

## HOLOCENE EXTINCTION OF ENDEMIC MAMMALS OF THE MEDITERRANEAN ISLANDS: SOME METHODOLOGICAL QUESTIONS AND AN UPDATE

Damià RAMIS & Josep Antoni ALCOVER

RAMIS, D. & ALCOVER, J.A. 2005. Holocene extinction of endemic mammals of the Mediterranean islands: some methodological questions and an update. In ALCOVER, J.A. & BOVER, P. (eds.): *Proceedings of the International Symposium "Insular Vertebrate Evolution: the Palaeontological Approach"*. Monografies de la Societat d'Història Natural de les Balears, 12: 309-318.

### Resum

L'objectiu d'aquesta contribució consisteix en millorar el coneixement de les causes i mecanismes relacionats amb l'extinció dels mamífers insulars endèmics a la Mediterrània durant l'Holocè, mitjançant l'anàlisi de les cronologies disponibles per a aquests fets. Aquesta aproximació és aplicada als taxa de Xipre, Creta, Còrsega-Sardenya i Mallorca-Menorca.

Es fan servir criteris de fiabilitat per tal d'establir un marc cronològic sòlid, acurat, per a la presència i absència a cada territori. La cronologia per a la presència dels endemismes és inferida a partir de les datacions absolutes directes obtingudes sobre col·lagen d'ossos d'aquestes espècies, tenint en compte les seves limitacions temporals a cada cas. Les cronologies derivades de la presència de restes faunístiques a contextos estratigràfics datats per altres medis són evitades, si és possible, a causa de potencials edats diacròniques. A la discussió s'introdueixen exemples d'aquestes distorsions potencials procedents d'excavacions mallorquines. Els indicadors per a la desaparició dels endemismes s'obtenen a partir de la seva absència a contextos estratigràfics (dipòsits arqueològics normalment). Aquesta anàlisi permet establir els intervals cronològics per als processos d'extinció a cada territori.

Els resultats són comparats amb les cronologies fiables per a la irrupció humana a cada illa. La manca de sincronia per a les extincions i la seva estreta relació amb la presència humana inicial a la majoria dels casos provoca el rebuig de causes estrictament ambientals com a explicació d'aquestes extincions. En ser analitzades les extincions dels mamífers de mida gran i mitjana, es pot trobar una estreta correlació amb l'edat inferida d'arribada dels humans moderns, encara que no s'ha documentat fins ara un solapament clar dels dos fets. En canvi, no es pot trobar el mateix patró en el cas de la desaparició dels petits mamífers. Mentre es documenta un llarg solapament temporal entre humans i petits mamífers a Còrsega-Sardenya i Creta (on *Crocidura zimmermanni* encara hi és present), l'extinció a les Balears i a Xipre sembla haver estat molt més sobtada, i la coexistència amb els humans primerencs encara no ha estat documentada.

**Paraules clau:** Illes mediterrànies, Extinció, Arribada humana.

### Abstract

The aim of this contribution consists of improving the knowledge of the causes and mechanisms related to the extinction of endemic insular mammals in the Mediterranean during the Holocene, through an analysis of the chronologies available for such events. This approach is applied to the taxa from Cyprus, Crete, Corsica-Sardinia and Mallorca-Menorca.

Reliability criteria are used in order to establish a solid, accurate chronological framework for their presence and absence in each territory. The chronology for the presence of endemics is inferred from direct absolute ages obtained from bone collagen of these species, taking into account their potential limitations in each case. Chronologies derived from the occurrence of faunal remains from stratigraphic contexts dated by other means are avoided where possible due to potential diachronic ages. Examples for these potential distortions coming from Mallorcan excavations are introduced in the discussion. Indicators for the disappearance of endemics are obtained from their absence in dated stratigraphic contexts (usually archaeological deposits). This analysis enables us to establish chronological intervals for these extinction events in each territory.

The results are compared to the reliable chronologies for human irruption in each island. The lack of synchrony for the extinctions and their close relationship to early human presence in most cases precludes strictly environmental causes for such extinctions. When the extinctions of large and medium-sized mammals are analysed, a close correlation can be found with the inferred time for modern human arrival, although a clear overlapping between these two events has not yet been recorded. However, the same pattern cannot be found for the disappearance of small mammals. While great overlapping is recorded between humans and small mammals in Corsica-Sardinia and Crete (where *Crocidura zimmermanni* is still present), the extinction in the Balearics and Cyprus seems to have been much more sudden, and their coexistence with early humans has not yet been recorded.

**Key words:** Mediterranean islands, Extinction, Human arrival.

## INTRODUCTION

Research on the chronology of human arrival and the extinction of endemic mammals in the Balearic Islands archipelago has been carried out during these last years by the present authors. Here, a comparison of the results obtained for Mallorca (and the other Gymnesic Islands) will be made with the data available for the other large Mediterranean islands — that is, Corsica-Sardinia, Crete, and Cyprus — in order to look for potential patterns of faunal extinction.

The species will be divided into two groups: large and medium-sized mammals on the one hand and small mammals on the other (Table 1). If a single species shows a specific behaviour within one of these groups then it will be individualized, if not, each species will be considered as following the same general pattern within the group in which it is included.

## METHODS

A chronological framework for the extinction of endemic mammals and for human arrival to all the aforementioned islands will be established. These chronologies will be outlined essentially from direct radiocarbon datings and from stratigraphic relationships. Hence, the last evidence for occurrence and the earliest indicators for absence of endemic species will be considered. In most cases the latter will come from the earliest archaeological deposits. That is, the most ancient human presence involves the first evidence for the absence of endemics in most cases.

Following conventions, dates coming from the calibration of radiometric results appear as 'cal BC' or 'cal AD'. They are expressed on the basis of their  $2\sigma$  statistical ranges. All of them have been calibrated following the program OxCal v3.5 (Bronk Ramsey, 2000). Uncalibrated radiocarbon ages are presented as 'BP'. Calendar dates not coming from radiocarbon analyses are expressed as 'BC' or 'AD'.

The use of radiocarbon datings in order to infer the chronology of certain events involves different limitations and potential distortions which are widely introduced in specific literature (e.g., Spriggs, 1989; Anderson, 1991; Spriggs & Anderson, 1993; Housley *et al.*, 1997; Tuggle & Spriggs, 2000; Zilhão, 2001). Several methodological procedures will be applied in order to avoid potential distortions of real ages for palaeontological or archaeological events. In the present work, the use of reliability criteria follows the proposals explained in previous publications (Alcover *et al.*, 2001; Ramis *et al.*, 2002).

Here, only two of these main features will be commented on the basis of examples recorded by the present authors in the excavation of Cova des Moro: (1) the presence of differently aged materials in the same sedimentological layer; and (2) distortions of the real age based on the results given by dating of associated long life-based samples.

In Cova des Moro (stratigraphic unit 406), 13 remains of *Eliomys morpheus* and 6 of *Asoriculus hidalgoi* have recently been recovered (2001-2002, unpublished results) through systematic sieving. Additionally, remains of *Eliomys quercinus* and *Apodemus sylvaticus* have also been identified in this faunal assemblage. Pottery types belonging to two different prehistoric phases have been recorded in this archaeological level. Firstly, those belonging to the earliest phase are characteristic undecorated types, which appear to be related to the incised Bell Beaker pottery from several other archaeological sites in the island. This characteristic pottery element is present in Mallorca during the uppermost part of the III millennium and possibly the lowermost part of the II millennium cal BC (Coll, 2001). Secondly, the main bulk of the material is chronologically attributed to the end of the II millennium cal B.C. or the beginning of the next one, on the basis of the presence of the same pottery types in the habitation structures of this period (e.g., Pons, 1999; Salvà, 2001). Two different AMS  $^{14}\text{C}$  datings were obtained for this stratigraphic unit, both based on collagen from two introduced bovid bone samples — Beta-155645: 3750±40 BP (2290-2030 cal BC) and Beta-162619: 2860±50 BP (1190-900 cal BC). These results are consistent and confirm those obtained through the analysis of the archaeological

	Large and middle-sized mammals	Small mammals
Mallorca-Menorca-Cabrera	<i>Myotragus balearicus</i> (*)	<i>Eliomys morpheus</i> (*) <i>Asoriculus hidalgoi</i> (*)
Corsica-Sardinia	<i>Megaceros cazioti</i> (*) <i>Cynotherium sardous</i> (*)	<i>Rhagamys orthodon</i> <i>Thyrrhencicola henseli</i> <i>Asoriculus corsicanus / similis</i> <i>Prolagus sardus</i> (*)
Crete	<i>Hippopotamus creutzburgi</i> (*) <i>Elephas creutzburgi</i>	<i>Mus minotaurus</i>
	<i>Candiacervus</i> sp.	<i>Crocidura zimmermanni</i>
Cyprus	<i>Phanourios minutus</i> (*)	<i>Mus</i> I
	<i>Elephas cypriotes</i>	<i>Mus</i> II

Table 1. Analysed species and islands. (\*)=Taxa with direct radiocarbon ages available.

Taula 1. Espècies i illes analitzades. (\*)=Taxa amb dates radiocarbòniques directes disponibles.

materials. AMS  $^{14}\text{C}$  dating on an *Eliomys morpheus* bone was carried out in order to check the assumed coetaneity between the endemic small mammal remains and the archaeological deposit where they had been found. The result obtained was Beta-162613: 12250 $\pm$ 80 BP (13500-11800 cal BC). This date indicates that the *Eliomys morpheus* remains from Cova des Moro, and probably also the *Asoriculus hidalgoi* remains, pre-date the archaeological context from which they were recovered (Ramis *et al.*, in press).

This first example illustrates the risk of chronologies not obtained from the materials themselves, but from their contextual association with other items with chronological implications. Stratigraphic association is helpful to the study of evolution and extinction patterns, but some possible limitations must be taken into account. The factors involved in the formation of a deposit are very numerous and diverse, and the taphonomic analysis offers some limitations to discern exactly the precedence of every single remain.

Secondly, a new instance of how charcoal-based radiocarbon dating can distort the real age of a feature has been recorded in Cova des Moro. A thin ash and charcoal layer containing introduced fauna and some flaked pebbles was first dated through the radiocarbon analysis of a charcoal sample (Calvo *et al.*, 2001). The result obtained was UtC-7877: 3961 $\pm$ 41 BP (2580-2300 cal BC). In order to check the validity of this age, a jaw of a domestic caprine from the same layer was also dated through radiocarbon analysis, Beta-162615: 3420 $\pm$ 50 BP (1880-1530 cal BC), that is yielding an age between 420 and 1050 years later than the former one (Ramis *et al.*, in press).

## RESULTS

### Mallorca-Menorca-Cabrera

#### Earliest human presence

After reviewing the evidence for the assumed early human presence in the Balearics, it was concluded that the first arrival in the Gymnesic Islands occurred in the III millennium cal BC (Alcover *et al.*, 2001; Ramis *et al.*, 2002). Currently, the most ancient archaeological contexts of the island of Mallorca date back to the end of the III millennium cal BC and are related to the Bell Beaker cultural tradition. The chronological evidence comes from Cova des Moro (Calvo *et al.*, 2001; Ramis *et al.*, in press), Coval Simó (Coll, 2001) and Ca na Cotxera (Calvo & Guerrero, 2002). A dating from this last site, KIA-17389: 3770 $\pm$ 30 BP (2290-2040 cal BC), provides the earliest reliable *terminus ante quem* for human presence in Mallorca, demonstrating this to be previous to 2040 cal BC.

The earliest chronological datum from the island of Menorca was obtained in the burial place of Biniai Nou (Plantamor & Marquès, 2001). The dating which demonstrates the earliest human presence is UtC-8949: 3745 $\pm$ 35 BP (2290-2030 cal BC), obtained on human bones.

Currently, the archaeological evidence available for the earliest human presence in Cabrera derives from sur-

face findings, in some caves of the island, of some pottery types (Trias, 1974) which can be placed roughly around 1000 cal BC. Recently, some new fragments have been discovered which are related to other pottery types (Riera, pers. com.) which in the Mallorcan and Menorcan reliable contexts are dated within the last third of the III millennium cal BC and the first half of the next one.

Apparently, and with some caution derived from the limitations of the archaeological record, no significant differences can be traced as to the earliest human presence in each island of the Gymnesic archipelago.

#### Large and medium-sized fauna

Traditionally, the *Myotragus* bone-based radiocarbon dating BM-1408: 4093 $\pm$ 392 BP (3700-1600 cal BC) had been considered as the most recent evidence for the survival of this species in Mallorca (Burleigh & Clutton-Brock, 1980). Nevertheless, the reliability of this dating has been recently called into question (van Strydonck *et al.*, 2005). Leaving aside this date, the result from Cova Estreta (Encinas & Alcover, 1997), UtC-5171: 5720 $\pm$ 60 BP (4720-4400 cal BC), can be considered as the most recent chronology for *Myotragus* presence in Mallorca. Evidence for later survival of this endemic caprine has been obtained recently from the other two Gymnesic Islands. A *Myotragus* specimen from Cova des Penyal Blanc, in Cabrera (Alcover *et al.*, 1997), yielded the result UtC-6517: 4785 $\pm$ 40 BP (3650-3380 cal BC), while the dating Beta-177237: 5060 $\pm$ 40 BP (3970-3760 cal BC) was obtained on another bone from Pas den Revull, in Menorca (Quintana *et al.*, 2003). The available chronology for *Myotragus* survival in each of the three Gymnesic Islands does not differ significantly, although it is a little earlier for Mallorca. Considering this fact and the geographic proximity of these islands, they will be considered here as a whole. Hence, the evidence from Cabrera, which demonstrates that *Myotragus* was living there after 3650 cal BC, will be considered as representative also for Mallorca.

#### Small mammals

The most recent available  $^{14}\text{C}$  age for *Eliomys morpheus* in Mallorca is UtC-5175: 6357 $\pm$ 44 BP (5480-5250 cal BC), obtained from collagen of bones collected at Cova Estreta (Encinas & Alcover, 1997). Therefore, *Eliomys morpheus* disappeared from Mallorca later than 5480 cal BC. The only available  $^{14}\text{C}$  age for *Asoriculus hidalgoi* in Mallorca is Beta-163133: 4280 $\pm$ 50 BP (3030-2690 cal BC), obtained on collagen from bones collected at Cova des Garrover (Bover *et al.*, submitted). This allows us to conclude that, with a  $p > 95.45\%$ , *Asoriculus hidalgoi* disappeared from Mallorca later than 3030 cal BC.

Some evidence related to the disappearance of both species can be mentioned. Both are absent from the most ancient archaeological sites, in which the introduced *Eliomys quercinus* and *Apodemus sylvaticus* remains have been found. Microfaunal analyses are available from some of the most ancient archaeological contexts — e.g., Coval d'en Pep Rave (Coll, 1981) or Coval Simó and Ca na Cotxera (unpublished); all of which show the absence of endemic mammals, while *Eliomys querci-*

*mus* and *Apodemus sylvaticus* (two human-introduced rodent species) are present in some of these deposits. Systematic sieving was applied in the case of the first two sites mentioned (excavations of 1980 and 1998-2001, respectively), while this aspect could not be confirmed for the recovery of the faunal assemblage from the open-air site of Ca na Cotxera (excavation of 1968). Additionally, no documentation of the presence of autochthonous small mammals has been recorded in younger archaeological deposits from Mallorca. The case of an assumed relationship in Cova des Moro (Ramis *et al.*, in press) has already been commented.

## Corsica-Sardinia

### Earliest human presence

There are several claims for human presence on these islands during the Lower and Middle Palaeolithic, based on certain characteristics of human remains (Spoor & Sondaar, 1986), faunal evolution dynamics (Sondaar, 1987), unstratified lithic industries (Martini & Ulzega, 1992), or taphonomic aspects of faunal assemblages (Klein Hofmeijer, 1996; Bonifay *et al.*, 1998; Bonifay, 2001); although most authors do not consider the evidence to be conclusive (Vigne, 1989; Cherry, 1992; Spoor, 1999; Pérez Ripoll, 2002). The earliest evidence for anatomically modern humans in Corsica and Sardinia belongs to the beginning of the Holocene, and is culturally placed in the Mesolithic. It is represented by several Corsican cultural assemblages from the caves or rock-shelters of Araguina-Sennola (Lanfranchi & Weiss, 1972), Curacchiaghju (Lanfranchi, 1967), Strettte II (Magdeleine, 1985), Torre d'Aquila (Magdeleine, 1995) and Monte Leone (Vigne *et al.*, 1998); and from layer 2 of Grotta Su Corbeddu in Sardinia (Sondaar *et al.*, 1984). Absolute chronology is available for all these sites, but was obtained through radiocarbon dating of long life samples (charcoal) or *Prolagus* bones. Human consumption of *Prolagus* is well attested in Corsica and Sardinia (Vigne & Desse-Berset, 1995), but the trouble with dating unmodified *Prolagus* remains could arise if the selected specimens came from a natural level and had been re-deposited in an archaeological layer later on.

Although these questions introduce some inaccuracy as to the exact age of the assemblages, the chronologies obtained for the Mesolithic in Corsica and Sardinia (placed mainly within the range between the X and VII millennia cal BC) do not differ significantly from that of the same period in the surrounding mainland. In order to select a *terminus ante quem* for human arrival, and taking into account the aforementioned factors, here *Prolagus* bone-based datings will be preferred to those obtained on charcoal samples. These come from two different sites (Su Corbeddu and Monte Leone). Both the most ancient and the most recent probabilistic chronological intervals obtained from these datings come from Monte Leone and, respectively, are AA-18111: 9750±175 BP (9800-8600 cal BC) and AA-18108: 8050±60 BP (7300-6700 cal BC). Thus, it would derive that human presence in Corsica could be previous to 8600 cal BC, while a slightly more conservative opinion would consider the event previous to 6700 cal BC.

## Large and medium-sized mammals

The most recent age for the survival of *Megaceros cazioti* comes from Grotta su Corbeddu in Sardinia (Klein Hofmeijer, 1996) with the result UtC-241: 11980±140 BP (13400-11500 cal BC). A similar result was obtained on *Cynotherium sardous* remains from the site of Castiglione 3, in Corsica (Salotti *et al.*, 2000) —Ly-965(OXA): 11760±110 BP (13200-11400 cal BC). The last evidence for endemic megafauna survival in Corsica and Sardinia also comes from Grotta su Corbeddu (Klein Hofmeijer, 1996), and consists of the radiocarbon dating made on a *Cynotherium sardous* bone which displayed the result UtC-2583: 11350±100 BP (11850-11050 cal BC).

## Small mammals

Direct dating on Corsican/Sardinian small-sized endemics is available for *Prolagus sardus*. The sites of Grotta Su Corbeddu and Monte Leone yield this information, as previously pointed out. This proves the survival of *Prolagus* until later than 7300 cal BC. However, the record from Monte di Tuda indicates the survival of the four autochthonous small mammals until Classic Antiquity (Vigne, 1992; Vigne & Valladas, 1996). Nevertheless, it must be noted that the fossil age does not derive from direct dating but from stratigraphic association to other materials.

## Crete

### Earliest human presence

There is well attested evidence for Mesolithic (X-IX millennia cal BC) navigation in the Aegean (Perlès, 1979; Sampson, 1998). It cannot be excluded that Crete was reached during this period, and evidence supporting this hypothesis may arise in the future (Broodbank & Strasser, 1991). Yet, currently, the most ancient chronological evidence for human presence on the island is sensibly later, coming from the inferior level of Knossos, which belongs to the Aceramic Neolithic period, dated to the late VII or VI millennium cal BC (Evans, 1971). Specifically, the dating BM-436: 7740±140 BP (7050-6250 cal BC) constitutes the earliest reliable date for human presence on the island, because of its short life source (wheat), and shows that the event is previous to 6250 cal BC.

## Large and medium-sized fauna

There is, as yet, no complete agreement on the faunal episodes for the Cretan Pleistocene, and several proposals based on the paleontological record are available. de Vos (2000) defends the existence of eight Cervidae species, belonging to the genus *Candiacervus*, from the radiation of a unique ancestor. Other authors differ in the number of species and also more than one radiation is recognized. Pleistocene megafauna also consisted of an elephant (*Elephas creutzburgi*) and a hippopotamus, both of reduced size (*Hippopotamus creutzburgi*).

Hamilakis (1996) asserted that little attention has been paid to the research of endemic faunal extinctions and, additionally, a series of direct absolute dating has

not been possible due to the lack of collagen in most samples. Currently, there is only one absolute age for the endemic fauna of the Late glacial or later. This was obtained on a hippo bone from Katharo Basin and displayed the result  $12135 \pm 485$  BP (13800–11200 cal BC), with no reference available of the laboratorium (Bachmayer & Zapfe 1985). Nevertheless, Reese *et al.* (1996: 47), on the basis of a personal communication of the original authors, point out that this result may be highly erroneous due to a possible deficiency in the dated sample. In the absence of any other chronological evidence, and taking into account its dubious reliability, this dating will be considered provisionally here as indicating the presence of large endemic mammals on Crete later than 13800 cal BC.

### Small mammals

There is no evidence, due to the lack of record, as to the survival of the endemic *Mus minotaurus* after the first human arrival to Crete (e.g., Vigne, 1999). Nevertheless, *Crocidura zimmermanni* is one of the few examples of small mammals from the true Mediterranean islands to survive until the present day, although its distribution seems to have been reduced to the Cretan inner mountain area since Minoan time (ca. 3000 cal BC), with the arrival of *Crocidura suaveolens* and *Suncus etruscus* (Reumer, 1996).

## Cyprus

### Earliest human presence

Claims for Mesolithic hunter-gatherers in Cyprus near 10000 cal BC (e.g., Simmons & Wigand, 1994; Wigand & Simmons, 1999) have been made on the interpretation of the record from Akrotiri-Aetokremnos (e.g., Simmons, 1991; 1999). However, several opinions consider this record to be a natural fossil assemblage (e.g., Bunimovitz & Barkai, 1996; Olsen, 1999; Pérez Ripoll, 2002). Their arguments seem more compelling to the present authors. Thus, the most ancient record for human presence on Cyprus belongs to the IX millennium cal BC and corresponds to the Early Aceramic Neolithic assemblages from the sites of Kalavasos-Tenta (Todd, 2002), Parekklisha-Shillourokambos (Guilaine, 1996; 2003; Guilaine *et al.*, 2000; Guilaine & Briois, 2002) and Kissonerga-Mylouthkia (Peltenburg *et al.*, 2000; 2002). Out of all this information, the dating OxA-7460:  $9315 \pm 60$  BP (8740–8320 cal BC), from the last site, obtained on a short life sample (barley), shows the earliest reliable *terminus ante quem* for human presence on the island, that is, 8320 cal BC.

### Large and medium-sized fauna

The Late Quaternary megafauna from Cyprus consisted of two dwarf species, an elephant (*Elephas cypriotes*) and a hippopotamus (*Phanourios minutus*). Several dates obtained with AAR and ESR methods are available from different sites, falling within the final millennia of the Pleistocene and the beginning of the Holocene. However, as the reliability of these results has been ques-

tioned (Reese, 1996; Wigand & Simmons, 1999) they will not be taken into account here. The other group of absolute datings for the Cyprian endemic large mammals consists of the data from Akrotiri-Aetokremnos (Wigand & Simmons, 1999). Several problems have been noted on the dated bones from this site, derived from variable contamination of the samples and from the dated organic fraction. Dates obtained on other materials (sediment, shell, charcoal) are also problematic. So, it can be concluded that a precise conversion of the radiocarbon dating into calendar ages is not possible in this case. The authors suggest that the deposit was formed in a short time (some centuries maybe) about 10000 cal BC (Wigand & Simmons, 1999). Only one of the radiocarbon dates on fossil remains was obtained on the collagen fraction. The sample was a *Phanourios* bone from an altered stratum, which offered the result TX-5976B:  $9420 \pm 550$  BP (10700–7300 cal BC). Provisionally, this date will be considered as representative for the chronology of the endemic megafauna presence on Cyprus, given that the result was obtained through the radiocarbon dating of the collagen fraction and is compatible with the propounded chronology for the deposit (Wigand & Simmons, 1999). Consequently, this dating indicates that the *Phanourios* extinction on Cyprus occurred later than 10700 cal BC.

### Small mammals

In Cyprus, two *Mus* species are the only small autochthonous mammals recorded during the Late Pleistocene and Early Holocene. After human establishment on the island, the presence of *Mus* was first identified in pre-ceramic levels from Khirokitia, in the VII millennium cal BC. On the basis of metrical analysis it was inferred that these remains could belong to one of the two endemic species, larger than *Mus musculus*, which had reached the island in later times (Davis, 1989). But, recently, two different *Mus* species have been recorded in the Kissonerga-Mylouthkia site, in pre-ceramic levels dated from the late IX and VIII millennium cal BC. One of them has been identified as the domestic mouse (*Mus musculus domesticus*), while some doubts persist as to the attribution of the other to one of the endemic species or, alternatively, to the mainland *Mus macedonicus* (Cucchi *et al.*, 2002).

## DISCUSSION AND CONCLUSIONS

Relevant relationships can be established when comparing the chronology for the last occurrences of the endemic mammals on each of the islands analysed and, on the other hand, the first well attested record for human presence in these territories.

As previously known, the extinctions of large and medium-sized mammals on the Mediterranean islands are not synchronous (e.g., Vigne, 1987; 1999). Their last recorded occurrence and the earliest evidence for absence yield the intervals within which each extinction event must be placed. These intervals overlap in all cases

except for *Myotragus*. Its extinction in the Balearics has been proved to be several millennia later than that of equivalent species in the other large Mediterranean islands.

It is important to note here that the heterochrony of such extinctions is closely related to the heterochrony of the human colonization of the large Mediterranean islands (Ramis & Alcover, 2004). The first human presence in the large Mediterranean islands is not synchronous: there is a huge gap between the early cultural evidence in Mallorca (and the Gymnesics in general) and the islands of the Central and East Mediterranean (Fig. 1).

Thus, a close relationship between human arrival and the large and medium-sized fauna in each large Mediterranean island can be strongly suggested. As a result, humans emerge as the most plausible agent for the turnover of large and medium-sized fauna during the Holocene and, given the lack of overlapping, each extinction event seems to have been very sudden. The factors that are better adapted to such a scenario are: (1) overhunting (e.g., Martin, 1984) and (2) introduction of alien diseases (MacPhee & Marx, 1997). However, currently there is no reliable evidence to test such possibilities.

Concerning the extinction of the small endemic

mammals, a very different relationship arises. Two different patterns can be observed (Fig. 2). A long coexistence between humans and small endemic mammals is recorded in Corsica-Sardinia and Crete. According to several authors (Reumer, 1996; Vigne *et al.*, 1997), a low-intensity pattern tending to extinction can be applied in these cases. This has been propounded especially for Corsica (e.g., Vigne, 1990; 1999; Vigne & Valladas, 1996; Vigne *et al.*, 1997), but extended in some cases to the whole Mediterranean islands (e.g. Vigne & Alcover, 1985; Vigne, 1987).

According to Vigne (1987; 1999), the effect of human hunting on the small endemic mammals through the Mesolithic and the Neolithic would have been a modification of the evolutionary tendency of the different species, with a size diminution. The role played by the introduction of new predators is considered as non relevant by this author, since the small mammals should have been adapted to hunting pressure by Pleistocene predator birds. The arrival of new competitors, like *Rattus rattus* (recorded on the island since the end of I millennium cal BC), is considered as a cause of the reduction of the population size and of the restriction of the distribution to woody areas. The final extinction of

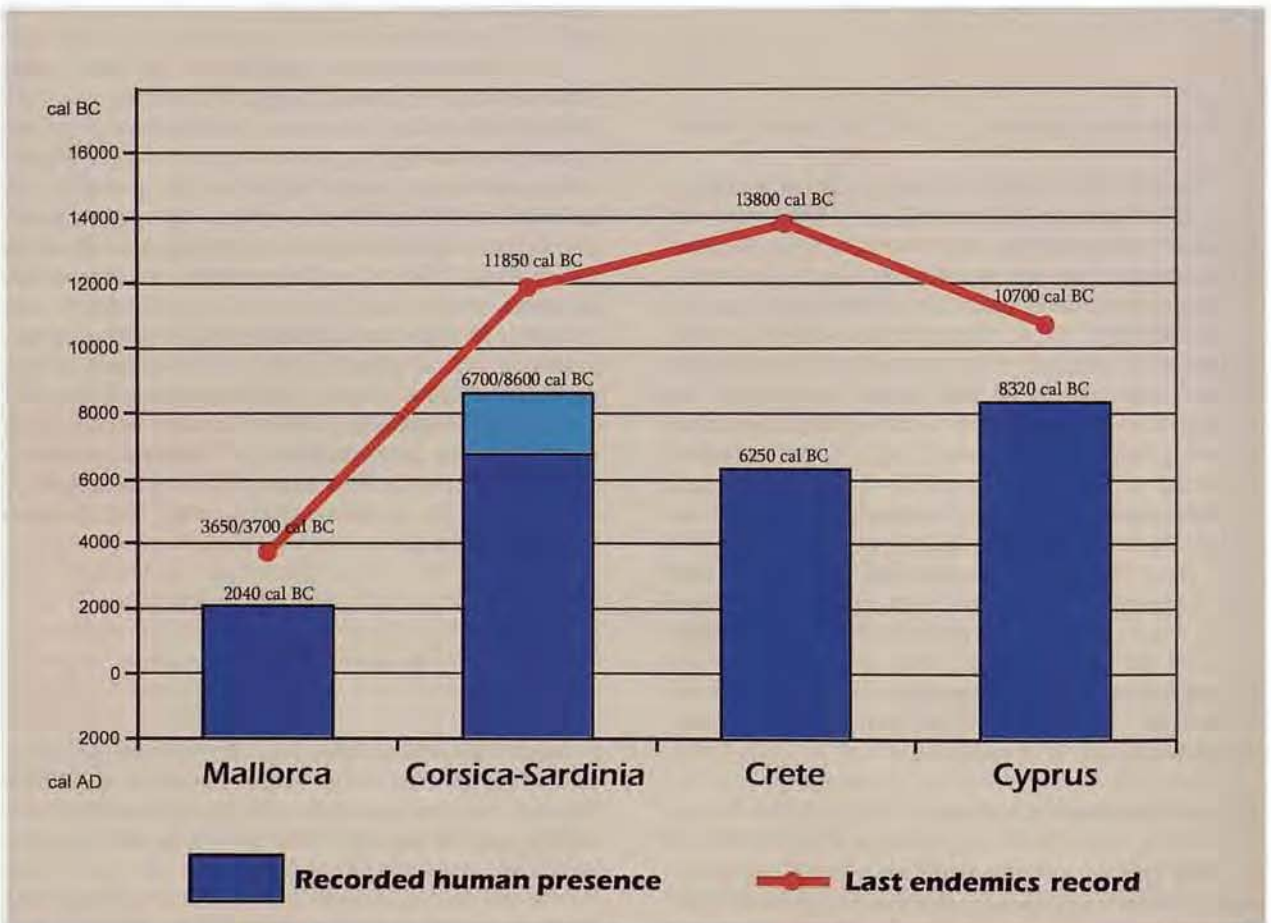


Fig. 1. Graphic comparison of the Mediterranean islands considered here, with the representation of the last available chronological record for large and medium-sized endemic mammals and, on the other hand, the period with recorded human presence in such territories.

Fig. 1. Comparació gràfica de les illes mediterrànies considerades, amb la representació del darrer registre cronològic disponible per als mamífers endèmics de mida gran i mitjana i, d'altra banda, del període amb presència humana documentada a cada territori.

these species would have taken place between I millennium AD and the beginning of the next one, as a result of the deforestation of their last habitats during Late Antiquity and the Early Middle Ages. In short, the extinctions of the endemic Corsican micro-mammals would be the final point of a gradual recession process motivated by the combined effect of the presence of new competitors and human modification of the environment (Vigne *et al.*, 1997).

Alternatively, a sudden extinction happens in the Gymnesics and Cyprus (the islands with a more intense isolation during the Plio-Pleistocene). Overhunting does not seem to be a key factor affecting the extinction of small sized mammals from Mallorca and Cyprus. Hence, the introduction of new diseases emerges as a possible explanation. This hypothesis bears some similarities with the proposal for extinction of autochthonous small mammals in the Caribbean islands as a result of the introduction of new pathogens. MacPhee & Iturralde-Vinent (2000) suggest the close relationship between the extinction of most of the small mammals from the Antilles, after coexisting with humans for several millennia, and the arrival of rats (*Rattus rattus*) from the Old World, possibly carrying new diseases.

The explanation of such different patterns is a matter for future research. The low-intensity pattern for extinction is applied to the species from islands with faunal incorporations during the Pleistocene, while the sudden extinction pattern corresponds to animals from islands with a much more extended period of isolation. The possibility that the Pleistocene arrival of new terrestrial vertebrates to Corsica-Sardinia (Sondaar, 1987) and Crete (van der Made, 1996) involved some genetic adaptations to the insular endemics, which made them more resistant to mainland pathogens, remains as a hypothesis to be tested.

Dating alone cannot solve the problem of the cause of faunal extinctions, but can be useful to test the different possible explanations (Brook & Bowman, 2002). Given the current impossibility to analyse the Late Quaternary extinctions in the Mediterranean through alternative sources, the use of chronological records constitutes a good approach to focus the event. The possibility that future research records of fossil remains dated to the last moments of species survival and evidence for coexistence with humans will improve our knowledge of the topic and allow us to test the hypotheses here propounded.

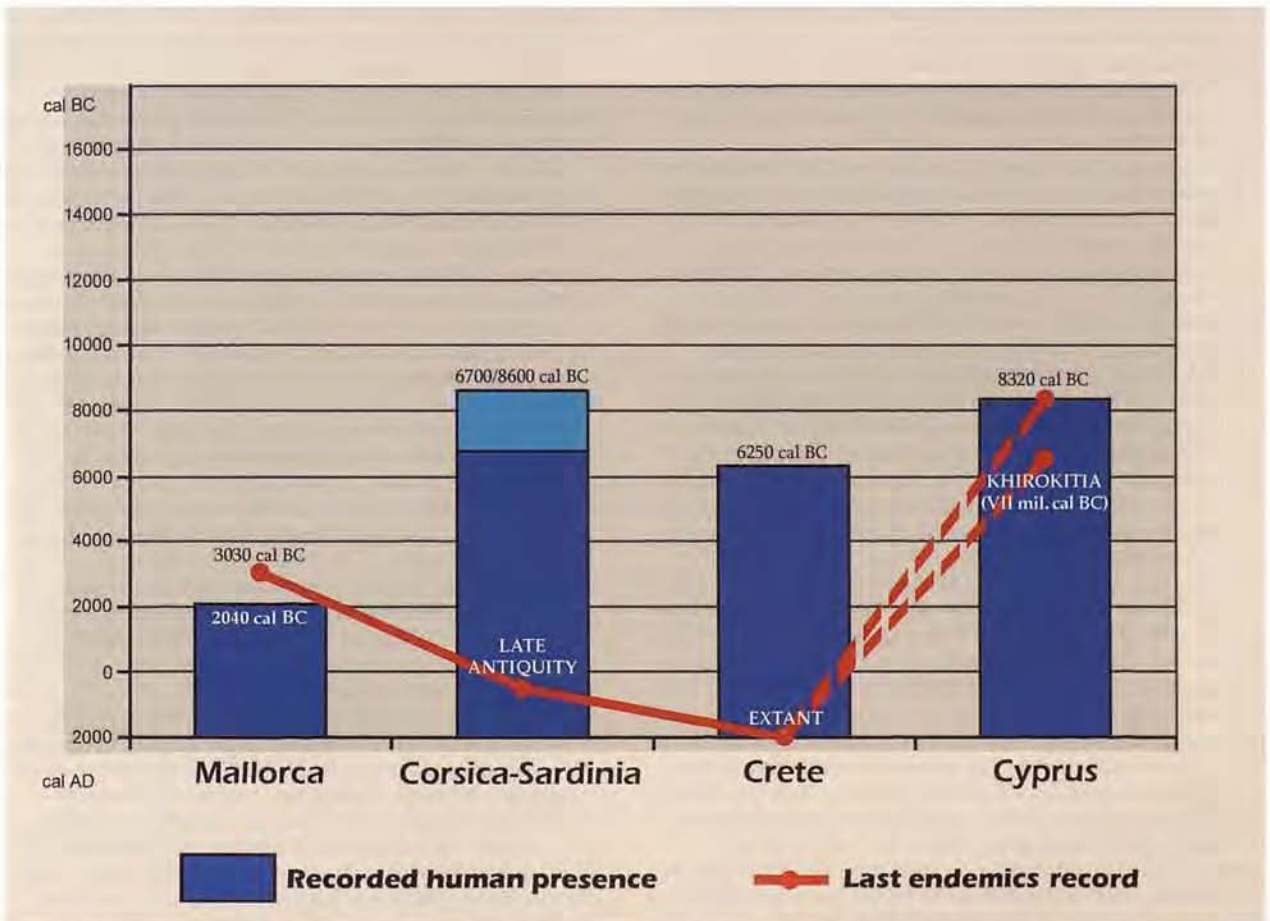


Fig. 2. Graphic comparison of the Mediterranean islands considered here, with the representation of the last available chronological record for small-sized endemic mammals and, again, the period with recorded human presence in such territories.

Fig. 2. Comparació gràfica de les illes mediterrànies considerades, amb la representació del darrer registre cronològic disponible per als mamífers endèmics de mida petita i, novament, del període amb presència humana documentada a cada territori.

## ACKNOWLEDGEMENTS

Mark van Strydonck and Mathieu Boudin permitted the use of still unpublished data of their research. Mateu Riera allowed the authors to mention the recent archaeological findings in Cabrera. This paper falls within the Spanish Research Project BTE2001-0589 of the *Dirección General de Investigación*.

## REFERENCES

- Alcover, J.A., Font, A. & Trias, M. 1997. Primera troballa de fauna pliocènica a Cabrera. *Endins*, 21: 79-82.
- Alcover, J.A., Ramis, D., Coll, J. & Trias, M. 2001. Bases per al coneixement del contacte entre els primers colonitzadors humans i la naturalesa de les Balears. *Endins*, 24: 5-57.
- Anderson, A. 1991. The chronology of colonization in New Zealand. *Antiquity*, 65: 767-795.
- Bachmayer, F. & Zapfe, H. 1985. Ein absolutes Altersdatum für die fossilen Zwergflusspferde der Insel Kreta. *Sitzungsberichte der Österreichischen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse*, 8: 165-166.
- Bonifay, E., Bassiakos, Y., Bonifay, M.-F., Louchart, A., Mourer-Chauviré, C., Pereira, E., Qini, Y. & Salotti, M. 1998. La Grotte de la Coscia (Rogliano, Macinaggio): Étude préliminaire d'un nouveau site du Pléistocène supérieur de Corse. *Paleo*, 10: 17-41.
- Bonifay, E. 2001. Grotte de la Coscia (Rogliano, Haute-Corse): stratigraphie et histoire du remplissage. *Bulletin de la Société des sciences historiques et naturelles de la Corse*, 696-697: 51-67.
- Bover, P., Ramis, D. & Alcover, J.A. Submitted. The chronology of the extinction of the autochthonous small mammalian fauna from Mallorca (Gymnesic Islands, Western Mediterranean Sea).
- Bronk Ramsey, C. 2000. OxCal Program v3.5. <<<Available at [www.rlaha.ox.ac.uk/oxcal/oxcal.htm](http://www.rlaha.ox.ac.uk/oxcal/oxcal.htm)>>>
- Broodbank, C. & Strasser, T.F. 1991. Migrant farmers and the Neolithic colonization of Crete. *Antiquity*, 65: 233-245.
- Brook, B.W. & Bowman, D.M.J.S. 2002. Explaining the Pleistocene megafaunal extinctions: Models, chronologies, and assumptions. *Proceedings of the National Academy of Sciences*, 99: 14624-14627.
- Bunimovitz, S. & Barkai, R. 1996. Ancient bones and modern myths: Ninth Millennium BC Hippopotamus hunters at Akrotiri Aetokremnos, Cyprus?. *Journal of Mediterranean Archaeology*, 9 (1): 85-96.
- Burleigh, R. & Clutton-Brock, J. 1980. The survival of *Myotragus balearicus* Bate, 1909, into the Neolithic on Mallorca. *Journal of Archaeological Science*, 7: 385-388.
- Calvo, M. & Guerrero, V. 2002. *Los inicios de la metalurgia en Baleares. El Calcolítico (c. 2500-1700 cal. BC)*. Ed. El Tall. Palma de Mallorca. 282 pags.
- Calvo, M., Guerrero, V.M. & Salvà, B. 2001. *La cova des Moro (Manacor, Mallorca). Campanyes d'excavacions arqueològiques 1995-1998*. Consell de Mallorca, Departament de Cultura i Joventut. Palma de Mallorca. Col·lecció *Quaderns de Patrimoni Cultural*, 4: 70 pgs.
- Cherry, J.F. 1992. Palaeolithic Sardinians? Some Questions of Evidence and Method. In Tykot, R.H. & Andrews, T.K. (eds.), *Sardinia in the Mediterranean: a Footprint in the Sea*: 28-39. Sheffield Academic Press. Sheffield.
- Coll, J. 1981. *El yacimiento arqueológico del Coval d'en Pep Rave*. Barcelona: Universitat de Barcelona (Unpublished Memoria de Licenciatura).
- Coll, J. 2001. Primeres datacions absolutes del jaciment de coval Simó. *Endins*, 24: 161-168.
- Cucchi, T., Vigne, J.-D., Auffray, J.-C., Croft, P. & Peltenburg, E. 2002. Introduction involontaire de la souris domestique (*Mus musculus domesticus*) à Chypre dès le Néolithique précéramique ancien (fin IX<sup>e</sup> et VIII<sup>e</sup> millénaires av. J.-C.). *C.R. Palevol*, 1: 235-241.
- Davis, S.J.M. 1989. Some more animal remains from the aceramic Neolithic of Cyprus. In Le Brun, A. (ed.), *Fouilles récentes à Khirokitia (Chypre) 1983-1986*: 189-221. Éditions Recherche sur les Civilisations, Mémoire 81. Paris.
- de Vos, J. 2000. Pleistocene deer fauna in Crete: its adaptive radiation and extinction. In Otsuka, H., Ota, H. & Hotta, M. (eds.), *International Symposium. The Ryukyu Islands - The arena of adaptive radiation and extinction of island fauna (Kagoshima, 5-7 November 1998)*. The Japan Society of Tropical Ecology. Kagoshima. *Tropics*, 10 (1): 125-134.
- Encinas, J.A. & Alcover, J.A. 1997. El jaciment fòssilífer de la cova Estreta. *Endins*, 21: 83-92.
- Evans, J.D. 1971. Neolithic Knossos; the Growth of a Settlement. *Proceedings of the Prehistoric Society*, 37: 95-117.
- Guilaine, J. 1996. Shillourokambos et les débuts du Néolithique à Chypre. *Espacio, Tiempo y Forma, Serie I, Prehistoria y Arqueología*, 9: 159-171.
- Guilaine, J. 2003. Parekklisha-Shillourokambos: périodisation et aménagements domestiques. In Guilaine, J. & Le Brun, A. (eds.), *Le Néolithique de Chypre. Actes du Colloque International organisé par le Département des Antiquités du Chypre et l'École française d'Athènes (Nicosie, 17-19 mai 2001)*. École française d'Athènes. Atenas. *Bulletin de Correspondance Hellénique*, Supplément 43: 3-14.
- Guilaine, J., Briois, F. 2002. Parekklisha Shillourokambos: An Early Neolithic Site in Cyprus. In Swiny, S. (ed.), *The earliest Prehistory of Cyprus. From colonization to exploitation*: 37-54. American School of Oriental Research. Boston.
- Guilaine, J., Briois, F., Vigne, J.-D. & Carrère, I. 2000. Découverte d'un Néolithique précéramique ancien chypriote (fin 9<sup>e</sup>, début 8<sup>e</sup> millénaires cal. BC), apparenté au PPNB ancien/moyen du Levant nord. *Comptes Rendus de l'Académie des Sciences de Paris, Sciences de la Terre et des planètes*, 330: 75-82.
- Hamilakis, Y. 1996. Cretan Pleistocene fauna and archaeological remains: The evidence from Sentoni cave (Zoniana, Rethymnon). In Reese, D.S. (ed.), *Pleistocene and Holocene fauna of Crete and its first settlers*. Prehistory Press. Madison. *Monographs in World Archaeology*, 28: 231-239.
- Housley, R.A., Gamble, C.S., Street, M. & Pettitt, P. 1997. Radiocarbon evidence for the Lateglacial Human Recolonisation of Northern Europe. *Proceedings of the Prehistoric Society*, 63: 25-54.
- Klein Hofmeijer, G. 1996. *Late Pleistocene deer fossils from Corbeddu cave*. Universiteit Utrecht, Faculteit Aardwetensch. Utrecht.
- Lanfranchi, F. de 1967. La grotte sépulcrale de Curacchiaghii. *Bulletin de la Société Préhistorique Française*, 64: 587-612.
- Lanfranchi, F. de & Weiss, M.-C. 1972. Le néolithique ancien de l'abri d'Araguina-Sennola. *Bulletin de la Société Préhistorique Française*, 69: 376-388.
- MacPhee, R.D.E. & Iturralde-Vinent, M.A. 2000. A short history of Greater Antillean land mammals: biogeography, paleogeography, radiations and extinctions. In Otsuka, H., Ota, H. & Hotta, M. (eds.), *International Symposium. The Ryukyu Islands - The arena of adaptive radiation and extinction of island fauna (Kagoshima, 5-7 November 1998)*. The Japan Society of Tropical Ecology. Kagoshima. *Tropics*, 10 (1): 145-154.
- MacPhee, R.D.E. & Marx, P.A. 1997. The 40,000-year plague. Humans, hyperdisease, and first-contact extinctions. In Goodman, S.M. & Patterson, B.D. (eds.), *Natural change and human impact in Madagascar*: 169-217. Smithsonian Institution Press. Washington.



- Magdeleine, J. 1985. Les premières occupations humaines de l'abri de Strette, Barbaghju. *Archeologia Corsa*, 8-9 (1983-84): 30-50.
- Magdeleine, J. 1995. Préhistoire du Cap Corse: les abris de Torre d'Aquila, Pietracorbara (Haute-Corse). *Bulletin de la Société Préhistorique Française*, 92 (3): 363-377.
- Martin, P.S. 1984. Prehistoric Overkill: The Global Model. In Martin, P.S. & Klein, R.G. (eds.), *Quaternary Extinctions. A prehistoric revolution*: 354-403. The University of Arizona Press, Tucson.
- Martini, E. & Ulzega, A. 1992. El más antiguo poblamiento humano de las islas del Mediterráneo. *Trabajos de Prehistoria*, 49: 113-130.
- Olsen, S.L. 1999. Investigation of the *Phanourios* bones for evidence of cultural modification. In Simmons, A.H. (ed.), *Faunal Extinction in an Island Society. Pygmy Hippopotamus hunters of Cyprus*: 230-237. Kluwer Academic/Plenum Publishers, New York.
- Peltenburg, E., Colledge, S., Croft, P., Jackson, A., McCartney, C. & Murray, M.A. 2000. Agro-pastoralist colonization of Cyprus in the 10th millennium BP: initial assessments. *Antiquity*, 74: 844-853.
- Peltenburg, E., Croft, P., Jackson, A., McCartney, C. & Murray, M.A. 2002. Well-Established Colonists: *Mylothkia* 1 and the Cypro-Pre-Pottery Neolithic B. In Swiny, S. (ed), *The earliest Prehistory of Cyprus. From colonization to exploitation*: 61-94. American School of Oriental Research, Boston.
- Pérez Ripoll, M. 2002. Extinció de la fauna endèmica y colonizació humana de las grandes islas del Mediterráneo. In Badal, E., Bernabeu, J. & Martí, B. (eds.), *El paisaje en el Neolítico mediterráneo*. Departament de Prehistòria i d'Arqueologia, Universitat de Valencia, Valencia. *Saguntum-PLAV*, Extra-5: 147-163.
- Perlès, C. 1979. Des Navigateurs méditerranéens il y a 10000 ans. *La Recherche*, 96: 82-83.
- Plantalamor, L.L. & Marqués, J. (coord.). 2001. *Biniaí Nou. El megalitisme mediterrani a Menorca*. Maó. *Treballs del Museu de Menorca*, 24. 188 pags.
- Pons, G. 1999. *Anàlisi espacial del poblament al Pretalaiòtic final i al Talaiòtic I de Mallorca*. Consell de Mallorca, Palma de Mallorca. *Col·lecció La Deixa*, 2, 265 pgs.
- Quintana, J., Bover, P., Ramis, D. & Alcover, J.A. 2003. Cronologia de la desaparició de *Myotragus balearicus* Bate 1909 a Menorca. *Endins*, 25: 155-158.
- Ramis, D. & Alcover, J.A. 2004. Irrupció humana y extinció faunística en las grandes islas del Mediterráneo durante el Holoceno. In Baquedano, E. & Rubio, S. (eds.), *Miscelánea en Homenaje a Emiliano Aguirre*, IV: 283-401. Museo Regional de la Comunidad de Madrid, Madrid.
- Ramis, D., Alcover, J.A., Coll, J. & Trias, M. 2002. The chronology of the first settlement of the Balearic Islands. *Journal of Mediterranean Archaeology*, 15 (1): 3-24.
- Ramis, D., Santandreu, G. & Carreras, J. In press. Resultats preliminars de l'excavació arqueològica a la cova des Moro entre 1999 i 2002. In *III Jornades d'Estudis Locals de Manacor 2004. Espai, fet urbà i societats (21 i 22 de maig de 2004)*. Ajuntament de Manacor, Manacor.
- Reese, D.S. 1996. Cypriot hippo hunters no myth. *Journal of Mediterranean Archaeology*, 9 (1): 107-112.
- Reese, D.S., Belluomini, G., Ikeya, M. 1996. Absolute dates for the Pleistocene fauna of Crete. In Reese, D.S. (ed.), *Pleistocene and Holocene fauna of Crete and its first settlers*. Prehistory Press, Madison. *Monographs in World Archaeology*, 28: 48-51.
- Reumer, J.W.F. 1996. Shrews (Soricidae) on islands, with special reference to *Crociodura zimmermanni* from Crete. In Reese, D.S. (ed.), *Pleistocene and Holocene fauna of Crete and its first settlers*. Prehistory Press, Madison. *Monographs in World Archaeology*, 28: 173-179.
- Salotti, M., Bellot-Gurlet, L., Courtois, J.-Y., Dubois, J.N., Louchart, A., Mourer-Chauviré, C., Oberlin, C., Pereira, E., Poupeau, G. & Tramoní, P. 2000. La fin du Pléistocène et le début de l'Holocène en Corse: apports paléontologique et archéologique du site de Castiglione (Oletta, Haute-Corse). *Quaternaire*, 11 (3/4): 219-213.
- Salvà, B. 2001. *El pretalaiòtic al llevant mallorquí (1700-1100 AC)*. *Anàlisi territorial*. Documenta Balear. Palma de Mallorca, 181 pags.
- Sampson, A. 1998. The Neolithic and Mesolithic occupation of the cave of Cyclope, Youra, Alonessos, Greece. *Annual of the British School at Athens*, 93: 1-22.
- Simmons, A.H. 1991. Humans, island colonization and Pleistocene extinctions in the Mediterranean: the view from Akrotiri Aetokremnos, Cyprus. *Antiquity*, 65: 857-869.
- Simmons, A.H. (ed.). 1999. *Faunal extinction in an island society. Pygmy Hippopotamus hunters of Cyprus*. Kluwer Academic/Plenum Publishers, New York, 381 pags.
- Simmons, A.H. & Wigand, P. 1994. Assessing the radiocarbon determinations from Akrotiri Aetokremnos, Cyprus. In Bar-Yosef, O. & Kra, R.S. (eds.), *Late Quaternary chronology and paleoclimates of the Eastern Mediterranean*: 247-264. Radiocarbon and American School of Prehistoric Research, Tucson.
- Sondaar, P.Y. 1987. Pleistocene man and extinctions of island endemics. *Mémoires de la Société Géologique de France*, N.S., 150: 159-165.
- Sondaar, P.Y., de Boer, P.L., Sanges, M., Kotsakis, T. & Esu, D. 1984. First report on a Paleolithic culture in Sardinia. In Waldren, W.H., Chapman, R., Lewthwaite, J. & Kennard, R. (eds.), *The Deya Conference of Prehistory. Early Settlement in the Western Mediterranean Islands and their Peripheral Areas*. Oxford. *BAR International Series*, 229: 29-47.
- Spoor, E. 1999. The human fossils from Corbeddu Cave, Sardinia: a reappraisal. In Reumer, J.W.F. & de Vos, J. (eds.), *Elephants have a snorkel! Papers in honour of Paul Y. Sondaar*. Natuurmuseum Rotterdam, Rotterdam. *Deinsea*, 7: 297-302.
- Spoor, C.F. & Sondaar, P.Y. 1986. Human fossils from the endemic island fauna of Sardinia. *Journal of Human Evolution*, 15: 399-408.
- Spriggs, M. 1989. The dating of the Island Southeast Asian Neolithic: an attempt at chronometric hygiene and linguistic correlation. *Antiquity*, 63: 587-613.
- Spriggs, M., & Anderson, A. 1993. Late colonization of East Polynesia. *Antiquity*, 67: 200-217.
- Todd, I.A. 2002. Kalavassos Tenta revisited. In Swiny, S. (ed), *The earliest Prehistory of Cyprus. From colonization to exploitation*: 95-108. American School of Oriental Research, Boston.
- Trias, M. 1974. Una campanya a les Illes de Cabrera. *Endins*, 1: 33-39.
- Tuggle, H.D. & Spriggs, M. 2000. The age of the Bellows Dune site O18, O'ahu, Hawai'i, and the antiquity of Hawaiian colonization. *Asian Perspectives*, 39 (1-2): 165-188.
- van der Made, J. 1996. Pre-Pleistocene Land Mammals from Crete. In Reese, D.S. (ed.), *Pleistocene and Holocene fauna of Crete and its first settlers*. Prehistory Press, Madison. *Monographs in World Archaeology*, 28: 69-79.
- van Strydonck, M., Boudin, M. & Eryvnyck, A. 2005. Humans and *Myotragus*: the issue of sample integrity in radiocarbon dating. In Alcover, J.A. & Bover, P. (eds.): *Proceedings of the International Symposium "Insular Vertebrate Evolution: the Palaeontological Approach"*. *Monografies de la Societat d'Història Natural de les Balears*, 12: 369-376.
- Vigne, J.D. 1987. L'extinction holocène du fond de peuplement mammalienn indigène des îles de Méditerranée occidentale. *Mémoires de la Société Géologique de France*, N.S., 150: 167-177.
- Vigne, J.D. 1989. Le peuplement paléolithique des îles: le débat s'ouvre en Sardaigne. *Les nouvelles de l'archéologie*, 35: 39-42.
- Vigne, J.D. 1990. Biogeographical history of the mammals on Corsica (and Sardinia) since the final Pleistocene. In *Atti dei Convegni Lincei. International Symposium on: Biogeographical Aspects of Insularity (Rome, 18-22 May 1987)*: 369-392. Accademia Nazionale dei Lincei, Roma.

- Vigne, J.D. 1992. Zooarchaeology and the biogeographical history of the mammals of Corsica and Sardinia since the last ice age. *Mammal Review*, 22 (2): 87-96.
- Vigne, J.D. 1999. The large "true" Mediterranean islands as a model for the Holocene human impact on the European vertebrate fauna? Recent data and new reflections. In Benecke, N. (ed.), *The Holocene history of the European vertebrate fauna. Modern aspects of research*: 295-322. Verlag Marie Leidorf. Rahden.
- Vigne, J.D. & Alcover, J.A. 1985. Incidence des relations historiques entre l'Homme et l'Animal dans la composition actuelle du peuplement des îles de Méditerranée. In *Actes du 110e Congrès National Sociétés Savantes (Montpellier, 1985), Section Sciences*: 79-91. Comité des Travaux Historiques et Scientifiques. Paris.
- Vigne, J.-D., Bailon, S. & Cuisin, J. 1997. Biostratigraphy of amphibians, reptiles, birds and mammals in Corsica and the role of man in the Holocene turnover. *Anthropozoologica*, 25-26: 587-604.
- Vigne, J.D., Bourdillat, V., André, J., Brochier, J.-E., Bui Thi Mai, Cuisin, J., David, H., Desse-Berset, N., Heinz, C., Lanfranchi, F., Ruas, M.-P., Thiebault, S. & Tozzi, C. 1998. Nouvelles données sur le Préneolithique corse: premiers résultats de la fouille de l'abri du Monte Leone (Bonifacio, Corse-du-Sud). In *Rencontres de Préhistoire récente. Deuxième session. Arles, 1996*: 251-260. APDCA. Antibes.
- Vigne, J.D. & Desse-Berset, N. 1995. The exploitation of animal resources in the Mediterranean Islands during the Pre-Neolithic: the example of Corsica. In Fischer, A. (ed.), *Man and sea in the Mesolithic*: 309-318. Oxbow Books. Oxford.
- Vigne, J.D. & Marinval-Vigne, M.-C. 1983. Méthode pour la mise en évidence de la consommation du petit gibier. In Clutton-Brock, J. & Grigson, C. (eds.), *Animals and Archaeology, 1. Hunters and their prey*. Oxford. *BAR International Series*, 163: 239-242.
- Vigne, J.D. & Valladas, H. 1996. Small mammal fossil assemblages as indicators of environmental change in Northern Corsica during the last 2500 years. *Journal of Archaeological Science*, 23: 199-215.
- Wigand, P. & Simmons, A.H. 1999. The dating of Akrotiri Aetokremnos. In Simmons, A.H. (ed.), *Faunal extinction in an island society. Pygmy Hippopotamus hunters of Cyprus*: 193-215. Kluwer Academic/Plenum Publishers. New York.
- Zilhão, J. 2001. Radiocarbon evidence for maritime pioneer colonization at the origins of farming in west Mediterranean Europe. *Proceedings of the National Academy of Sciences*, 98 (24): 14180-14185.