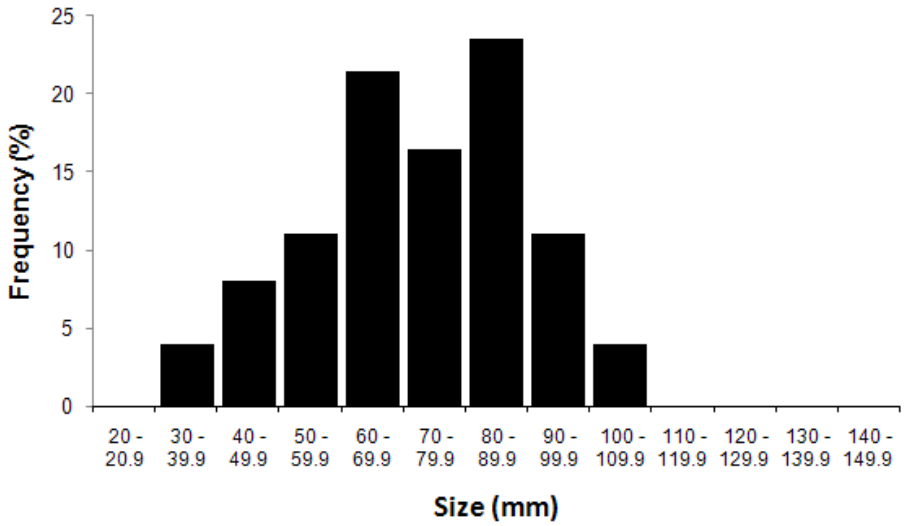



**Figure 6.** Shell size frequencies of *Concholepas concholepas* from LV 007 (Late Holocene).

LV116 in Arcaico Medio, and one of 21 in Arcaico Tardío, *C. concholepas* represents 41.2% and 18.0%, respectively, of all shells in these collecting stations. *Loco* is also well represented at site LV46a (Figure 5).

Shells found in residential settlements are the result of local and familiar consumption, while the majority of shells used for consumption were fleshed in workshop settlements. In consequence, despite of the relatively large diversity of marine resources found in residential settlements, inferences about their abundance made with the material retrieved from those sites could be underrepresented due to the apparently widespread procedure of not discarding shells in residential zones. Besides the existence of workshop and residential settlements in the area, the fact that shells in workshop settlements are larger and have a reduced size range (approximately 40 to 145 mm) than those found in residential settlements (20 to 120 mm) also supports this hypothesis.

**Late Holocene**

The number of coastal settlements slightly increased along the southern border of *Norte Semiárido* during the Late Holocene, from 3,400 to 2,160 B.P. All these sites were self-sufficient in terms of food production and hence, were among the most stable residential settlements on the coast (Méndez 2003; Méndez and Jackson 2004). Their long lasting shellmiddens, now as large as small hills, host a large diversity of molluscs with a wide range of shell sizes. Among them, *loco* is well represented and in several sites, such as LV007 (Figure 6), LV014 in Punta Penitente (Méndez 2002) and LV034 in Paso Inferior Conchalí (Barrera and Belmar 2000), is the most abundant species. In site LV049, Middle Holocene samples collected from a 50 x 50 cm test pit yielded only 24 *loco* shells from 7.9 - 11.7 cm in length while Late Holocene *loco* samples from the same pit represented 8.3 % of the total number of individuals, from 18 species. Unfortunately, *loco* shells from this last sample were too badly broken to determine their size. Other stable settlements from the same time period, such as Punta Curaumilla from the Central Chilean coast (Jerardino et al. 1992) and Laguna El Peral from Northern Chile (Falabella and Planella 1991), are similar to those just described before (Berdichewsky 1963).

The diversity of exploited marine resources in *Norte Semiárido* was reduced during the Late Holocene, especially after the arrival of more human groups, agriculturalists and pottery-makers. During the same period of time, the proportion of *C. concholepas* remnants notoriously diminished compared to that of other exploited species of gastropods.

**Discussion and conclusions**

Until today, those at Los Vilos are the oldest, most complete and best studied sites, deposits, and shell middens or marine molluscs in Chile. The knowledge obtained from these sites defines a frame of reference to understand the role of molluscs in early human groups that settled in *Norte Semiárido*, and the effects of early societies on the malacological fauna of the Chilean coast. During the Early and Middle Holocene, settlers completed their diet with marine organisms, such as echinoderms, crustaceans (Báez and Jackson, in preparation), marine mammals, fish (Jackson and Báez 2005) and at least, 36 species of molluscs. Representing approximately 25% of all littoral molluscs known in the central region of Chile (Table 1, Figure 7), only 21 of these species were directly consumed. The others were either epibionts that reached shell middens attached to other marine organisms or shells gathered by humans with purposes other than alimentary.

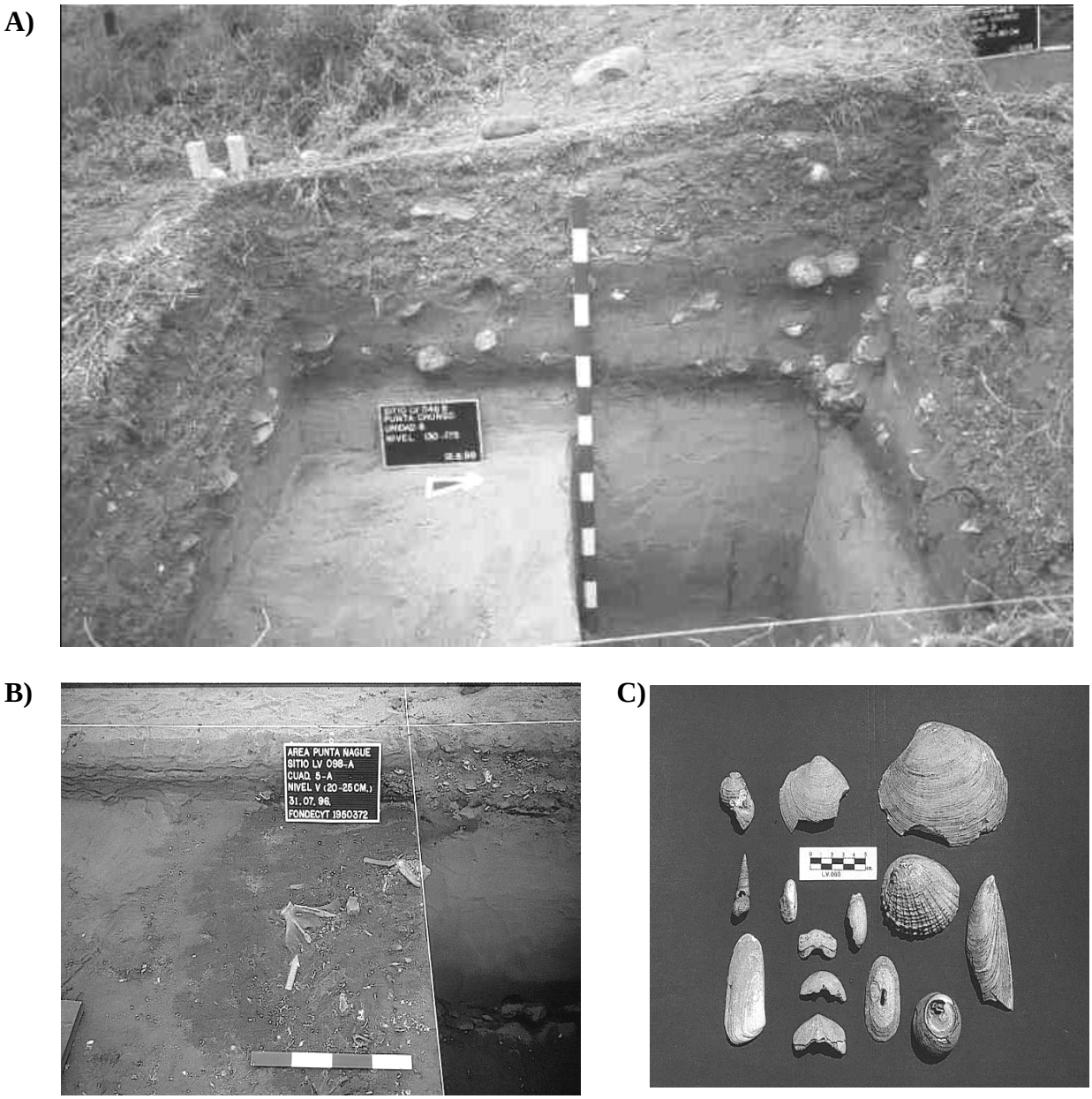



**Figure 7. A)** Archeological context from the Holocene at Los Vilos. Site showing the predominance of *loco* shells, *Concholepas concholepas*, at different levels; **B)** Site with the remnants of other marine resources; **C)** Holocene mollusks diversity.

As a way of comparison, the reader should keep in mind that all species consumed by hunter-gatherers are still exploited today. Modern "shell gatherers" (Figure 8) are capable of modifying the structure of natural populations and communities living in the rocky intertidal with great efficiency. Indeed, the low densities of *loco* in modern Chile are the direct consequence of human activities (Reid and Osorio 2000): while the density of *loco* living in protected reserves oscillates between 1.6 and 4.3 individuals/m² (Castilla and Durán 1985; Moreno et al. 1986; Durán et al. 1987) individuals of this species are almost impossible to find in coastal areas frequented by humans. During the Holocene, humans were also capable of modifying ancient marine communities and populations, as demonstrated by the evidence found in shell middens from Curaumilla-1, and many others from different latitudes (Jerardino et al. 1992). However, our findings at Los Vilos suggest that modifications of the ancient environment owing to human activities did not occur. Indeed, the size of human groups living in the area was too low to produce any impact on the ecology of coastal organisms, as it has been shown by Falabella and Planella (1991). Even though the size of human groups at Los Vilos increased along the Holocene (Méndez 2003; Méndez and Jackson 2004), it never reached numbers that could affect either the densities of *loco* or the diversity of littoral molluscs. Moreover, hunter-gatherers conducted non-selective shell gathering activities mostly in the intertidal and the lower subtidal, while the largest densities of *loco* occur at greater depths, especially during

**A)**

**B)**

**Figure 8. A)** Coastal collectors in Los Vilos; **B)** Today shell midden of *Concholepas concholepas.*

the mating season C. *concholepas* was the most exploited mollusc during the Early Holocene at Los Vilos. In early settlements, *loco* was seldom collected and most of its shells were rather small. Later on, during the Early Holocene, larger individuals of *loco* were exploited in association with other marine species, such as key-hole limpets (*Fisurella* spp.) and the bivalve *Mesodesma donacium*, as evidences from Caleta Ñagué and especially from Punta Purgatorio suggest. However, even then, the wide size range of *loco* shells found in middens suggests the reduced selectivity of gatherers.

| Period and Site | Early Holocene (LV 098a) | Middle Holocene (LV 036) | Late Holocene (LV 046a I) | Total |
|---|---|---|---|---|
| Species from: | | | | |
| *Euromalea rufa* | --- | 13 | 1 | 14 |
| *E. lenticularis* | 6 | --- | --- | 6 |
| *Mesodesma donacium* | 427 | --- | 3 | 430 |
| *Protothaca thaca* | 2 | 1 | --- | 3 |
| *Acanthina monodon* | 1 | --- | 4 | 5 |
| *Acanthopleura echinata* | --- | 14 | 4 | 18 |
| *Collisella orbigny* | --- | --- | 5 | 5 |
| *C. ceciliana* | --- | --- | 1 | 1 |
| *C. sp.* | --- | 5 | --- | 5 |
| *Concholepas concholepas* | 15 | 155 | 63 | 233 |
| *Chiton granosus* | --- | --- | 1 | 1 |
| *Ch. latus* | --- | 1 | 1 | 2 |
| *Ch. sp.* | 15 | --- | 1 | 16 |
| *Choromytilus chorus* | --- | --- | 1 | 1 |
| *Diloma nigerrima* | --- | --- | 4 | 4 |
| *Fisurella costata* | --- | 19 | 7 | 26 |
| *F. crassa* | --- | 32 | 8 | 40 |
| *F. latimarginata* | --- | 10 | 3 | 13 |
| *F. maxima* | --- | --- | 2 | 2 |
| *F. nigra* | --- | --- | 3 | 3 |
| *F. picta* | --- | --- | 2 | 2 |
| *F. sp.* | 13 | --- | 4 | 17 |
| *Nodilittorina peruviana* | --- | --- | 2 | 2 |
| *Marinula pepita* | --- | 2 | --- | 2 |
| *Oliva peruviana* | --- | --- | 1 | 1 |
| *Perumytilus purpuratus* | --- | 5 | 2 | 7 |
| *Prisogaster niger* | --- | 3 | 1 | 4 |
| *Scurria parasitica* | --- | --- | 6 | 6 |
| *Tegula atra* | 15 | 109 | 3 | 127 |
| Total | 494 | 369 | 133 | 996 |
| Nr. of species | 8 | 13 | 25 | 29 |

**Table 1.** Mollusc species found in selected Holocene sites at Los Vilos.

Archaeological findings dating from the Middle Holocene provide evidence on the migration of people from residential settlements, located close to Los Andes Mountains, to the coastal workshop settlements, especially on summers. This temporal transhumance to the coast increased when the climate turned to arid and terrestrial resources became scarce (Jackson 2002), given that coastal localities always offered to settlers resources in abundant and predictable fashion.

Palinologic results also indicate a change of climate during this period of time correlated to changes in the using of *loco* as a resource through the cultural sequence at Los Vilos. Arboreal and fresh-water taxa were absent from Los Vilos, specially at Quebrada de Quereo and Quintero sites, and the cover of coastal *matorral* (i.e., a dense and impenetrable community of shrubs and dwarf trees) was decreasing after 10,000 B.P., probably as a consequence of the arid climate. Humid areas and wetlands were not to be seen in the zone until 1,720 B.P. (Villagrán 1982; Villagrán and Varela 1990; Núñez et al. 1994).

During the Late Holocene, the diversity of species used as food resources increased as what seems to be the result of an increasingly better understanding of the environment by the inhabitants of Los Vilos. The density of shell middens also increased, suggesting that climatic conditions became favourable, and the dependence of hunter-gatherers on particular marine species was reduced.

Sea level changes were also common in the Holocene (Kraft 1985). In *Norte Semiárido*, the last transgression episode occurred in 6,000 B.P. The waters raised 3 to 5 meters above the present day sea level, flooding the Middle Holocene coast line (Ota and Paskoff 1993). Sea level rise affected the availability of molluscs physically limiting the access of humans to certain localities along the coastal line. In the Middle Holocene, these areas isolated to humans remained unexploited and held abundant marine resources as well as individuals of larger size than those found in areas already populated. As new settlements appeared in these areas, natural resources were immediately used, leaving behind enough

archaeological evidence to, erroneously, suggest humans as the culprits of exhausting mollusc resources in the region.

Examples of these situations are common along the Chilean coast, South of Los Vilos, and in some small peninsulas located to the North. Transgressive sea level changes, occurring as a consequence of tectonic risings in the area (Prieto and Jackson 2000) did not affect the availability of intertidal resources and the accessibility of humans to them. Indeed, most of the Holocene´s intertidal landscape was very similar to that we see in the region today, especially along the coast South of Los Vilos, where *locos* and rocky shores are common.

One interesting hypothesis advanced by Botkin (1980) explains the long sequence of *loco* exploitation in Los Vilos based on the efficient *loco* reproductive strategy and the exploitation of diverse resources exerted by human groups living in the region. This situation has been particularly well described for Punta Curaumilla sites (Jerardino et al. 1992; Ramírez et al. 1991), as evidenced by the presence in shell middens of small *C. concholepas* individuals. Apparently, in the Late Holocene, settlers incorporated different dietary elements in their gathering, widening the diversity of exploited resources. Given that the average *loco* shell size did not change significantly along the Holocene, there is no compelling evidence to affirm that small shells of *loco* were the sign of overexploitation. On the contrary, shell size reduction was probably the result of the diversification of resources. Moreover, the collection of molluscs was concentrated on the intertidal and shallow subtidal, and human remains with auditive exostosis, indicative of deep water diving, have been recovered only once.

According to Moreno (2004), the largest events of recruitment of *loco* are observed just after the summer (in the southern hemisphere), especially those with frequent *surazos* (i.e., strong winds from the South), abundant sunlight through February, and low pressure fronts after March. These are the times when the strongest upwelling occurs (Poulin et al. 2002). When February winds blow from the North and rain is abundant, recruitment is delayed to June and July, and is not as successful. Being dependent on strong upwelling phenomena, *loco* recruitment at Los Vilos was negatively correlated to the extreme oceanographic phenomena of El Niño and La Niña. The similarity between the diversity at Los Vilos and Curaumilla-1 (Jerardino et al. 1992) is due to the fact that all shells remnants in shell middens come from the intertidal and shallow subtidal, areas that are refuges to the endemic fauna of Chile and Perú when El Niño events occur (Báez and Martin 1992).

Our data suggest that marine resources were not necessarily overexploited along the Holocene at Los Vilos and recorded changes in size, abundance, and availability of *loco* were minimal both in temporal and spatial scales. Archaeological evidence of cultural effects in *loco´*s Holocene sequence at Los Vilos, is minimal. Changes in diversity and abundance of molluscs in shellmiddens were most probably caused by paleoclimatic changes than human behaviour. We conclude that through the Early Holocene coastal occupation was permanent and human subsistence depended basically on marine resources, locals gathered a wide variety of species, but intensively exploiting only few of them. During the Middle Holocene, humans occupied the coast only seasonally, when shellfish gathering was easy to predict and molluscs were abundant. There was intensive exploitation of some marine mollusc species as well as a dependence on terrestrial species. The collection of marine species in 6,500 B.P. was associated to more arid and dry climate conditions, scarcity of other resources, and changes in the sea level. During the Late Holocene, climatic conditions more similar to those present today, allowed the proliferation of human settlements on the coast, without the strong dependence on particular marine species.

**References cited**

Acuña, E. and J. Stuardo 1979 Una estimación de clases anuales y crecimiento relativo en muestras de dos poblaciones de *Concholepas concholepas* (Bruguière, 1789). *Biología Pesquera* 12: 131-142.

Arias, E. 1991 *Reclutamiento de Concholepas concholepas en la zona submareal de Chiloé, Chile. Proceedings of the XI Jornadas de Ciencias del Mar, Viña del Mar, 27-29 May, 1991*. Congreso de Ciencias del Mar, edited by Instituto de Oceanología, pp. 8. Chile: Universidad de Valparaíso.

Báez, P., D. Jackson, and M. Bahamondes 2003 Pesquerías pre-hispánicas de Chile: abundancia de recursos y recolección costera de subsistencia a comienzos del Holoceno en la Provincia de Choapa. In *Actividad Pesquera y de Acuicultura en Chile*, edited by E. Yáñez, pp. 317-325. Ediciones Universitarias de Valparaíso, Valparaíso.

Báez, P., J. Arata and D. Jackson 2004 El *loco Concholepas concholepas* (Bruguiere, 1789) (Mollusca: Gastropoda: Muricidae) como recurso durante el Holoceno Temprano-Medio en Los Vilos, Chile central. *Nota Científica, Investigaciones Marinas.*, (Valparaíso) 32(1): 107-113.

Báez, P. and J. W. Martin 1992 Decapod Crustacean Larvae Collected off Northern Chile during an El Niño Event (February-March, 1983). *Contributions in Science Natural History Museum of Los Angeles County* 432: 1-10.

Barrera M. and C. Belmar 2000 Rescate del sitio arqueológico Nº18 Paso Inferior Conchalí: Nuevas evidencias del Complejo Papudo en el Norte Semiárido de Chile. *Valles, Revista de Estudios Regionales* 5-6: 135-146. La Ligua.

Berdichewsky, B. 1963 Culturas Precolombinas de la Costa Central de Chile. *Antropología* 1: 17-33.

Botkin, S. 1980 Effects of human exploitation at Malibu Creek, California. In *Modeling changes in prehistoric subsistence economies,* edited by T. K. Earle and A. L. Christenson, pp. 121-139. New York: Academic Press.

Brattstroem, H. and A. Johanssen 1983 Ecological and regional zoogeography of the marine benthic fauna of Chile. *Sarsia* 68: 289-339.

Bruguière, J. 1789 *Encyclopédie Méthodique, Histoire Naturelle des Vers* 1: 1–344. Panckoucke: Paris.

Camus, P. 1990 Procesos regionales y fitogeografía en el Pacífico Sudeste: El efecto de "El Niño-Oscilación del Sur". *Revista Chilena de Historia Natural* 63: 11-17.

Camus, P. 2001 Biogeografía marina de Chile continental. *Revista Chilena de Historia Natural* 74: 587-617.

Castilla, J. C. 1988 Earthquake-Caused Coastal Uplift and Its Effects on Rocky Intertidal Kelp Communities. *Science* 242: 440-443.

Castilla, J. C. and J. Cancino 1976 Spawning behavior and eggs capsules of *Concholepas concholepas* (Mollusca: Gastropoda: Muricidae). *Marine Biology* 37: 255-263.

Castilla, J. C. and L. R. Durán 1985 Human exclusion from the rocky intertidal zone of Central Chile: the effects on *Concholepas concholepas* (Gastropoda). *Oikos* 45: 391-399.

Castilla, J. C. and P. Schmiede 1979 Hipótesis de trabajo sobre la existencia de zonas marítimas tampones en relación a Recursos Marinos Bentónicos (Mariscos y Algas) en la Costa de Chile: In *Seminario/Taller sobre el Desarrollo e Investigación de los Recursos Marinos de la VIII Región, Chile*, edited by V. A. Gallardo, pp. 145-167. Vicerrectoría de Investigación, Universidad de Concepción.

Castilla, J. C., C. Guisado and J. Cancino 1979 Aspectos ecológicos y conductuales relacionados con la alimentación de *Concholepas concholepas* (Mollusca: Gastropoda: Muricidae). *Biología Pesquera* 12: 99-114.

Cervellino M., A. Llagostera, R. Weisner and G. Castillo 2000 El Obispito: Primeras evidencias tempranas en la costa de la región de Atacama. *Contribuciones Arqueológicas* 5(1): 483-510.

Craig, A. K. and N. P. Psuty 1968 *The Paracas papers. Studies in marine desert ecology*, Vol. 1, Nr 2. Reconnaissance Report. Occasional Publication Nº 1, Department of Geography, Florida Atlantic University, Boca ratón, Florida.

DeVries, T. 2000 Two New Neogene Species and the Evolution of Labral Teeth in *Concholepa*s Lamarck, 1801 (Neogastropoda: Muricoidea). *The Veliger* 43(1): 43-50.

DiSalvo, L. H. 1988 Observations on the larval and post-metamorphic life of Concholepas concholepas (Bruguière, 1789). *The Veliger* 30: 358-368.

Durán, L. R., J. C. Castilla and D. Oliva 1987 Intensity of human predation on rocky shores at Las Cruces in central Chile. *Environmental Conservation* 14: 143-149.

Durán, R. and J. C. Castilla. 1988. Determinación de la fecundidad de Concholepas concholepas (Bruguière, 1789) (Gastropoda, Muricidae) en condiciones de laboratorio. *Biología Pesquera* (Chile) 17: 39-45.

Falabella F. and M. Planella 1991 *Comparación de ocupaciones precerámicas y Agro-Alfareras en el litoral de Chile Central*. Actas del XI Congreso Nacional de Arqueología Chilena Tomo III, pp. 95-112.

Gallardo, C. 1979 El ciclo vital del Muricidae *Concholepas concholepas* y consideraciones de sus primeros años de vida en el bentos. *Biología Pesquera* (Chile) 12: 79-89.

Galli-Olivier, C. 1967 Pediplain in northern Chile and the Andean uplift. *Science* 158: 653-655.

Guisado, C. and J. C. Castilla 1983 Aspects of the ecology and growth of an intertidal juvenile population of *Concholepas concholepas* (Mollusca: Gastropoda: Muricidae) at Las Cruces, Chile. *Marine Biology* 78: 99-103.

Jackson, D. 2002 Cazadores y Recolectores del Holoceno Medio del Norte Semiárido de Chile. Masters thesis, Departamento de Antropología, Facultad de Ciencias Sociales, Universidad de Chile.

Jackson, D. 2003 Evaluating evidence of cultural associations of Mylodon in the semiarid region of Chile. In *Where the South Winds Blow, Ancient evidence of Paleo South Americans*, edited by L. Miotti, M. Salemme, and N. Flegenheirmer, pp. 77-81. Center for the Study of the First Americans, College Station, Texas.

Jackson D., P. Báez and L. Vargas 1995 Secuencia ocupacional durante el Arcaico en la comuna de Los Vilos, Provincia de Choapa. *Hombre y Desierto* 9: 99-110.

Jackson D., P. Báez, R. Seguel, and J. Arata 1996 Campamento Arcaico para la Explotación del Intermareal: Significado del desconche local de Moluscos. *Valles* 2: 89-109, La Ligua.

Jackson D., P. Báez and R. Seguel 1997 Nuevas evidencias estratigráficas para el Complejo Huentelauquén en la Provincia del Choapa, IV Región. *Revista Chilena de Antropología* 14: 145-156.

Jackson D., R. Seguel, P. Báez and X. Prieto 1999 Asentamientos y evidencias culturales del Complejo Huentelauquén en la comuna de Los Vilos, Provincia de Choapa. *Anales del Museo de Historia Natural de Valparaíso* 24: 5-28.

Jackson D., C. Méndez and P. De Souza 2004 Poblamiento Paleoindio en el norte-centro de Chile: Evidencias, problemas y perspectivas de estudio. *Complutum* 15: 165-176.

Jackson, D., P. Báez and J. Arata 2004 Composición malacológica, estrategia de subsistencia y cambios paleoambientales en un asentamiento arcaico, Norte Chico de Chile. *Boletín de Sociedad Chilena de Arqueología* 37: 37-48.

Jackson, D. and P. Báez 2005 Recursos litorales del Semiárido de Chile: Adaptaciones costeras durante el Holoceno. In *Biodiversidad Marina: Valoración, Usos y Perspectivas. ¿Hacia donde va Chile*?, edited by E. Figueroa, pp. 149-164. Editorial Universitaria, Santiago.

Jackson D. and C. Méndez 2005 Reocupando el espacio: Historia de un asentamiento multicomponente, sus relaciones Inter-sitios y los cambios ambientales de la costa del Choapa. *Werken* 6: 97-111.

Jerardino, A., J. C. Castilla, J. M. Ramírez, and N. Hermosilla 1992 Early coastal subsistence in Central Chile: A systematic Study of the Marine-Invertebrate Fauna from the Site of Curaumilla-1. *Latin American Antiquity* 3(1): 43-62.

Kraft, J. 1985 Maine environments: Paleogeographic reconstruction in the littoral region. In *Archaeological sediments in context*, edited by J. Stein and W. Farrand, pp: 111-125. Center for the Study of Early Man, University of Maine at Orono, Maine.

Larraín, A. P. 1975 Los equinodermos regulares fósiles y recientes de Chile. *Gayana Zoología* (Chile) 35: 3-189.

Leiva, G. E. and J. C. Castilla 2001 A review of World marine gastropod fishery: evolution of catches, management and the Chilean experience. *Reviews in Fish Biology and Fisheries* 11 (4): 283 – 300. Springer Netherlands.

Llagostera, A. 1979 9,700 Years of Maritime Subsistence on the Pacific: An Analysis by means of Bioindicators in the North of Chile. *American Antiquity* 44: 309-324.

Llagostera A., R. Weisner, G. Castillo, M. Cervellino and M. Costa-Junqueira 2000 El Complejo Huentelauquén bajo una perspectiva macroespacial y multidisciplinaria. *Contribuciones Arqueológicas* 5(1): 461-481.

Maldonado, A. 2004 *Cambios vegetacionales y climáticos en Chile durante el Holoceno: análisis de polen en el extremo norte del cinturón de vientos del oeste*. Unpublished Ph.D. dissertation. Facultad de Ciencias, Universidad de Chile.

Maldonado A. and C. Villagrán 2002 Paleoenvironmental changes in the semiarid coast of Chile (-32ºS) during the last 6200 cal years inferred from a swamp-forest pollen record. *Quaternary Research* 58: 130-138.

Manríquez, P. S. Navarrete, A. Rosson and J. C. Castilla 2004 Settlement of the gastropod *Concholepas concholepas* on shells of conspecific adults. *Journal of the Marine Biological Association of the United Kingdom* 84: 651-658.

Manríquez, P. H. and J. C. Castilla 2001 The significance of Central Chile marine protected areas as seeding grounds for the gastropod *Concholepas concholepas* (Bruguière, 1789). *Marine Ecology Progress Series* 215: 201-211.

Martínez, P. and S. A. Navarrete 2002 Temporal and spatial variation in settlement of the gastropod *Concholepas concholepas* in natural and artificial substrata. *Journal of the Marine Biological Association of the United Kingdom* 82: 257-264.

Méndez, C. 2002 Cazadores recolectores costeros y sus contextos de tareas: Una visión desde el asentamiento holocénico temprano de Punta Penitente (L.V. 014), Los Vilos, IV Región. *Chungara* 32(2): 153-166.

Méndez, C. 2003 Orígenes del asentamiento Holócenico Tardío de Cazadores Recolectores en el Litoral del Choapa: Ensayo para la generación de una hipótesis de investigación. *Revista Werken* 4: 43-58.

Méndez, C. 2004 *Una sociedad de cazadores Recolectores en Movimiento Durant la primera Mitad del Holoceno Tardío (- 400 a 2000 años A.P.) en Los Vilos*. Masters tesis, Universidad Católica del Norte y Universidad de Tarapacá.

Méndez C. and D. Jackson 2004 Ocupaciones humanas del Holoceno Tardío en Los Vilos (IV Región, Chile): Origen y características conductuales de la población local de cazadores recolectores del litoral. *Chungara* 36(2): 279-293.

Montané J. and R. Bahamóndes 1973 Un nuevo sitio Paleoindio en la Provincia de Coquimbo, Chile. *Boletín del Museo Arqueológico de La Serena* 15: 215-222.

Moreno, C. 2004 Efectos de El Niño en el Reclutamiento de *Concholepas concholepas* y *Tegula atra* (Mollusca, Gastropoda) en la costa de Valdivia, Chile. En *El Niño-La Niña 1997-2000. Sus Efectos en Chile*, edited by S. Avaria, J. Carrasco, J. Rutllant and E. Yánez, pp. 179-189. CONA, Valparaíso, Chile.

Moreno, C. A., K. M. Luneke and M. I. Lépez. 1986 The response of an intertidal *Concholepas concholepas* (Gastropods) population to protection from man in southern Chile and the effects on benthic sessile assemblages. *Oikos* 46: 359-264.

Moreno, C. A., A. Reyes and G. Asencio. 1993 Habitat and movements of the recruits of *Concholepas concholepas* (Mollusca: Muricidae) in the rocky intertidal of southern Chile. *Journal of experimental Marine Biology and Ecology* 171: 51-61.

Núñez L., J. Varela and R. Casamiquela 1983 *Ocupación Paleoindia en Quereo*. Monografía, Universidad del Norte, Antofagasta.

Núñez L., J. Varela and R. Casamiquela 1987 Ocupación Paleoindia en el centro norte de Chile: Adaptación circumlacustre en las tierras bajas. *Estudios Atacameños* 8: 142-185.

Núñez L. and C. Santoro 1990 Primeros poblamientos en el cono Sur de America (XII-IX Milenio a.P.). *Revista de Arqueología Americana* 1: 91-139.

Núñez L., J. Varela, R. Casamiquela and C. Villagrán 1994 Reconstrucción multidisciplinaria de la ocupación prehistórica de Quereo, Centro de Chile. *Latin American Antiquity* 5(2): 99-118.

Otlieb, L. 1995 Paleoclimas cuaternarios en el norte grande de Chile. In *Cambios cuaternarios en América del Sur*, edited by J. Argollo and Ph. Mourguiart, pp. 225-246. La Paz: Ortom.

Otta Y. and R. Paskoff 1993 Holocene deposits in the coast of north-central radiocarbon ages and implications for coastal changes. *Revista Geoógica de Chile* 20(1): 25-32.

Poulin, E., A. T. Palma, G. Leiva, E. Hernández, P. Martínez, S. A. Navarrete and J. C. Castilla 2002 Temporal and spatial variation in the distribution of epineustonic competent larvae of *Concholepas concholepas* along the central coast of Chile. *Marine Ecology Progress Series* 229: 95-104.

Prieto, X. and Jackson D. 2000 Evolución geomorfológica, características holocénicas y su relación con ocupaciones humanas en el área de Los Vilos, IV Región. *Contribuciones Arqueológicas* 1(2): 667-677.

Rabí, M., C. Yamashiro and M. Quiroz 1996 *Revisión de la biología y pesquería del recurso chanque Concholepas concholepas (Bruguiere, 1789) (Mollusca: Gastropoda: Muricidae).* Informe Progresivo, Instituto del Mar del Perú 31:3-23.

Ramírez J., N. Hermosilla, A. Jerardino, and J. Castilla 1991 *Análisis bio-arqueológico preliminar de un sitio de cazadores recolectores costeros: Punta Curaumilla-1, Valparaíso*. Actas del XI Congreso Nacional de Arqueología Chilena, pp. 81-93.

Reid, D. and C. Osorio 2000 The shallow water marine Mollusca of the Estero Elefantes and Laguna San Rafael, Southern Chile. Bulletin of Natural History Museum, London UK, 66(2): 109-146.

Rivas, D. and J. C. Castilla 1987 Dinámica de poblaciones intermareales de *Concholepas concholepas* (Bruguiere, 1789) (Mollusca: Gastropoda: Muricidae) en Chile Central. *Investigaciones Pesqueras* 34: 3-19.

Richardson III, J. 1998 Looking in the Right Places: Pre-5.000 B.P. Maritime Adaptations in Perú and The Changing Environment. *Revista de Arqueología Americana* 15: 33-56.

Rollins, H. B., J. B. Richardson, and D. H. Sandweiss. 1986. The Birth of El Niño: Geoarchaeological Evidence and Implications. *Geoarchaeology* 1: 3-15.

Salinger, M. J. 1981 Paleoclimates north and south. *Nature* 291: 106-107.

Sánchez Romero, J. 1973 Historia Marítima del Perú. El mar gran personaje. *Aspectos biológicos y pesqueros del mar peruano* 1(2): 19 –493.

Sandweiss D., H. McIcnnis, R. Burger, A. Cano, B. Ojeda, R. Paredes, M. del C. Sandweiss y M. Glascock 1998 Quebrada Jaguay: Early South American Maritime Adaptations. *Science* 281: 1830-1832.

Stotz, W., P. de Amesti, D. Martínez and E. Perez. 1991 Lugares de asentamiento y desarrollo de juveniles tempranos de Concholepas concholepas (Bruguière, 1789) en ambientes inter y submareales de la IV Región, Coquimbo, Chile. *Revista de Biología Marina,* Valparaíso 26(2): 339-350.

Stuardo, J. 1979 Sobre la clasificación, distribución y variación de *Concholepas concholepas* (Bruguière, 1789): Un estudio de Taxonomía Beta. *Biología Pesquera* (*Chile)* 12: 5-38.

Valdés, J., L. Otlieb and A. Sifeddine 2003 Variaciones del sistema de surgencia de Punta Angamos (23 S) y la Zona de Mínimo Oxígeno durante el pasado reciente. Una aproximación desde el registro sedimentario de la Bahía de Mejillones del Sur. *Revista Chilena de Historia Natural* 76(3): 347-362.

Varela, J. 1983 Evolución paleogeográfica en la zona comprendida entre Los Vilos y Quebrada El Negro (Provincia de Choapa) durante el Cuaternario Superior. *Terra Aridae* 2(1): 285-298.

Vásquez J., Véliz D. and R. Weisner 1996 Análisis malacológico de un yacimiento de la Cultura

Huentelauquén, IV Región, Chile. *Gayana Oceanológica* 4(2): 109-116.

Villalba, R. 1994 Fluctuaciones climáticas en latitudes medias de América del Sur durante los últimos 1.000 años: Sus relaciones con la oscilación del Sur. *Revista Chilena de Historia Natural* 67: 543-561.

Villa, R. and C. Villagrán 1997 Historia de la vegetación de bosques pantanosos de Chile central durante el Holoceno medio y tardío. *Revista Chilena de Historia Natural* 70: 391-401.

Villagrán, C. 1982 *Estructura florística e historia del bosque pantanoso de Quintero (Chile, 5ta. Región) y su relación con las comunidades relictuales de Chile Central y Norte Chico*, Vol. III. Proceedings of the Congreso Geológico Chileno, pp. 377-402. Universidad de Chile.

Villagrán, C. M., T. Kalin-Arroyo and C. Marticorena 1983 Efectos de la desertización en la distribución de la flora andina de Chile. *Revista Chilena de Historia Natural* 56: 137-157.

Villagrán, C. 1995 El Cuaternario en Chile: evidencias de cambio climático. En *Cambios cuaternarios en América del Sur*, editado por J. Argolloand y Ph. Mourguiart, pp. 191-214. La Paz: Institut français de recherché scientifique pour le développement en coopération. ORSTOM – UR 12 "Géosciences de l'environnement tropical" – Universidad mayor de San Andrés. UMSA.

Villagrán C. and J. Varela 1990 Palynological evidence for increased aridity on the Central Chilean coast during the Holocene. *Quaternary Research* 34: 198-207.