

## Modeling the Impacts of Mediterranean Island Colonization by Archaic Hominins: The Likelihood of an Insular Lower Palaeolithic

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### Abstract

*It has been suggested that the islands of the Mediterranean were first settled during the Pleistocene. Attention has in particular been paid to recent claims that the occupation of Crete by hominins dates to the Middle Pleistocene. This paper examines what—if Lower Palaeolithic pre-modern hominins did indeed colonize the Mediterranean islands—environmental and evolutionary impacts this would have had, what forms these impacts would have taken, and what traces these forms would leave. Such impacts are modeled using information derived from island biogeography, historical ecology, and evolutionary biology. Probable outcomes of colonization scenarios—including turnover in insular faunas, ecological cascade events, and morphological changes in isolated populations of Homo—are compared to the palaeontological and palaeoenvironmental record for the Mediterranean islands. The absence of any obvious correlation casts doubt on large-scale and sustained colonization of the more remote Mediterranean islands during the Lower Palaeolithic, although this does not preclude the possibility of chance and short-lived colonizations by pre-modern hominins.*

**Keywords:** *biogeography, colonization, Lower Palaeolithic, Mediterranean islands, palaeoenvironments*

### Introduction

A central recognition of the archaeology of human dispersals is the universal tendency for both humans and our near relatives to be very reluctant island colonists (Gamble 1996: 203-40). Data that suggest otherwise are, then, especially significant, and in this significance become worthy of close scrutiny. This is no less the case in the prehistoric Mediterranean. The date of the initial colonization of the middle sea's islands by humans and human ancestors has received considerable attention in the past (Sondaar 1998; Cherry 1981; Dawson 2011; 2013; Phoca-Cosmetatou 2011), but there has been a noticeable recent surge in academic interest in eastern Mediterranean data (e.g., Ferentinos *et al.* 2012; Tourloukis and Karkanas 2012). This interest can be attributed to the discovery of artifacts in

southern Crete that bear a typological affinity to Lower Palaeolithic forms (Strasser *et al.* 2010; 2011). Based on the Cretan and other Aegean data (Kopaka and Matzanas 2009; Efstratiou *et al.* 2013; Galanidou *et al.* 2013), and drawing on contentious evidence from Sardinia (Cherry 1992; Hofmeijer and Sondaar 1992; Sondaar 1998), some scholars have challenged the received model of colonization, in which the *sustained* presence of humans on the Mediterranean islands was thought, by Cherry and others, to be primarily a Holocene phenomenon (e.g., Cherry 1981; 1990; Broodbank 2006; Dawson 2011). It has been suggested that the Cretan data indicate a heretofore unsuspected intellectual and technological capacity and willingness amongst pre-modern hominins to traverse the Mediterranean, arrive at, and thrive upon its

islands (Strasser *et al.* 2011: 559; Panagopoulou and Karkanas 2014).

This paper attempts to establish the likelihood of Lower Palaeolithic (2600–300 kya) Mediterranean island colonization. In doing so, it focuses neither on the spatial and temporal distribution of the data themselves—although such an exercise may well be illuminating—nor on their reliability. Rather, it seeks to understand what impacts island colonization during the Lower Palaeolithic would have had on our human ancestors and their environments and what patterns in palaeoenvironmental data would correspond to these impacts, thereby providing (or failing to provide) proxy evidence for such colonizations. To understand why this is a productive

approach, and one perhaps more productive than dealing with the data directly, involves considering both the nature of these data and how the general understanding of Mediterranean island colonization has been affected by them.

### Great Expectations in the Colonization of the Mediterranean Islands

For several reasons, these newer data have muddled rather than clarified the general picture of colonization dynamics during the Quaternary of the Mediterranean (see Figure 1 for correspondence between cultural and geological chronologies). First, lack of chrono-stratigraphic control over artifacts that are then dated solely

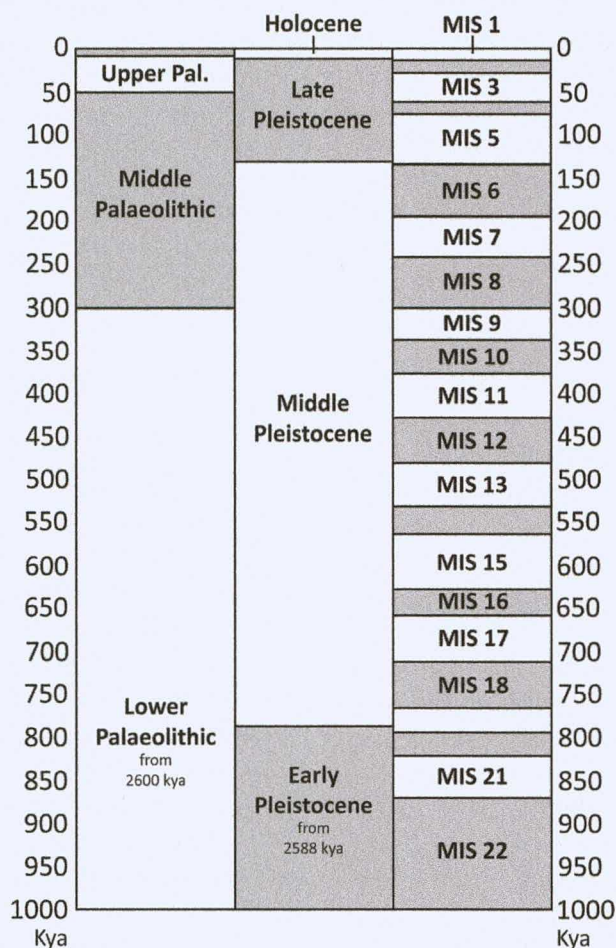


Figure 1. Correspondence between the cultural, geological, and Marine Isotope Stage chronologies.

on a typological basis (Chelidonio 2001; Kopaka and Mantzana 2009; Tourloukis and Karkanias 2012: 2-3) is obviously problematic. Dating artifacts by a combination of typological criteria and pedological context (i.e., top- and sub-soil), which is in turn dated via association with large-scale geological phenomena (in the Cretan case geotectonic uplift of palaeocoastal environments; Strasser *et al.* 2010; 2011), in the absence of strict stratigraphic context, further complicates the situation. There is evident need for more and better radiometric data, especially when other studies have indicated the ease with which radiometric dating can dispel doubts about the antiquity of a lithic assemblage; for example, the Epipalaeolithic/Mesolithic credentials of the sites at Ouriakos on Lemnos and Maroula on Kythnos have been established with absolute dating (Sampson *et al.* 2010; Efstratiou *et al.* 2013).

Second, the confusion over what constituted an island at a given point in the past has also been problematic. Because of geotectonic dynamism and the effects of ice-weight on the lithosphere, palaeogeographic reconstruction of past configuration of shorelines is inevitably inexact to a degree, and frequently fades into probability. It is certain, for example, that Cyprus, Crete, and the Balearics have all been separated from mainland Eurasia since the re-opening of the Strait of Gibraltar following the Messinian Salinity Crisis, 5.96–5.33 mya (Krijgsman *et al.* 1999). The status of Corsardinia, Sicily, and the Adriatic, Tyrrhenian, Ionian, and Aegean islands is more moot, during the Middle as well as the Lower Palaeolithic. The issue of these islands' insularity depends on how the relevant marine and terrestrial topography is modeled and with which Quaternary Marine Isotope Stage (MIS) we are dealing (Lambeck 2004; Lykousis 2009). For example, it is *probable* that during MIS 2 (29–14 kya, including the Last Glacial Maximum [LGM]), the Ionian Islands were narrowly separated from the Balkan peninsula (van Andel and Shackleton 1982: 449, fig. 2; Lykousis 2009: fig. 5). It is *certain* that they were either narrowly

separated from or tenuously connected to the peninsula, but the actual barrier such minute and cyclically non-existent water gaps would present in terms of dispersal capacity is unclear. Framing the crossing of such water gaps, if indeed they existed, in terms of 'seafaring' (Ferentinos *et al.* 2012) disingenuously implies an unnecessarily grandiose aspect to crossing <5km of water. The same point may be made concerning discussions of the 'insularity' of the Sporades during glacial maxima (van Andel and Shackleton 1982: figs. 2 and 3). In either case, Mousterian Middle Palaeolithic material assigned to 110–135 kya (Ferentinos *et al.* 2012: 2169–70) could derive from either very short water crossings or terrestrial dispersal events. Falling within MIS 5 and its constituent phases (123–71 kya), thereby covering both glacials and interstadials, the insularity of the Ionian archipelago would have been contingent (Lykousis 2009). Other islands with typologically Lower Palaeolithic material, such as Lesvos (Galanidou *et al.* 2013), were demonstrably connected to the Eurasian mainland at lower sea-stands.

Finally, as Broodbank has already noted (2006: 200), a tendency to treat Lower, Middle, and Upper Palaeolithic colonization as essentially qualitatively similar processes of 'seafaring' (Strasser *et al.* 2010; 2011: 553; Ferentinos *et al.* 2012) has been unhelpful. Considering the likely differences in behavioral and ecological context between *Homo sapiens* in the aftermath of the LGM and pre-modern forms of *Homo* in the Lower Palaeolithic, we might reasonably expect sea-crossings by various species separated by tens of millennia to be very different phenomena in terms of motivation, logistics, and technology.

These caveats notwithstanding, it is vital to understand more fully both the nature of the data and the likelihood of island colonization by pre-modern hominins in the Lower Palaeolithic. These have profound implications not only for our understanding of the peopling of the Mediterranean and of Europe, but also and more widely in terms of the dispersal abilities of human ancestors, a topic of enduring and discipline-wide

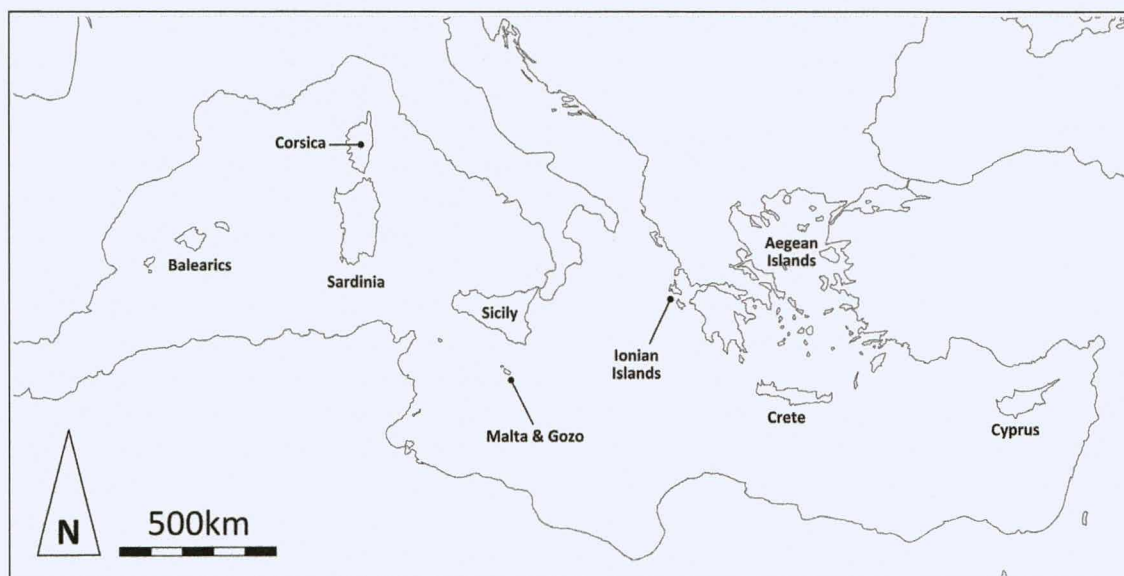


Figure 2. The Mediterranean, depicting islands mentioned in the text.

significance. There are two avenues by which we might explore the veracity of this model of early island colonization: (1) by reviewing the plausibility and acceptability of the data, or (2) by modeling likely archaeological scenarios corresponding to the Lower Palaeolithic colonization of the remote Mediterranean islands. This paper takes the latter route, and considers the possible human and environmental implications of Lower Palaeolithic colonization of those Mediterranean islands that have remained such over the duration of hominin evolution—the Balearics, Crete, Cyprus, and (probably) the islands of the central Mediterranean, including Sardinia and Corsica (Figure 2). Lessons from island biogeography, community ecology, and evolutionary biology are invoked to establish probable ecological outcomes of colonization scenarios. The likely palaeoenvironmental and archaeological signatures of colonization are then compared to the respective records, in order to establish which qualitative and quantitative aspects of colonization are most likely to have obtained. The emphasis is on establishing what we might reasonably suppose to have happened if pre-modern members of *Homo* had arrived on Mediterranean islands and

persisted there over geological spans of time, and whether proxies for such processes are evident. In essence, the question posed is: if pre-modern hominins had colonized the Mediterranean islands, what would we expect to have happened, and what traces would this leave?

In answering these questions, it is necessary to understand the full range of possibilities concerning interaction between island environments and pre-modern hominins: how would expectations differ between a lone *H. erectus* or *H. heidelbergensis* washed up on the strand and a thriving population of Acheulean-using pre-moderns on Crete? It is possible to reduce the cluster of variables implicated in this interaction into four broad scenarios of colonization:

- (1) *No colonization.* No colonization of the Mediterranean isolates during the Lower Palaeolithic.
- (2) *Ephemeral colonization* (the ‘Robinson Crusoe’ problem). Colonizing hominins experienced instantaneous or rapid localized extinction/abandonment.
- (3) *Unsustainable permanent colonization.* Colonizing hominins experienced gradual localized extinction/abandonment.

- (4) *Sustainable colonization.* Colonizing hominins maintained a viable population and became successfully established on the islands over the very long term.

Clearly, these are simplifications. The Mediterranean's Quaternary islands may have conceivably experienced very different sets of environmental interactions with hominins (if they did at all), and the temporal scales and nuances of the macro-scale processes outlined above inevitably elide into one another. Additionally, and especially as regards the fourth scenario, whether or not colonist populations experienced genetic exchange with mainland groups has importance for understanding likely long-term structural effects, although for reasons discussed below such exchange is unlikely. That said, these scenarios cover the range of expectations based on whether hominins did or did not cross to islands and, if they did, what happened next. What is required is a mode of understanding what the effects of each would be on colonizer and colonized, and how we might search for these effects or their proxies in the available records. The initial discussion therefore addresses both the likely nature of colonist/island ecodynamics in the context of an island colonization by an archaic hominin, and also the ecogeographic limitations imposed on such a colonizing population. To do this, and to illuminate the Mediterranean data more fully, requires dealing with material not often implicated in discussions of Mediterranean prehistory: specifically, the palaeoanthropological record of island southeast Asia.

### Modeling the Recursive Impacts of Colonizing Hominins on Island Habitats

#### *What Colonists do to Islands: Lessons from Historical Ecology*

Humans have had profound impacts on their environments, and on island environments in particular (Quammen 1996). It is not unreasonable to begin with the proposition that archaic

hominins, too, would have left their mark on Pleistocene ecologies. The most effective method of constructing a model of likely impacts by a hominin colonizing the Mediterranean islands would be to note the palaeoenvironmental impacts of analogous situations. A central problem in doing so is the paucity of the data; the only other example (itself a subject of debate) of island colonization in pre-modern hominins outside of the Mediterranean comes from island southeast Asia, an example that has been argued to demonstrate the plausibility of Mediterranean late Early-Middle Pleistocene island colonization (Panagopoulou and Karkanas 2014; see Broodbank 2006: 205). These data are extremely suggestive, both in understanding the effects of colonists on islands, but also *vice versa*, and are worth considering in some detail.

The island of Flores in Indonesia has a unique fossil record. From the cave of Liang Bua, remains of very small yet undeniably *Homo*-like beings have been recovered, alongside archaeological and palaeontological material that hint at the behavioral and environmental context of this creature (Morwood *et al.* 2004). The earliest skeletal remains appear at 74 kya (Morwood and Jungers 2009; Roberts *et al.* 2009), although stone tools from elsewhere on Flores imply the existence of this or an ancestral form from 1020 kya (Brumm *et al.* 2010). Debate has focused particularly on whether these fossils represent a new species, *H. floresiensis*, or pathological individuals of a previously recognized hominin species (Martin *et al.* 2006; Falk *et al.* 2007; Morwood and Jungers 2009). It is not the intention to rehearse these debates here; the bulk of evidence (see Aiello 2010) appears to support the interpretation that these fossils represent a previously unknown species of hominin, presumably derived from a larger-bodied ancestor (there is no evidence that ancestral species with a comparable body size, i.e., Australopithecines, entered Asia). These data are relevant in the discussion of Palaeolithic sea-crossings for two related reasons: first, that Flores appears not to

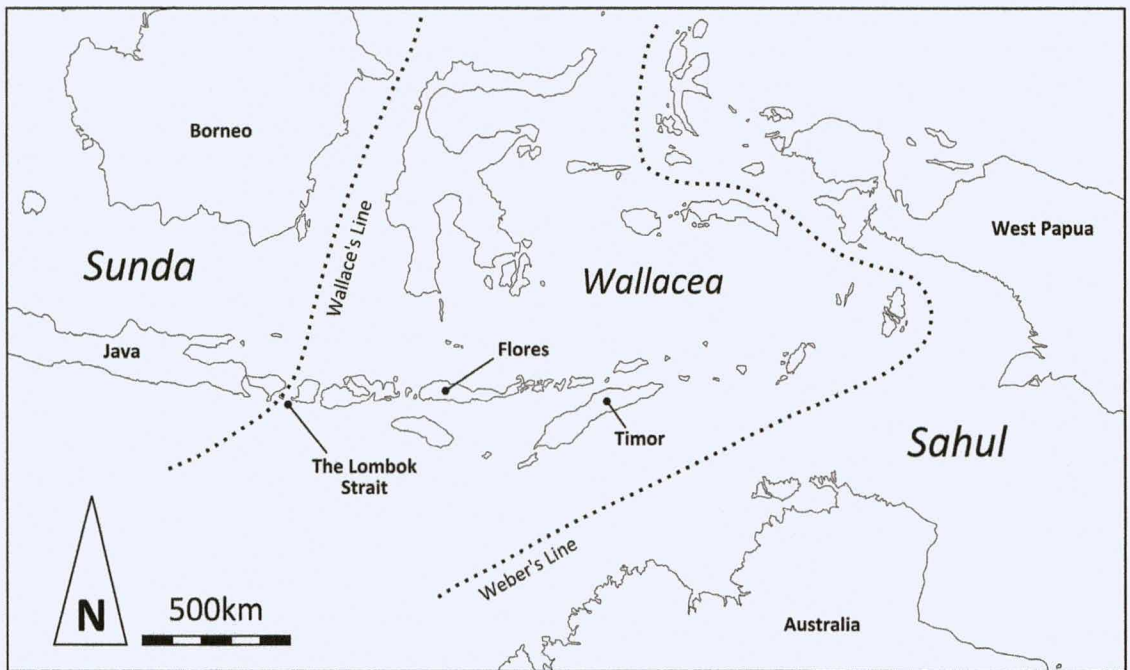


Figure 3. Island southeast Asia, depicting islands mentioned in the text. Biogeographic zones in italics, biogeographic barriers as dashed lines.

have been connected to Asia during the Pleistocene; and second, that the species apparently underwent a dwarfing process.

The fact that Flores has been insular during the span of the evolution of *Homo* (Hantoro *et al.* 1995) provides the first evidence that members of that genus aside from *H. sapiens* were capable of crossing open bodies of water. Flores lies to the east of Wallace's Line (Figure 3), a biogeographic barrier that runs between Bali and Lombok and separates (mostly) Asian and Australian faunas (van Oosterzee 1997). Very few terrestrial mammals—with their relatively low dispersal capacity—have crossed this barrier. For the ancestors of *floresiensis* to have done so would have involved crossing approximately 20–30 km of open sea, a feat not repeated by hominins until the peopling of Australia and Near Oceania by modern humans ~46 kya (Kirch 2010), at which time *floresiensis* was still thriving. This early sea-crossing and the subsequent history of the species' development

on Flores have enormous significance for understanding the relationship between pre-moderns and island environments, but we must be absolutely clear about what form this significance takes.

The story of *floresiensis* begins not with its fossils, but with the environmental impacts of its ancestors. These first colonists were possibly *H. erectus*, considering the presence of this species in neighboring Java (e.g., Storm 2012), but could conceivably have been an older species. Stone tools from two sites on Flores, Wolo Sege (dated to 1020 kya; Brumm *et al.* 2010) and Mata Menge (dated to 880 kya; Sondaar *et al.* 1994; Brumm *et al.* 2006), provide the first evidence for hominin presence on the island. The morphological similarities between these lithic assemblages and that from Liang Bua give good reason to suppose that these tools represent the first (archaeologically visible) incursion of *Homo* into the island. The appearance of hominins on Flores seems to correlate with a biotic turnover

event dated to the latter part of the Early Pleistocene at ~900 kya. Van den Bergh *et al.* (2009) report a disturbance in the Early Pleistocene fauna of the island, with a dwarfed stegodont and a giant tortoise disappearing from the palaeontological record. Subsequently, a larger stegodont (*Stegodon florensis*) becomes prominent in the island's fauna.

While there is substantial time depth involved, the appearance of hominins in a previously isolated environment and the subsequent disappearance of endemic species is suggestive. It hardly demonstrates conclusively that the colonizing hominin (whether *erectus*, or some other form) was a ruthless stegodont butcher, and the Flores data in their current form make it difficult to extrapolate from this case to other possible cases. These data do, however, provide food for thought on the relationship between arrivals of hominin colonists and large-scale community compositional events. In the only definite case in which pre-modern hominins colonized an island, dwarfed and relatively high-value prey species disappeared. This aligns well with expectations not necessarily about hominin impacts on island ecologies, but about the impacts of large-bodied omnivorous or carnivorous vertebrates more generally. What are the wider implications of considering new predator–prey relationships in previously isolated ecosystems?

Anatomically modern humans (AMH) actively prey on other taxa, and accumulating data suggest archaic forms of *Homo* behaved similarly (e.g., Ferraro *et al.* 2013; Bunn and Gurtov 2014). Certainly, the type, frequency, and calorific significance of predation differ within our own species dependent on behavioral and environmental context, and almost certainly differed between AMH and archaic forms. That said, *Homo* is a genus comprised of medium- to large-bodied species which display evidence for omnivory. The ecological niches occupied by this genus, especially prior to the development of food-producing subsistence strategies, are analogous to those of other large omnivorous and car-

nivorous species. Such species occupy the higher tiers of foodwebs, and hominins similarly should be understood as occupants of the upper levels of trophic hierarchies, with attendant implications for their importance within them. Island environments tend to be hostile towards animals of this sort, due to restrictions on range size and insular poverty of prey in both qualitative (fewer species) and quantitative (smaller populations of these species) terms, as well as the general tendency for large-bodied animals to have limited dispersal capacity (Heaney 1986; Crooks 2002; Raia and Meiri 2006). This renders the per area carrying capacity for higher-tier predators of islands less than that for comparable extents of mainland habitat. Consequently, if they do not rapidly become locally extinct—a likelihood—colonists of such species should have profound ecological impacts as breeding populations establish themselves. Comparable to equivalent non-insular populations, their impacts on prey species' demography should be greater, while the range of what constitutes prey should expand. The disappearance of species which, in human behavioral ecology terms, should convey very high fitness upon archaic hominins (as high-protein and relatively defenseless prey; Bird and O'Connell 2006: 146–49) from Flores at around the period of first colonization by the latter is suggestive, and could be interpreted as a result of predation pressure exerted by colonizing hominins. Conceivably, similar extinction events of preferred prey taxa in the Mediterranean could provide proxies for hominin colonization horizons. This would be expected even in the absence of the Flores data, considering the fragility of Mediterranean insular faunas and evidence for hominin subsistence behaviors.

Lax and Strasser (1992: 211–17) were correct to highlight that hominin impacts on endemic species occur via several pathways, of which primary predation is only one. The vulnerability of endemics to habitat fragmentation via colonizing human agents has only recently been appreciated (Henle *et al.* 2004;

Laurance 2010), and the transfer of pathogens between humans, commensals, and endemics needs greater appreciation. Importantly, habitat alteration and the appearance of commensals and domestics are associated with agropastoral societies; the environmental impact of hunter-gatherers could conceivably be greatly reduced by comparison. To assume that every arrival of a species of hominin in a previously pristine environment resulted in the decimation of that environment's biota fails to recognize variability in human subsistence behaviors. In short, the arrival of *Homo* in new contexts should not necessarily result in overkill, and in particular the disappearance of large mammals from the palaeontological record. To suppose that the arrival of a colonizing hominin would have no observable environmental impacts, however, is to misunderstand the nature of community ecological processes.

Hominin predation on island taxa that were previously unexposed to such predation should have demographic implications for populations of those taxa, even if such pressure does not result in localized extinction. A central recognition of community ecology is that demographic dynamism within one species should result in consequent dynamism in neighboring species (whether predators, competitors, or symbionts), promoting change throughout the ecosystem (Holt 2002; Terborgh 2010). For example, predation on endemic ungulates (not an unlikely scenario in the Pleistocene Mediterranean) by a newly-established hominin would release deciduous plants from predation on saplings. This would permit growth and recolonization in these species, affecting not only surface flora but also soil composition, taxa that rely symbiotically on deciduous vs coniferous vegetation, and the trophic neighbors of these taxa (see Figure 4 for an instance of such ecosystem-wide change on Christmas Island). Recognizing ecologies as symbiotically interlocked suggests the type of events that should accompany the sudden appearance of higher-tier consumers: not only

turnover events affecting likely prey species, but also *ecological cascades*. Extinction of certain prey species may not always be expected, but community-wide impacts should be. Cascade events of this type should be observable palaeoenvironmentally via the palaeontological record.

Colonization of biogeographically remote islands by apex predators is unlikely for several reasons; taxa which, against the odds, successfully colonize such an island are proportionally more exposed to localized extinction than taxa closer to the trophic base. If such a colonization event were successful in the long term, this should have profound effects on the insular biota—not just those fauna that might be supposed to be preferred prey items (thereby resulting in turnover), but across biotas in the form of ecological cascades, as predatory impacts on demography have recursive effects on the trophic neighbors of prey species. In essence, both turnover and associated cascade events should be visible palaeontologically and thereby palaeoenvironmentally—not only as extinction events (probable but not certain), but also as simultaneous increasing/decreasing frequency across the spectrum of observable taxa. The arrival of continental apex predators in an insular context should drive down overall endemism, as hyper- or maladapted taxa experience greater vulnerability to both direct predation and other impact pathways. As prime examples of such predators, these bioevents should accompany the establishment of insular populations of hominins.

#### *What Islands do to Colonists: Lessons from Biogeography and Evolutionary Biology*

As island environments are transformed by the arrival of new colonists, so insularity as a biogeographical property has transformative structural effects on colonizing populations. Again, a brief consideration of the Indonesian data is significant in modeling comparable colonization scenarios in the Pleistocene Mediterranean.

A viable breeding population of an archaic form of *Homo* colonized Flores. In what manner



**Figure 4.** Ecosystem-wide change on Christmas Island. An endemic crab *Gecarcoidea natalis* keeps the understorey defoliated via its foraging (A). The introduction of the Yellow Crazy Ant (*Anoplolepis gracilipes*) reduces the crab population via direct predation, permitting ecological release in the plant species which comprise *natalis*'s diet (B). This leads to ecosystem-wide change, transforming the floral, faunal, and pedological composition of the understorey (O'Dowd *et al.* 2003: 815, fig. 1).

did this happen? *Homo* contains the only species with the cognitive organization to deliberately undertake risky, long-distance voyaging in anticipation of future rewards, but it is not clear how far back in the genus this ability extends, leaving open the possibility both of deliberate, active colonization, or of passive chance dispersal. A repeated series of crossings would suggest intentionality, whereas a single or very few events would indicate chance crossing (Dennell *et al.* 2014). While chance crossing seems intuitively unlikely, other mammals (including primates) evidently experience passive short-range dispersal events. Rather, the presence of a population of a species next to a narrow water gap over millennial scales makes it inherently likely that, eventually, a random dispersal will occur. Natural rafts, which occur in tropical and subtropical environments (Trivedy *et al.* 1978), facilitate this dispersal in otherwise weak swimmers. A consideration of the temporal scale of the Flores colonization event raises the question of colonization demographics. While it remains unclear what constitutes a minimum viable population size in *Homo* and its constituent species, population biology and demographic ecology indicate that the larger a colonization

the better its long-term chances of survival, with increasingly smaller populations increasingly exposed to stochastic effects (Lande 1993; Demetrius *et al.* 2004). That said, increased risk of localized extinction in small populations does not make a small population unviable, merely proportionately less viable diachronically. If such an instance of colonization were a random event, this would imply a very small population; if active, deliberate colonization, a larger population may be implied (Dennell *et al.* 2014).

The morphology of *floresiensis* provides likely answers to these questions, and in doing so sheds light on what may be expected in comparable Mediterranean contexts. *H. floresiensis* is small, ~1 m tall. This implies that (a) it bears a strong affinity to known small-bodied hominids (i.e., Australopithecines) or an unknown similarly small-bodied species of hominin, or (b) it underwent a process of dwarfing from a larger-bodied ancestral hominin, a reversal of the usual trajectory within *Homo*. The former scenario seems unlikely, because (a) of the absence of evidence for Australopithecine colonization of Eurasia, and (b) that despite the evident diversity in Eurasian archaic *Homo*, there is no species within the genus which approaches *floresiensis* in scale. The

latter scenario (dwarfing from an early member of *Homo*) is arguably the more efficient explanation, and could best be explained by the fact that Flores has remained insular over geological time. The peculiar effects of islands on body size in their inhabitants have been recognized in various iterations of the 'island rule'. Put broadly, larger animals tend to get smaller on islands while smaller animals get larger (Foster 1964; van Valen 1973; Lomolino 1985; Lomolino *et al.* 2006; Palombo 2008). The reasons for this insular nanism and gigantism are probably several, related to island areas, the restrictive ecological nature of islands, and their capacity to promote speciation while remaining individually species-poor. There appears to be a generally optimal *Bauplan* in terms of body size and energy efficiency for terrestrial vertebrates towards which, when released from pressures of predation, the morphologies of mammals, reptiles, and occasionally birds, seem to gravitate. Taxa smaller than this happy medium tend to experience gigantism, whereas larger taxa may get smaller. This is not, however, a series of perfectly understood processes. Ecological release (Meiri *et al.* 2006) probably has relevance in explaining gigantism (especially in arthropods), due to the relatively poor dispersal abilities and subsequent insular survival rates of higher-tier predators. Conversely, nanism in certain vertebrates may have to do with resource poverty in island environments. Taxa higher in trophic structures—such, indeed, as carnivores, as noted above—must adapt to qualitatively (in terms of species number) and quantitatively poorer trophic webs on a given island (e.g., Raia and Meiri 2006).

Whatever the exact nature of the driving forces behind island dwarfing and gigantizing (probably a combination of energy efficiency and novel trophic logics), primates seem to follow the island rule. As medium- to large-bodied mammals occupying medium to (in the case of *Homo*) higher tiers in trophic structures, dwarfing could be expected in colonizing members of the order. This is borne out by comparative

morphometric studies of insular primates (Bromham and Cardillo 2007; Welch 2009), which demonstrate that *floresiensis* falls within the range expected if an early form of *Homo* underwent island dwarfing at a scale comparable to primates examined in the studies. Such long-term morphological developments can only occur in the context of zero or negligible exchange of genetic material with other populations. The dwarfing of *floresiensis* provides the most compelling evidence that the ancestral colonization event was not one that was repeated, and that the flow of genetic material across Wallace's Line was evolutionarily insignificant.

This has pronounced implications for modeling similar colonization events in the Pleistocene Mediterranean. It suggests that—contrary, perhaps, to intuitive approaches to the intellectual capacity of members of *Homo*—biogeographic limitations were as real for pre-modern hominins as for other colonizing mammals. If the 30 km of the Lombok Strait effectively prohibited genetic flow between two populations of *erectus* (a possible ancestor of *floresiensis*, considering the evidence from Java; Storm 2012), the same may be expected between, for example, isolated Mediterranean islands and mainland Eurasia, locally specific oceanographic conditions notwithstanding. If colonizing populations of *erectus* or *heidelbergensis* reached these islands, the Flores data suggest they were much more likely to represent evolutionary traps, rather than facilitating further island colonization. The lurking suspicion is that random dispersal events, rather than habitual seagoing, best explain these Pleistocene data, and this seems to be supported by the comparative florescence of insular artifactual data in certain parts of the world (e.g., Tasmania, the Solomons) during the Upper Palaeolithic associated firmly with the one species of *Homo* which seems especially good at long-range dispersal. Before considering this last point in more detail, however, it is necessary to return to the four scenarios of colonization outlined at the beginning of this

paper. Bearing in mind the likely ecological and evolutionary effects of Pleistocene colonization, it becomes possible to model tentatively the likely archaeological and palaeoenvironmental signatures of each event, and compare these signatures to the record.

### *Modeling Environmental and Evolutionary Impacts and Their Proxies*

Four scenarios of possible hominin colonization of the more remote Mediterranean islands have been suggested, ranging from no settlement (1), to large-scale and long-term colonization during the late Early-Middle Pleistocene (4). A brief review of the effects and limitations that island colonization has on both islands and colonists is suggestive of what we might expect to have occurred in analogous situations in the Mediterranean, and what visible outcomes (palaeontological and palaeoenvironmental) this would have. Specifically, this can be used to model the likely and relative visibility of the four proposed scenarios in the record. As scenario (1) would clearly have no environmental impacts and correlates, we begin with the second scenario.

(2) *Ephemeral colonization* (the 'Robinson Crusoe' problem). Colonizing hominins experienced instantaneous/rapid localized extinction/abandonment. Based on the probable individual life expectancies of a reproductively unviable group of individuals, the probable scale: <10–100 years.

This scenario would have minimal impacts, whether in terms of disturbance of insular ecological regimes or in structural changes in hominin behavior or morphology. From an archaeological perspective, 'Robinson Crusoe'-type events (unintentional, small-scale, and short-lived isolation rather than deliberate colonization) are problematic: thanks to the minute spatial and temporal scales involved, exacerbated by taphonomic selection, such events would be hard to detect in the archaeological record; statistically, their chance discovery is remote. From the palaeoenvironmen-

tal perspective, it is unlikely that such a short-lived population would have pronounced impacts on biotic composition. The mathematical likelihood (in terms of chance dispersal of neighboring continental populations over the very long term) yet inherent low-visibility of 'Robinson Crusoe' events in the Mediterranean has interesting implications for their observation and recovery, considered more fully below.

(3) *Unsustainable colonization*. Colonizing hominins experienced gradual localized extinction/abandonment. Based on the likely demographic instability of a small group and its exposure to stochastic effects, extinction could be experienced rapidly, or the population could persist over the millennial scale. Probable scale: 1000–10,000 years.

This scenario should have impacts on the environmental record, and is probably on the cusp of archaeological visibility. Over this temporal scale the biotic composition of an island the size of Crete or Cyprus (~10,000 km sq) would alter. The timeframe involved may not result in extinction events, but cascade-like effects should take place as the demographics of preferred prey species are affected by predation, and these should be observable palaeontologically. This scenario assumes biogeographic isolation from mainland populations. Taphonomic processes and their relative infrequency in sealed deposits would probably militate against large-scale observation of hominin fossils or artifacts.

(4) *Sustainable colonization*. Colonizing hominins maintained a viable population and became successfully established on the islands over the long-term. This scenario assumes maintained population over evolutionary time, so probable scale: >10,000 years.

This scenario should be conspicuous across palaeoenvironmental and archaeological records. The long-term predation on endemics by a stable population of archaic hominins should generate extinction events and drastically reduce

endemism, causing cascades throughout trophic systems. Based on evidence from Flores, this population should remain genetically isolated: morphological changes should be expected given the timeframe involved. An interesting consideration involves the role of the hominin population as a reservoir; over >10,000 years, further chance dispersal events to neighboring unoccupied islands in a stepping-stone manner may well occur. Based on the data from southeast Asia, however, it is unlikely that genetic flow would be retained between isolated populations, with islands acting as engines of allopatric speciation.

A key problem that should be anticipated relates to the visibility of each of these scenarios in the palaeoenvironmental and archaeologi-

cal records, after taphonomic processes have exacted their toll. Figure 5 depicts on a log-log scale the likely temporal and spatial ranges over which these scenarios would manifest themselves, from the small and brief (2) to the large and enduring (4). Scenarios (3) and (4) should be observable archaeologically, but scenario (2) presents problems. Taking into account its small scale, the aggregate material outcomes of this scenario would arguably fall below a threshold of visibility, and this has implications for understanding the history of hominin activities on Mediterranean islands in deep time. Leaving this problem temporarily aside, it becomes possible to compare these likely outcomes to sets of palaeontological and palaeoenvironmental data from the Mediterranean isolates.

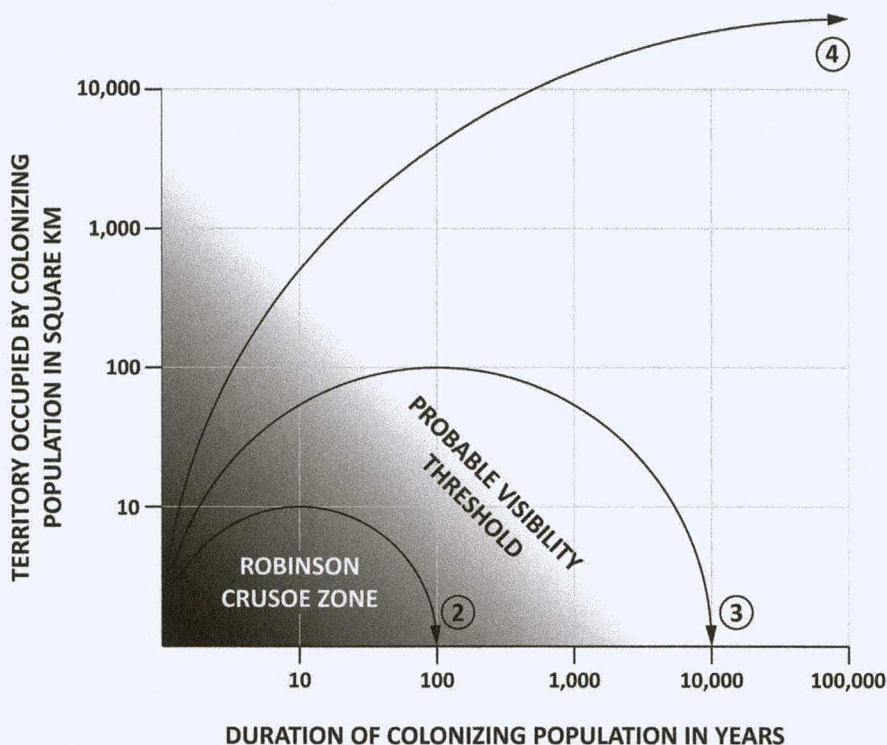


**Figure 5.** Schematic plot of spatial and temporal visibility of colonization scenarios on a log-log scale. Scenarios (2) through (4) are represented. Shaded area (lighter to darker) indicates decreased likelihood of archaeological and palaeoenvironmental visibility, culminating in very small and essentially undetectable 'Robinson Crusoe' events (2). By contrast, large-scale and sustained colonization (4) should be very visible. Unsustainable colonization (3) lies on the cusp of visibility.

## **Ambiguous Outcomes: Palaeontological and Palaeoenvironmental Data**

### *Looking for Large-Scale Bioevents in the Pleistocene Mediterranean*

Data that may conceivably provide a means of accessing hominin ecodynamics in Mediterranean deep time are not evenly distributed. Because of both the time depth involved and the Mediterranean's characteristic aridity, palynological data, for example, are of little use in understanding Pleistocene bioevents, although the temporal reach of the pollen record just about embraces potential changes resulting from large-scale early Holocene colonization by farmers (Bottema and Sarpaki 2003). At very large temporal and spatial scales proxy climatic data can be used to reconstruct likely changing rainfall regimes between glacial maxima and interstadials, although the Mediterranean's orogenic complexity, exacerbated by fluctuations in sea-level of ~100m, prohibits anything but the feeblest grasp of specifics at the regional or local level. Happily, the palaeontological record of the Mediterranean islands, whilst certainly uneven, is comparatively well studied. Palaeontological data are clearly of first order importance in and of themselves in observing ecological change but can also thereby, to a limited extent, be used to reconstruct macro-scale environmental conditions.

The island faunas of the Mediterranean, like insular taxa elsewhere, tended towards extreme endemism during the Quaternary (e.g., Palombo 2008: 2). Consequent defenselessness against newly-arrived predators is relevant in the context of Mediterranean-wide extinctions at the end of the Holocene, coincident with large-scale island colonization by modern humans; endemic mammals experienced an astounding 88.9% extinction rate at the Pleistocene-Holocene boundary (Alcover *et al.* 1998: 916). This loss in biodiversity relates to the definite impacts of anatomically modern humans on fragile ecosystems, whether farmers or also (probably) hunter-gatherer communities. The concern here, however,

is with the less well-understood faunal record prior to ~50 kya. Based on the reasoning in the first half of this paper, interest lies not so much in individual extinctions within this record, but in island- or Mediterranean-wide biotic events. Individual species come and go, but it is likely to be turnover and/or cascade events that signal long-term impacts of pre-modern hominins. As such the data for the individual Mediterranean isolates are considered, not on a species-by-species basis, but with respect to evidence for turnover events and evolutionarily sudden shifts in endemism. The aim is not to review viable palaeoenvironmental conditions for each island, but rather to grasp palaeontological discontinuities (as opposed to continuities), and their relative scale, as indicative of wider uncharacteristic environmental lurches and ruptures that might be representative of a new, higher-tier predator establishing a breeding population.

With the Balearic islands—Mallorca, Menorca, Ibiza, Formentera, and numerous islets—the situation seems refreshingly clear. Despite the relative proximity of these islands to the Iberian coast, their mammalian faunas were consistently highly endemic throughout the entirety of the Pleistocene with very limited evidence for turnover (Bover and Alcover 2003; Palombo *et al.* 2006: 153-55). The genus *Myotragus* (mouse-goat) is the most famous taxon in a fauna that traces its roots to the Messinian Salinity Crisis (a large lagomorph, *Nuralagus rex*, appears to have been outcompeted by the mouse-goat genus on Menorca in the Pliocene). Despite the gradual and specific waxing and waning of *Myotragus*, if any of the various species of hominin which made mainland Iberia their home (Broodbank 2013: 91-93) colonized the Balearics, they had no discernable palaeoenvironmental or palaeontological impact; similarly, there is no archaeological evidence to suggest such a colonization event. This is in stark opposition to the evidence for increased human activity in the Holocene western Mediterranean (Alcover 2008) coincident with the recent final demise of the last and

most fully studied myotragid, *M. Balearicus*, between 3640 and 2135 BC (Lalueza-Fox *et al.* 2002: 501). *Myotragus* is unknown on Ibiza and Formentera, both of which nonetheless possessed their own highly endemic and markedly depauperate faunas (Marra 2005: 6-7).

The central Mediterranean islands—Malta, Gozo, Comino, Pantelleria, Lampedusa, and Linosa—are slightly more obscure, both palaeontologically and palaeogeographically. The palaeontological record is most complete for the Maltese archipelago, which, palaeogeographic reconstruction suggests, was united into a much larger landmass during glacial maxima (this landmass may conceivably have been cyclically connected to Sicily, allowing the larger island's quasi-continental fauna to disperse into the archipelago; Shackleton *et al.* 1984: 310, fig. 2). The deposits at Ghar Dalam (Malta) still provide the most complete and best-understood palaeontological sequence. The basal stratum (8) is considered to be Early-Middle Pleistocene (Hunt and Schembri 1999: 9-18); the first fossil-rich stratum (7) dates to late Middle-early Late Pleistocene, and contains evidence for several endemics, including two species of dwarfed hippopotami (*Hippopotamus pentlandi* and *H. melitensis*), a subgenus of *Elephas* (*Palaeoloxodon*), various endemics belonging to Rodentia, and the famous Maltese giant swan (*Cygnus falconeri*), amongst other birds. Following a sterile hiatus (Stratum 6), Strata 4 and 5 (dated to the Late Pleistocene) are rich in non-exotics, including deer, bear, wolf, fox, and possibly horse. While dwarfing in some of these forms (e.g., *Cervus elephas*) may suggest continued, or more likely glacially-cyclical, insularity, the sudden appearance of continental fauna at around MIS 2 (29–14 kya) and the disappearance of the endemics implies a large-scale turnover event (perhaps consistent with the reunification of Malta and Sicily at the LGM). The Middle Pleistocene fauna, however, are strongly endemic (Hunt and Schembri 1999: table 4) and exhibit little evidence of high-impact bioevents. If

hominins arrived on the central Mediterranean isolates, they left no discernible palaeoenvironmental or archaeological trace; it is not until the sixth millennium BC that there exists firm evidence for the appearance of *Homo* on Malta (Robb 2001; Dawson 2013: 109-12).

The palaeoenvironmental and palaeontological record on Crete is more challenging (Lax 1996; Sondaar *et al.* 1996). As with other Mediterranean isolates, the desiccation and subsequent re-inundation of the basin at 5.96–5.33 mya seem responsible for the arrival and subsequent isolation of mainland faunas. During the Early and Middle Pleistocene the mammalian fauna was highly endemic, with the *Kritimys* biozone notable for endemics such as *Hippopotamus creutzbergi* and *Elephas creticus*, both dwarfed forms with mainland ancestors that possessed relatively high dispersal abilities. Palaeontological evidence suggests a turnover event ~600–400 kya and the disappearance of hippopotamids (Sondaar *et al.* 1996: 65; Marra 2005: 10). The subsequent fauna (late Middle-Late Pleistocene, *Mus* biozone) is problematic. Deer are prevalent (*Candiacervus*), although the phylogenetic relationships between various proposed species are profoundly obscure; it has been argued (de Vos 1996) that the variation seen is derived through radiation from a single Middle Pleistocene colonist. There is evidence for a dwarfed elephant (*E. creutzbergi*), although again the phylogenetic relationships are obscure. A large endemic tortoise is observed in strata that also contain *Candiacervus* spp. (Brinkerink 1996: 207), along with the usual (for the Mediterranean) endemic rodents and birds.

In attempting to extract ecological meaning from these complicated data, it seems at the very least that Crete witnessed a turnover event some time during the Middle Pleistocene. This turnover was broadly coincident with MIS 15-11 (621–374 kya), a series of fluctuations culminating in MIS 11, a pronounced interstadial (Olson and Hearty 2009). The *Kritimys* fauna are succeeded by one that suggests recolonization

from mainland sources (i.e. by *Candiacervus* and *Elephas*, amongst others), but which again becomes rapidly—if relatively less—endemic. The possible implications of this overall picture are considered in the following section.

The palaeoenvironmental record of Cyprus offers no such complications (Reese 1995). The Pleistocene fauna shows no evidence for turnover, and a tendency towards extreme endemism, with notably dwarfed elephants and hippopotami as well as a murid and a fruit bat. No disturbance is obvious until the Pleistocene-Holocene boundary and the first evidence for the appearance of *H. sapiens* on the island. It is not the intention here to rehearse debates surrounding the status of the site at Akrotiri *Aetokremnos* (e.g., Ammerman and Noller 2005), as this site is well outside the immediate temporal remit of this paper. Suffice it to say that the correspondence between maritime activity in the early Holocene and the disappearance of an endemic species that had persisted over geological time is at least suggestive, if not conclusive, of an anthropogenic cause. It is easy to sympathize with the conclusion that the colonization of Cyprus, whether Epipalaeolithic or Pre-Pottery Neolithic (Knapp 2010: 81-101), represents the first disturbance by a hominin of an ecosystem that had been largely isolated since the Messinian.

Sicily and Corsardinia cast a long shadow over the topic of hominin island ecodynamics in the Middle Pleistocene (see Broodbank 2006: 204-205), primarily because of their size, claims for early occupation, and their proximity to mainland Italy at glacial lowstands. Sicily, the largest island in the Mediterranean, is—and has been over the Quaternary—so close to Italy that it falls into the quasi-insular category. We do not currently know whether the island and its small satellites have been definitively connected to mainland Europe during glacial maxima (probably not, although the dynamic local geotectonic environment around the Strait of Messina obscures the detail), but the minute water gap remaining would constitute a signifi-

cantly less effective barrier to dispersal than that separating, for example, Cyprus from Anatolia and the Levantine mainland. Middle Pleistocene data from Sicily would be interesting, but would have less profound implications than equivalents from demonstrably isolated islands; for that reason, Sicily is left out of the current discussion.

Corsardinia—the unified form of Sardinia and Corsica at glacial maxima—is for several reasons problematic. Assertions of pre-Holocene colonization rest on two claims. In terms of the first, the implications of disputed fossil evidence from the Corbeddu Cave (Cherry 1992; Sondaar 1998) are unlikely to be resolved in the near future. The second and more interesting, from the perspective of this paper, is what appears to be a turnover event in the Middle Pleistocene, with the replacement of the highly endemic *Nesogoral* fauna with several mainland species. Sondaar *et al.* (1986) have suggested that this replacement should be attributed to the appearance and long-term establishment of a population of *Homo* on the island. Vigne (1992) points out that, in a manner comparable to the Cretan situation, the colonizing *Tyrrenenicola* fauna nonetheless rapidly radiates into endemic forms (which follow the island rule), suggesting very weak predation pressure. The decimation of this fauna correlates well with increased Holocene island colonization, with only the tenacious *Prolagus sardus* surviving into the later Holocene on a refugium.

The Sardinian Middle Pleistocene turnover event is striking, not just in its existence but in its parallels to Crete. As with Crete, turnover followed by a trend towards (but not attaining) pre-turnover levels of endemism is perplexing, and suggests that, if this does signal the appearance of an apex predator, then this species was not successfully established over evolutionary time. The situation is made more complex by the status of Corsardinia's insularity. During glacial maxima and with the expansion of the Tuscan archipelago the sea-gap between its northern tip and mainland Italy would have

been smaller (perhaps 10–20 km; Shackleton *et al.* 1984: 308, fig. 1), making it less remote than steadfastly insular Cyprus or the Balearics, but further from the mainland than a tenuously-separated island such as Zakynthos. Rates of chance dispersal, not only for hominins but other higher-tier colonizers, would consequently have been increased, allowing limited potential for continental invasions. The question of turnover followed by a move back towards endemism on Crete and Corsardinia is considered below.

Taken together, these palaeontological data can be used to reconstruct large-scale events

in the Pleistocene ecosystems of the remote Mediterranean islands. The general trends are plotted in Figure 6, following Marra (2005). While it is impossible, because of the impact of taphonomic variables, fully to quantify turnover vs continuity as in intact living biosystems, it is nonetheless obvious that there are clear parallels and dissonances. At one end of the spectrum, Cyprus and the Balearics remain strongly endemic with little to no evidence for turnover events or trophic cascades, albeit with some species flickering in and out of focus. The central Mediterranean islands similarly experience pronounced endemism in the Middle Pleistocene,

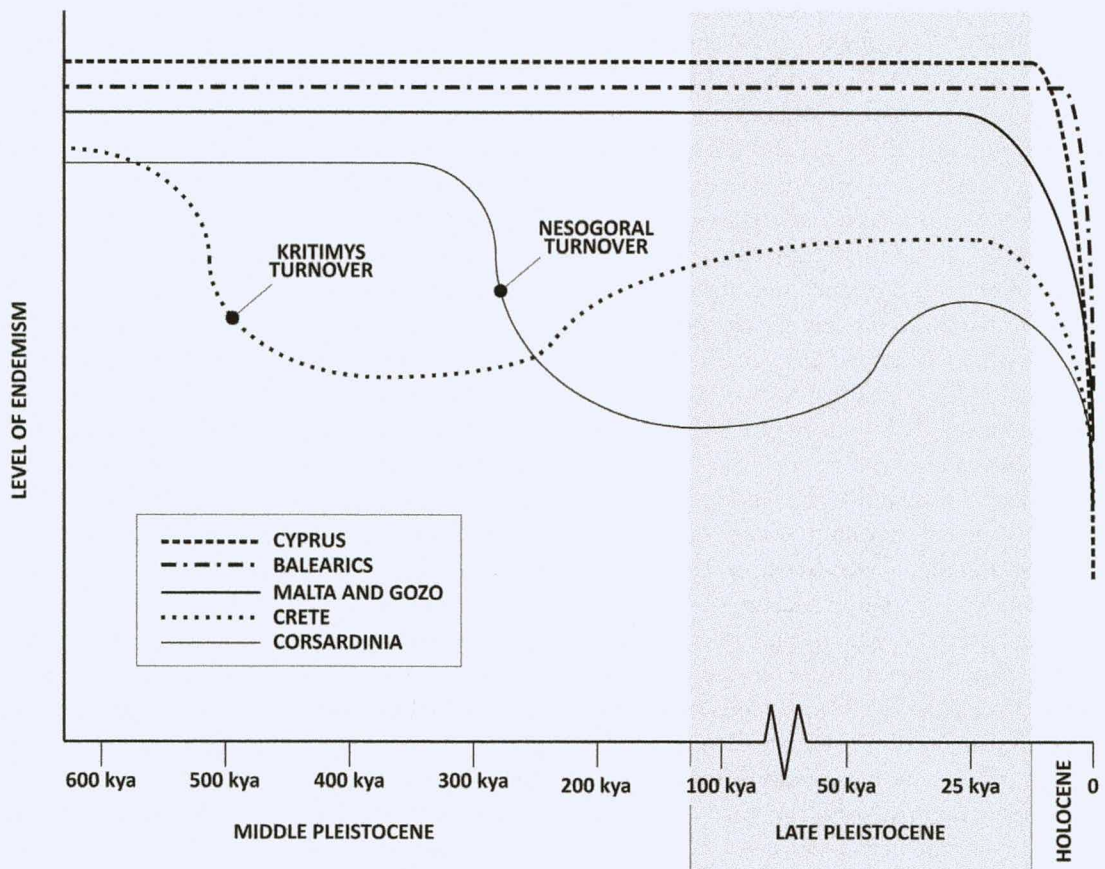


**Figure 6.** Schematic representation of trends in levels of endemism on Mediterranean islands, 600 kya to present. Endemism cannot be quantified in the palaeontological record, but this figure illustrates likely trends, including apparent Middle Pleistocene turnover on Corsardinia and Crete (the lack of temporal resolution in terms of these bioevents renders dates very approximate). The massive loss of endemism since the LGM is also evident.

although they do witness turnover both before and after this, including continental invasion followed by subsequent endemism around MIS 2 (29–14 kya). Crete and Corsardinia are the more complicated cases, with extinctions clustering in the Middle Pleistocene (probably) between MIS 15–9 (621–300 kya) followed by recolonization of continental fauna and subsequent appearance of endemic species. Such data highlight divergent Quaternary natural (and human) histories, but taken in aggregate can shed light on which of the various colonization scenarios seem most likely to have obtained in the remote Mediterranean islands.

#### *Probable Colonization Scenarios in the Lower Palaeolithic Mediterranean*

For the Balearics and Cyprus, the most probable colonization scenarios for the Lower Palaeolithic are no colonization (1) or 'Robinson Crusoe' events (2). The absence of palaeoenvironmental impact events associated with the appearance of breeding populations of hominin, combined with the absence of Middle Palaeolithic archaeological data for either, suggests that an absence of colonization is probable. Conceivably—and this is a problem likely to be common for all Mediterranean islands—a 'Robinson Crusoe' scenario could remain undetected at either end of the Mediterranean. In the central Mediterranean islands, the situation is a little less clear, but it is nonetheless the case that scenarios (1) or (2) are most probable, at least for the Lower Palaeolithic. The biogeographic disturbance at the LGM seems to be related to an influx of continental Sicilian fauna associated with increased proximity to the Sicilian-Italian landmass. It is not impossible that this could have involved modern humans, considering the Aurignacian presence in Sicily (Chilardi *et al.* 1996), although bears as large-bodied omnivores occupy apex positions in trophic systems comparable to those of hominins. Prior to the end of the Late Pleistocene, however, the data resist the possibility of hominin colonization.

In the case of Crete, there is the vague possibility that the Middle Pleistocene turnover (i.e., the transition from the *Kritimys* to *Mus* fauna) might correspond to the ecological signature of unsustainable colonization (scenario 3). The replacement of dwarfed endemic ungulates with mainland species could, conceivably, suggest ecological pressure exerted via increased predation, although this would implicate other taxa alongside *Homo*. The development of endemism (e.g., *Candiacervus*) in the *Mus* fauna, however, militates against any long-term establishment in the sense of sustainable colonization being probable; in this case (scenario 4) endemism would be expected to remain very low. The same conclusions can largely be drawn for Corsardinia. There is evident turnover in the Middle Pleistocene, but the subsequent re-emergence of endemism suggesting sustained colonization by a continental apex predator is unlikely.

The problem inherent with scenario (3) in this instance and elsewhere is its likely existence on the cusp of archaeological and palaeoenvironmental visibility (see Figure 5). This problem is exacerbated by the probable impacts of glacial cycles on island ecologies. It remains possible that glacial-interstadial transitions could have generated insular turnover, and it is interesting in this regard just how severe or mild glacial maxima and interstadials may have been prior to the Late Pleistocene. Such episodes would repeatedly stress fragile insular faunas which, on adapting to newly-established climatic regimes, would subsequently be stressed by the next glacial-interstadial transition. Either way, while something clearly caused the extinction of the *Kritimys* (Crete) and *Nesogoral* (Corsardinia) complex endemics, further work on attempting to correlate these events with either cyclical climatic stress, mainland invasions during glacial lowstands, or both, would be very desirable. Before such work is undertaken, the indications from the rest of the remote insular Mediterranean are that the Pleistocene basin was not an easily accessible or optimal environment for hominins. How to access and define

'Robinson Crusoe' events, lying on or below the threshold of detectability, will remain a challenge for island archaeologists globally.

### **Conclusions: Crossing Deep Water in Deep Time**

It is unlikely, based on the evidence for palaeoenvironmental dynamics, that there was sustained and deliberate colonization of the remote Mediterranean islands by archaic forms of *Homo* in the Lower Palaeolithic. Such colonization—as studies of the ecological and evolutionary dynamics of colonizing taxa suggest—would have had transformative ecological impacts for which there is little evidence. Specifically, trophic cascades and biotic turnover deriving from the introduction of a colonizing apex predator like *heidelbergensis* should be observable palaeontologically and palaeoenvironmentally. In contrast, on the Balearics, Cyprus, and the central Mediterranean islands (excepting Sicily and its satellites), there is strong evidence for the retention of biological endemism throughout the Pleistocene, militating against the likelihood of colonization on any noticeable scale.

Crete and Corsardinia complicate this picture slightly. Both witness biotic events in the Middle Pleistocene, although several factors inhibit associating this with the appearance of colonizing populations of *Homo*: the chronological resolution of these events is too gross to correlate them with archaeological data, which themselves lack radiometric dates. Turnover events may signal invasion processes by continental faunas, but this need not include *Homo* (although it conceivably could). And, finally, the repeated stressing of the glacial-interstadial cycle may be implicated in island-specific bio-events. In general, however, the palaeoenvironmental data that would signal large-scale and long-term colonization by an apex predator such as an archaic hominin are extremely thin.

This is not to conclude that archaic hominins did not arrive on Mediterranean islands.

Mammals, despite their low dispersal capacities, nonetheless can penetrate maritime boundaries. Considering the hundreds of millennia in which hominins have circumambulated the Mediterranean's shores, such chance dispersal is statistically quite likely, as is the chance dispersal of other familiar predators of Pleistocene Eurasia. The increased likelihood of these events—as distances between terrestrial niches become progressively smaller—may in part explain turnover events on Crete and Corsardinia, islands which, while not separated from the mainland by trivial distances during glacial maxima, have never been as remote as Cyprus. But in either case, such random events lack relevance in understanding the diversity of human dispersals around the planet (e.g., Broodbank 2013: 93–95), unless they result in scenarios like that witnessed in Flores—itself in one sense only a curiosity running contrary to general patterns in hominin expansions. It remains the case that our own species is the only apparent member of the genus *Homo* with the time and the inclination deliberately to aim for, arrive at, and survive upon remote islands. A Mediterranean awash with seagoing archaic hominins is, then, inherently unlikely.

This conclusion has implications for understanding hominin dispersal not only in the Mediterranean, but on a global scale. It is clear that anatomically modern humans have, since ~50 kya, possessed the cognitive and social apparatus to undertake deliberate, active colonization of distant landmasses. Conversely, there is little evidence that archaic forms of *Homo* behaved similarly. Central questions remain, not least as to whether *H. neanderthalensis* possessed similar behavioral capacities, and to what extent island colonization as a behavioral phenomenon is implicated in the ongoing discussion of behavioral modernity.

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Thomas Leppard received his PhD from the Joukowsky Institute for Archaeology and the Ancient World at Brown University in 2013, with a dissertation that addressed the relationship between spatial and social organization in colonizing communities in the Mediterranean and Caribbean. He has recently published articles on patterning in global island colonization (*Journal of Island and Coastal and Archaeology* 9: 1-15) and on Mediterranean Early Neolithic social organization and land-holding strategies (*World Archaeology* 46: 484-501). He continues fieldwork in the western Pacific, eastern Caribbean, and western Mediterranean.

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