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Global Patterns in Island Colonization during the Holocene

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Abstract

Analysis of the spatial and temporal structure of global island colonization allows us to frame the extent of insular human cultural diversity, model the impact of common environmental factors cross-culturally, and understand the contribution of island maritime societies to big historical processes. No such analysis has, however, been undertaken since the 1980s. In this paper we review and update global patterns in island colonization, synthesizing data from all the major island groups and theaters and undertaking quantitative and qualitative analysis of these data. We demonstrate the continued relevance of certain biogeographic and environmental factors in structuring how humans colonized islands during the Holocene. Our analysis also suggests the importance of other factors, some previously anticipated—such as culturally ingrained seafaring traditions and technological enhancement of dispersal capacity—but some not, such as the relationship between demographic growth and connectivity, differing trophic limitations impinging on colonizing farmers versus hunter-gatherer-foragers, and the constraining effects of latitude. We also connect colonization with continental dynamics: both the horizontal transmission of farming lifestyles earlier in the Holocene, and subsequent centrifugal processes associated with early state formation later in the Holocene.

Keywords Biogeography · Connectivity · Demography · Dispersal · Islands · Migration · Seafaring

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Introduction

Rising sea levels over the present century will submerge, render uninhabitable, or otherwise profoundly alter most of the world's islands, thereby terminating or drastically redirecting the dynamic and often distinctive histories of countless islanders and island societies. Most of this insular long-term history is accessible primarily through archaeology, allied to cognate fields among the social to environmental and biomolecular sciences. Despite manifest indications of deeper time Pleistocene island occupation, much of this island history also stands out as a Holocene phenomenon, closely associated with changes in insular geographies and environments after the last glacial maximum, and marked by a surge in the numbers and types of islands that have been peopled since then. Often, though far from always, this surge aligns with major shifts in food production, particularly various forms of farming, from agropastoralism to tropical horticulture, coupled with the affordances offered by new waterborne transport technologies. It is therefore a sharp irony that Holocene colonization of the planet's islands was enabled, in generic terms, by the kinds of innovations whose cumulative consequences now threaten the future viability of island life.

The dynamics of island societies over the course of this Holocene window of opportunity matter for three reasons (Broodbank, 2018). The first is intrinsic, for those primarily engaged in island-focused studies, and the other two extrinsic—whether in a comparative, behavioral sense (drawing equally on island anthropology and anthropological archaeology more generally) to shed light on broader social and political processes, or in terms of the contributions that islanders have made, not least through enhancing marine connectivity, to wider global patterns of interaction. Despite this evident importance, however, truly global and diachronic analysis of island societies across the Holocene remains surprisingly rare.

This paper concentrates on one enduring central issue in the archaeology of islands, namely the patterns and processes visible in the colonization (taken sensu lato to imply reasonably durable settlement by a viable population) of the world's islands over this timespan. Although there is far more to island life than merely getting there, colonization presents a crucial initial threshold, and a touchstone for numerous wider issues in insular social, geographical and environmental analysis. Moreover, island colonization is one insular phenomenon that has in fact been previously analysed at an explicitly comparative global scale, albeit some four decades ago, by Keegan and Diamond's trail-blazing 'Colonization of islands by humans: A biogeographical perspective' (1987). This landmark paper still provides an informative benchmark of empirical knowledge (although, as we shall see, much has been since discovered or clarified), and acts, equally, as an ongoing resource for interpretative inspiration and critical response, not least thanks to its deployment of models from the then recently-theorized field of island biogeography to inform an exploration of the structure of human colonization of islands. Unfortunately, however, while Keegan and Diamond's study has had an enduring impact, discussion of spatial and temporal patterning in island colonization at the global scale has hardly advanced since—indeed their 1987 paper proved to be not only the first global synthesis of its kind but also, to date, the last. Our principal aim is to revisit the global problematic that Keegan and Diamond first addressed, by updating the empirical picture with the results of some 35 years of additional research, and then asking how these patterns are best explained, within or outside the frameworks they adopted.

In terms of timeframe, we take our upper boundary as the beginning of the Holocene, though with acknowledgement where appropriate of the existence and sometimes crucial legacy of a prior Pleistocene insular presence, whether of other hominin species or later hunter-gatherer-forager/fisher (henceforth HGF) populations (recently summarized in Gaffney, 2021; see also Leppard & Runnels, 2017 for the wider contention surrounding Pleistocene maritime dispersals). As for the lower temporal boundary, the global extension of European voyaging from c. AD 1500, and its transformative (often severely deleterious) economic, political, and biological implications, provides a natural stopping point. The date ranges for the internal divisions of the Holocene employed here are Early (9700–6200 BC), Middle (6200–2200 BC) and Late (2200 BC onwards) (Walker et al., 2018, 2019).

Turning to what constitutes an island, it is axiomatic that all habitats are patchy and thus quasi-insular (Diamond, 1975; Simberloff & Abele, 1982), and equally that all landmasses are ultimately surrounded by water. The distinctiveness of islands is therefore more a question of degree than type, and no less sustainable for that (for example, the Americas and Kapingamarangi Atoll are both fragments of land surrounded by water, but the geometry and scale differ immensely, with the Americas seven and a half orders of magnitude larger and spanning just over 120 degrees of latitude). We concentrate here on marine (as opposed to lacustrine or riverine) locations, and adopt the reasonably robust convention that the term applies to sea-girt land, from the size of Greenland downwards, that required sea-crossings to reach at the relevant time—thereby embracing both continental and oceanic islands in the technical sense of their mode of genesis. We maintain this working definition regardless of whether the landmass was of a size to be perceived as an island by its inhabitants, and so include several ‘matchbox continents’, to employ Held’s (1989, p. 10) felicitous phrasing, as well as several thousands of smaller examples down to minimum thresholds for inhabitability, which themselves varied with island environment and islanders’ lifeways. Within this remit we strive for as comprehensive a coverage as is compatible with an overall synthesis, focusing both on major theaters of long acknowledged importance, such as the Mediterranean, Caribbean and Oceania (Near and Remote), but devoting equal attention to others whose archaeology of islands has more recently come into focus, notably Island Southeast Asia (ISEA), the Indian Ocean and North Atlantic, as well as the northern and eastern Pacific rims and Atlantic Africa. Excluded are those islands at circum-Arctic latitudes, whose peopling (if it occurred before c. AD 1500) involved ice- rather than sea-transits; several barely insular cases, typically closely interdigitated with indented continental margins (for example, islands off the Scandinavian and Chilean coasts, in the Red Sea and Persian Gulf (Khosrowzadeh et al., 2017), and the inshore satellites of Australia and other continents); and, of course, the remotest isolates in the southern Atlantic and Pacific, and sub-Antarctic generally, which were only discovered in the past few hundred years (for example, Kerguelen, the Falklands and Tristan da Cunha).

Admittedly, in certain regions rising post-glacial sea-levels rendered what constitutes an island (and likewise its size, and distance from mainlands or other islands) a dramatically moving target. Yet while modest eustatic fluctuations, alongside tectonics, isostatic rebound and coastal sediment deposition, continued to re-shape local to regional insular, and other coastal, configurations throughout the Holocene, global sea-levels had largely stabilized by around 4000 BC, and the rate of rise had been tailing off for the preceding two millennia. Therefore, the pragmatic relevance of the insularization of terminal Pleistocene and initial Holocene landmasses, as sea levels rose, is strongly dependent on the chronology of Holocene colonization in a specific island theater, and whether a Palaeolithic population was already in situ. Thus, to anticipate (and setting aside minor fluctuations), postglacial changes of these kinds will not emerge as a major issue for Holocene island colonization in the Caribbean, Remote Oceania, outer North Atlantic, and most of the Indian Ocean (probably barring Sri Lanka). On the other hand, it will be highly pertinent to initial Holocene dynamics in ISEA and Near Oceania, the Atlantic façade of northwest Europe, as well as (to a limited degree, thanks to generally steep coasts that delivered a quasi-modern insular geography relatively swiftly in the Holocene) the Mediterranean. In these latter instances, substantial site loss and the potential invisibility of coastal exploitation become associated challenges for our understanding. Last but not least, one well-known case of Pleistocene walk-on followed by Holocene insularization and population isolation needs to be addressed here, namely Tasmania and its island neighbors created by the sundering of the Bass Strait (Jones, 1995). Given the lack of subsequent incursions until the colonial era (in contrast, as we shall see, to other insularizing large islands with extant HGF populations), Tasmania remains outside the remit of this synthesis, albeit remarkable as testimony to long-term HGF endurance.

Our investigation proceeds initially by reviewing the archaeological evidence and spatio-temporal patterning for each island-rich theater, taken in approximately the chronological order of new colonizing activity within the Holocene, and aiming to establish both common and idiosyncratic regional dynamics. It then explores, via a series of analyses, the nature of the major drivers, commonalities, and differences that can be identified. Included among these, and building on Keegan and Diamond's lead, are a series of explorations of the role of island size, configuration and environment. These are then combined with an evaluation of rather different social and cultural factors, including extra-insular ones, such as enhanced dispersal abilities, mobility and the availability of maritime technology, and the demography, subsistence modes and political economies of nearby continental regions suitable as staging zones. First, though, it seems prudent to outline a few significant challenges to this ambition of new synthesis.

Challenges for a New Synthesis

The challenges confronting a new synthesis are considerable and varied. First and foremost, the data are now far richer than in 1987, thanks to the enormous amount of archaeology undertaken over the few past decades on islands worldwide. On the positive side, this offers scope to refine, and often substantially alter, our understanding of specific colonization histories. Yet equally, such investigations have been very unevenly distributed, in line with multiple regional priorities, without regard to any unified global agenda. Certain islands and island groups have received concentrated attention, whereas others remain comparatively poorly known; likewise the field and analytical approaches pursued, as well as the formats in which information is presented and interpreted, vary wildly. This unevenness largely precludes a strictly quantitative, multivariate approach to the world's islands and islanders *en masse* (at least without vastly more data-analyzing resource). Nonetheless, as we will demonstrate, reliable region-by-region synthesis, followed by global comparison and evaluation, remains an eminently feasible goal.

Particularly challenging in terms of their diverse evidential and reporting traditions are the chronometric data allied with differing regional terminologies. For example, in Remote Oceania the obtaining of radiometric assays is largely standard practice; conversely, in the Mediterranean, large-scale programs of ^{14}C and AMS ^{14}C dating are rarer, with highly variable quality of information. A recent study (Katsianis et al., 2020) estimated that 48% of published Greek dates lacked reported δ^{13}C values (crucial for assessing reservoir corrections of marine/freshwater samples and comparison with terrestrial chronologies). Within the Mediterranean, the norm is instead to date to broad cultural phases constructed from well-understood ceramic morphotypes (such as Early/Middle/Late Neolithic, Copper Age etc.)—reliable at a gross sub-millennial scale but making for low chronological resolution when identifying specific horizons of activity. Even within theaters, some putative colonization horizons remain contentious in terms of their chronology, such that it is inadequate to rely simply on reported dates, and alternative possibilities require evaluation within their broader contexts. For instance, in the case of the Mariana Islands (see further below) the currently most plausible initial horizon at c. 1200 BC is more readily explicable if we consider macro-scale dynamics for Remote Oceania as a whole (for example, Rieth & Athens, 2019; parenthetically, this study also demonstrates the power of Bayesian approaches in the context of rich and regionally coherent, rather than globally inclusive, datasets). Where radiocarbon dates are available in real quantity, and especially where refined by chronometric hygiene techniques and Bayesian modeling, one marked result has been to tighten the tempo of colonization processes. Examples, to which we shall return, include the new 'short chronologies' for much of Remote Oceania (Allen & Morrison, 2013; Wilmshurst et al., 2011), or recent models of long-distance colonization in the Caribbean (Fitzpatrick, 2006, 2013, 2015).

Our protocol with regard to chronometric, and specifically radiometric (primarily ^{14}C and AMS ^{14}C) dating, is as follows: in the interests of ready comparability for different regional specialists, we utilize BC/AD simply as the commonest scheme across the many island theaters we discuss; where possible we refer primarily to calendrical dates, rather than regional cultural phases. In general, our analysis is not conducted at a level of chronological granularity (usually only to centennial scales) sufficient to justify an extensive excursus on ^{14}C best practice; minor discrepancies in the data typically do not materially impact our attempts to elucidate patterning. Where the converse is true—for example, in Madagascar—we review the competing claims in greater detail. The exceptions are our occasional references to attempts to parse otherwise divergent or tightly clustered data respectively via chronometric hygiene or Bayesian-led approaches (for example, in the North Atlantic). Moreover, as our primary aim is to review and interpretatively synthesize, we do not present any new dates. For further details of previously published dates (laboratory number, calibration specifics, and so on), the reader is referred in each instance to the publication in question.

The next challenge concerns what interpretative inferences the data can sustain, and what kinds of processes they imply. Above, we offered a brief definition of island colonization for the purposes of this investigation. To a large extent, 'colonization' does indeed remain a reasonable, coherent gloss for a cluster of discrete behaviors involving enduring (if not necessarily eternal) establishment of permanent (i.e., not seasonal) settlement on a given island, and it has proven operationally useful at comparative scales (Braje et al., 2017). But as Cherry (1981, 1984) long ago pointed out, other forms of activity, including reconnaissance, resource acquisition, or seasonal visitation deserve serious consideration, both as island-exploiting activities in their own right and as regards how their archaeological signatures might be distinguished, in terms of visibility and relative to the residues of longer-term settlement. Additional indeterminacy is introduced by Dawson's (2014, pp. 42–68) emphasis on archaeological signatures of island abandonment, or ultimately 'failed' colonization. Overall, stratified and materially rich cultural deposits supported by robust absolute dates undoubtedly do provide the best evidence for human presence, and in principle, the more of these that exist, the stronger the inference that they represent colonization. Yet people impact environments along a variety of pathways, and islands are especially sensitive to these impacts, so that patterned environmental change, even in the absence of cultural deposits, may sometimes also be reasonably taken as indicative of human activity in some form (for example, Prebble & Wilmshurst, 2009; clearly, such change can also be non-anthropogenic, but when contemporary, or not, with independently identified initial cultural activity it usefully enables interpretative choices to be made, on the basis of parsimony, between competing dates for initial colonization horizons). Because our remit covers all global island theaters and a spectrum of subsistence behaviors, permanency itself is to an extent necessarily variably and contextually defined. This results in some cases where colonization is easier to appraise definitively (for example, Remote Oceania, or the North Atlantic), and others in which it is not so easily separated from more transitory processes—the exploitation of small islands in ISEA being one good example. Viewing colonization as a continuum of clustered human behaviors does not preclude relating and comparing those behaviors to one another, or trying to understand their causation and patterning; it simply suggests that a sensitivity to context should be borne in mind.

The final issue to highlight at this stage is how most fruitfully to draw upon, yet not be overly restricted by or confined to, the insights into human island colonization that derive from theoretical and applied island biogeography. The intellectual debt here is enormous, given island biogeography's role in providing an influential framework for interrogating and explaining structure in the human colonization of islands, both in Keegan and Diamond's global analysis (1987), and other parallel regional initiatives (Cherry, 1981, 1984 for the Mediterranean; Terrell, 1976, 1977 for the Pacific). Since the pioneering work of MacArthur and Wilson (1967) on the effects of an island's size and distance on the range of taxa dispersing to and surviving there, island biogeography has of course itself evolved, generating increasingly rich insights into animal and plant dispersals to islands, and how species alter after arrival, including faunal 'island syndromes' (such as changes in body size, behavioral or ecological naïveté, or subsequent loss of dispersal capacity) and equivalent responses in island flora (Losos & Ricklefs, 2009, 2010; Triantis et al., 2016; Valente et al., 2017, 2020; Warren et al., 2014; Whittaker et al., 2017). Beyond island archaeology, these insights and agendas have unsurprisingly also encouraged strong convergences with population ecology and conservation biology.

Many of these insights were emergent at the time when Keegan and Diamond were developing the ideas contained in their 1987 paper. Thus, they explored not just primary biogeographic considerations (islands' raw geometric properties and their implications for environmental heterogeneity) as influences on islanders' colonization dates and sequences, but also the subtler secondary ways in which insularity might promote predictable structure in human (as in other biotas') colonizing behavior: accidental versus purposeful dispersal, ecological competition, niche shifts, and demographic bottlenecks. As already apparent during the 1980s, and ever since, such biogeographical perspectives certainly do provide some compelling, thought-provoking explanatory frameworks for *part* of the patterning observed in the colonization of islands by people. Within these explanatory frameworks, arguably the main challenge that remains today is to evaluate the relative importance of each insular factor (or combination of factors) in accounting for the observed patterning. For example, and again to anticipate slightly, what was the relative importance of configurational effects versus demographic competition in explaining certain key features of Remote Oceanic settlement, such as its rapidity, or the existence of the 'Polynesian outliers'?

Equally—as explicitly recognized by Keegan and Diamond (1987, pp. 80–83)—there remains a lot of general 'noise' in the relationship between biogeographically-derived expectations and the observed pattern of island peopling that can only to a degree (now sharply decreasing) be blamed on poor data. Likewise, important unanswered questions relate to the broader absolute timings and contexts of such processes. These two considerations prompt the crucial question as to what specifically human attributes were equally fundamental to generating regional and global patterns. Intriguingly, one of the most attractive models developed by Keegan and Diamond is that of 'autocatalysis', by which favorable coastal and archipelagic configurations (such as easily accessible and rewarding islands, trending seaward to ever more distant and/or challenging ones) enabled cumulatively reinforced learning among islanders, encouraging their onward exploration and stimulating colonizing sequences far beyond that which the spatial metrics might have predicted—a feedback process dependent on the cognitive abilities and behavioral plasticity of our own species. Further to this point, a range of additional, specifically cultural factors can readily be identified that are likely to have profoundly shaped the timing and ways in which people colonized islands, including subsistence modes and social dynamics in mainland staging areas and the islands themselves, seafaring technology and other navigational skills, and the degree of investment in maritime voyaging and networking by coastal societies along the continental rims of island-studded seas. Any truly comprehensive understanding will therefore need to embrace both island biogeographical and cultural frameworks as complementary and mutually constitutive. It will also have to relate insular patterning to trajectories beyond the world of islands. We can now turn to the first of our regional theaters, and the one evincing the earliest specifically Holocene developments in island life.

The Mediterranean

The Mediterranean Sea is a moderately-sized middle latitude embayment of the Atlantic. Sandwiched between 30 and 45 degrees north, it experiences warm, dry summers and mild, wet winters, shaped by its position on a western continental seaboard (Rick et al., 2020). Its islands, most of which cluster along its northern flank, are in global terms relatively close to the mainland and to each other, and include five outsized islands of between 8000 and 25,000 sq. km, along with a multitude of much smaller examples (Fig. 1). Extensive continental shelves entailed larger littoral exposure during glacial periods, but the vast majority had been eliminated or sharply reduced, save occasionally locally, by the start of the Holocene.

The overall pattern of Holocene island colonization, as initially defined by Cherry (1981, 1984, 1990) and recently reaffirmed in its essentials (Dawson, 2014), is well understood. This process begins relatively early in global terms, and appears

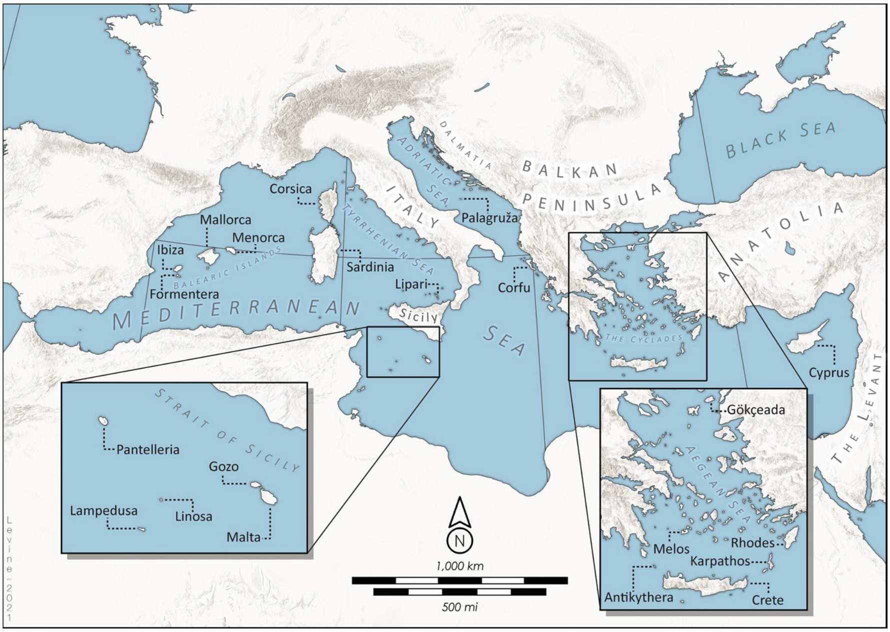


Fig. 1 The Mediterranean: toponyms mentioned in the text

to have been effected, until the late third millennium BC, entirely by paddled craft (Broodbank, 2010). Prior to this Holocene expansion, the extent, temporal depth, and drivers of some undoubted level of antecedent Pleistocene activity are contentious (Broodbank, 2013, pp. 82–137; Leppard & Runnels, 2017), though the exploitation of obsidian from the island of Melos by the terminal Pleistocene remains rightly emblematic of early seafaring (Renfrew & Aspinall, 1990). There is richer and better-understood evidence for Early Holocene HGF island activity, which is cumulatively indicative of growing maritime exploration and knowledge networks, and sometimes clearly involved experiments in longer-term island living through the exploitation of local insular (including obsidian) and marine resources. Much of this is concentrated on the largest islands (Mesolithic on Sardinia, Corsica, Sicily and Crete, plus a slightly earlier local Epipalaeolithic at the Pleistocene–Holocene transition on Cyprus), as well as a handful of smaller islands, the latter perhaps more indicative of seasonal exploitation (Broodbank, 2006; Cherry & Leppard, 2018a; Plekhov et al., 2021). Yet the striking lack of secure transitional stratigraphic sequences between such late HGF and subsequent Neolithic agropastoral contexts suggests that HGF communities, while interesting in their own right and assuredly contributory to the dissemination of maritime and insular knowledge to later island settlers, had little impact on the ancestry or structure of subsequent colonization processes involving farmers (as we shall see, arguably unlike the situation in ISEA and the Caribbean).

Early to Middle Holocene Agropastoral Colonization

Early Holocene agropastoral settlement of the insular Mediterranean was essentially contemporary with the full realization of Neolithic lifeways in the Levantine core of the Southwest Asian Neolithic and its expansion westward. Cyprus, closest to such Pre-Pottery Neolithic (PPN) communities, was settled first, at around 9000 BC, possibly capitalizing on prior Levantine HGF experience of the island (Knapp, 2010). This early spur out into the Mediterranean represented a cul-de-sac, however, as subsequent island colonization further west only began two or more millennia later, and was initially closely associated with the arrival of Neolithic lifestyles in the Aegean littoral. Radiocarbon dates from the basal stratum at Knossos (still the earliest known Neolithic community on Crete) suggest first settlement at around the same time as at western Anatolian sites such as Ulucak and the arrival of farming in mainland Greece (Brami, 2015; Douka et al., 2017), between 7000 and 6500 BC. This contemporaneity, and discontinuities in cultural sequences at sites with both Mesolithic and Neolithic deposits (for example, Munro & Stiner, 2015), support the likelihood that Aegean farming spread primarily through targeted demographic movements, often partly maritime in nature, from Anatolia (despite continued reservations in some quarters: Sampson, 2018). Yet, aside from Crete and Gökçeada (Atici et al., 2017)—the former the fifth largest Mediterranean island, and the latter only c.10 km from the mainland—the first Aegean farmers were apparently largely uninterested in island living, despite knowledge inherited from HGF exploration and their ongoing exploitation of insular resources such as obsidian (Çilingiroğlu & Çakırlar, 2013).

An initial preference for large islands, and/or those readily accessible from mainlands, continued as agropastoralism expanded westwards during the Middle Holocene. Sicily, Sardinia, and Corsica all have evidence for farming settlement by 6000–5700 BC (Freund et al., 2015; Luglié, 2017), with minimal evidence for cultural, technological, or genetic overlap with antecedent HGF populations (Marcus et al., 2019). Accordingly, between c. 9000 and 5700 BC, the 'big five' Mediterranean islands had all been permanently settled by agropastoral communities. These communities manifestly had knowledge of, and the capacity to reach, smaller islands, even those further from the mainland, as extensive early Neolithic use of desirable obsidians from Melos and Lipari testifies. Yet at this stage smaller islands were rarely if ever desirable as targets for settlement, save for a few so close to the mainland (or to quasi-peninsular islands such as Sicily) that proximity dampened any disadvantages of smaller size (for example, certain Dalmatian and other Adriatic islands, plus Corfu). The salient exception is the Maltese archipelago, which appears to have been reached by the mid sixth millennium (Malone et al., 2019; Robb, 2001), although, as we discuss below, more substantive suites of ^{14}C dates may indicate that this was not an ultimately successful venture. Tiny mid-Adriatic Palagruža, with a few sherds of Early Neolithic Impressed pottery (again, broadly sixth millennium BC), can be thought of as a waystation linking the Balkans to the southern Italian Neolithic farming hub of the Tavoliere, rather than permanently settled (Forenbaher & Kaiser, 2011).

Middle to Late Holocene Agropastoral Colonization

The first widespread horizon of agropastoral life on the smaller, drier, and more remote islands of the Mediterranean dates most convincingly to the fifth millennium BC, both in the Aegean and the small archipelagoes that orbit Sicily. In the Aegean, this millennium witnesses the appearance of farming villages in the Cyclades, situated to take advantage of local sweet spots (Broodbank, 2000, pp. 117–49). Further west, the radiometric and ceramic-derived dates are less secure. In particular, the presence of 'Stentinello' wares (essentially local variations on an Impressed theme), which on Sicily can date as early as the mid sixth millennium, has traditionally been understood to indicate similarly dated settlement on the small Tyrrhenian islands (for example, Mannino, 1998). A recent analysis, however, provides Stentinello with a broader chronology of 5600–4000 BC (Freund et al., 2015, p. 208), overlapping with dates on Lipari attributed to the later 'Diana' horizon (Dawson, 2014, table 4.7). Evidently, a broader robust program of redating is in order. Notwithstanding a possible radiocarbon hiatus that hints at discontinuities in the colonization cycles of Malta and Gozo (Malone et al., 2019), the overall period 5000–4000 BC was one clearly of expanding insular horizons in the central Mediterranean.

The fourth and third millennia BC witness the final, most extensive expansion of settlement in the insular Mediterranean. This process involved an infilling of the last remaining gaps in the Aegean, related to a diversification in settlement types:

the appearance of small-scale ‘farmsteads’ beyond the environs of larger village sites (Halstead, 2008), while the latter evolved to make new claims (in often new locations) over maritime knowledge and practices (Broodbank, 2000, pp. 211–319). Further west, the high tide of this expansion of island lifeways is witnessed by increasingly convincing evidence for permanent occupation (rather than sporadic exploitation) in the smallest Tyrrhenian islands and the relatively remote islands in the Strait of Sicily—Pantelleria, Lampedusa, and Linosa, as well as various other in-shore islets along the north- and southwestern Mediterranean littoral. The data from Pantelleria are equivocal, and permanent settlement may only, in the final analysis, prove to be a second-millennium phenomenon (Ardesia et al., 2006); but there was clearly a much earlier exploitation of the island’s obsidian, possibly mediated by maritime North African groups as well as people from the more usually assumed northern side of the Sicilian strait (Broodbank & Lucarini, 2019, pp. 221–23).

The only wrinkle in this otherwise fairly smooth pattern comes from the Balearics (Mallorca, Menorca, Ibiza, and Formentera), all relatively remote islands in the extreme west of the Mediterranean, but the first two of substantial size. The dates are contested, but the bulk of the evidence most plausibly suggests a colonization of the Gymnesics (the two larger islands) in the late third millennium BC, and of the Pityusics (smaller Ibiza and Formentera) over the course of the second or even first millennium BC (Alcover, 2008; Cherry & Leppard, 2018b; Ramis et al., 2002), within the regional Copper and Bronze Ages respectively. This interpretation may of course change, and palaeoenvironmental data do hint at earlier Middle Holocene biotic disturbance, which need not, however, be anthropogenic (Burjachs et al., 2017). In any case, the relatively late colonization of the Balearics presents an exception to Mediterranean patterning that still requires explanation.

Although the vast majority of Mediterranean islands were colonized by the beginning of the Late Holocene, and the terminal third millennium BC in that sense represents a natural stopping point for our discussion, it is important to note that the subsequent second millennium BC witnessed a prodigious shift in inter-island Mediterranean dynamics, and that further cycles of island abandonment and resurgent settlement extended longer still, with turnovers at the thresholds to and from the Classical and Roman world (earlier first millennium BC and later first millennium AD). Although the vast majority of initial insular colonizing activity had occurred well before the appearance of sailing vessels, first reliably evidenced in the East Mediterranean (probably deriving from a Nilotic tradition) around 2500–2000 BC (Broodbank, 2010), the expansion of this distance-shrinking technology integrated islands and transformed trans-basin relationships (Broodbank, 2013; Leppard et al., 2021), not least as the first Mediterranean urban societies conducted many of their interactions by sea. The establishment of the current, semi-arid Mediterranean climate regime during the Late Holocene may also have played a role in these transformations and in the periodic evidence for island abandonment, as small, dry islands were rendered more environmentally marginal, as well as easier to by-pass by increasingly long-range shipping technologies.

Summary: The Mediterranean

Inhabitants of the Mediterranean littoral were adept at reaching its islands from at least the terminal Pleistocene and sometimes rather earlier (Broodbank, 2006). Their millennia-long, widespread Early Holocene reluctance to do so for purposes of settlement provides suggestive evidence concerning the factors driving and constraining island colonization. The initial preference for big islands, or islands extremely proximate to continental coast, has long been noted, and interpreted explicitly in biogeographic terms (Cherry, 1981, 1984), and a biogeographic model remains a powerful predictor of early versus late colonization (Plekhov et al., 2021). However, recognizing the palpable ability to traverse substantial sea-gaps, this preference may relate less to raw island geometry, and more to the fact that the 'big five' islands possess many of the features that attracted early agropastoral interest in continental environmental niches too, such as abundant workable soils and relatively reliable orographically-derived hydrologies. Big islands were, in essence, analogous to mainlands and better suited to the 'mixed' agropastoralism of the first farmers; smaller, drier, rockier islands less so. It is notable that the expansion into smaller islands in the Aegean and central Mediterranean peaks around 4000–2000 BC, a period when Mediterranean-wide settlement was expanding into less advantageous niches (Halstead, 2008), contemporary with drying climatic conditions increasingly approximating those of the Mediterranean today, as well as the first flashes of pronounced social inequalities across the basin (it would not be surprising if these macro-scale changes were related). Accordingly, the outline of Mediterranean island colonization may be seen less as a function of constraining distance (in a context where crossings tended to be modest, rarely more than 25–50 km or one to two days even in paddled canoes), and more as emergent from demographic and other drivers working in tandem. In other words, small islands tended to be unattractive prospects for effectively obligate Mediterranean agropastoral populations, unless something radical happened to alter the calculus of moving versus staying (Plekhov et al., 2021; cf. Cherry & Leppard, 2018a)—a theme that will prove recurrent. Such a focus on 'push' factors operating on continental fringes, and less on the intrinsic appeal of island lifestyles, may likewise best account for the apparent lateness of Balearic colonization, broadly within the timespan of Late Holocene aridification.

There are other exceptions, of course, and lessons from these. Malta is remote and dry, and yet was colonized early. Big Karpathos, and bigger Rhodes, were seemingly initially bypassed *en route* to Crete. These disparate examples hint at the role of strategic planning, reconnaissance, and possible inheritance of earlier HGF knowledge in establishing over-the-horizon destinations. Sub-regional patterns in Mediterranean island colonization also suggest the relevance of modest autocatalysis (as defined above; Broodbank, 2000, 2006), and a self-reinforcing tradition of seagoing, discovery, and settlement clearly has a role to play in accounting for faster or slower colonization sequences and the settlement dates of some of the Mediterranean's remoter outliers, as it does in the Pacific and possibly the North Atlantic.

The Caribbean

The Caribbean Sea and Gulf of Mexico together represent a conjoined low-latitude Atlantic embayment, the former comparable in size to the Mediterranean, partly enclosed by Florida and South and Central America, and lying between 10 and 30 degrees north (Fig. 2). The prevailing climate is subtropical to tropical, with consequent exposure to cyclonic activity. Geotectonically, the Caribbean Islands, which (like the Mediterranean) comprise a small number of giants juxtaposed with an abundance of far smaller islands, derive from interactions between the Caribbean and North and South American plates. As a result, they form a crescent around a sea essentially devoid of interior islands, but with comparatively easy access to and from nearby parts of Central, South and North America—although, as will be seen, directionality in human colonization has not necessarily always corresponded neatly with geographic configuration. The peopling of these islands within our timeframe was effected entirely by paddled vessels, with no evidence for use of the sail in the pre-contact Caribbean.

In this theater there is no Pleistocene precursor, in large part due to the much younger peopling of the Americas (contrast, however, the earlier Holocene evidence, below, from North America's Pacific coast islands). Island colonization in the Caribbean comprised three independent, chronologically widely separated

Fig. 2 The Caribbean: toponyms mentioned in the text

processes, the first two involving (initially) HGF groups. The first is an uncontroversial colonization of Trinidad from northeastern South America, c. 6000 BC (for example, Boomert, 2000; Pagán Jiménez et al., 2015; Tankersley et al., 2018). The second is a more extensive expansion to the Greater (c. 5000–4000 BC) and subsequently Lesser Antilles (Napolitano et al., 2019). Although various routes have been proposed (for example, Callaghan, 2003; Wilson et al., 1998), a consensus is emerging that only multiple and complex migration processes from several origin points can account for this second process (Keegan & Hofman, 2017; Rodríguez Ramos, 2013). This early occupation has traditionally been termed a Lithic Age (alternatively Casimiroid) in the Greater Antilles and an Archaic Age (or Ortoiroid) in Trinidad and the Lesser Antilles (Keegan, 1994; Rouse, 1992). However, these distinctions are no longer supported by archaeological evidence (Keegan & Hofman, 2017), and we therefore refer to all the earliest phases of occupation in the Caribbean as 'Archaic' for lack of a better term (Hofman & Antczak, 2019). The third colonization horizon, in which horticulturalist groups are at least partly implicated, occurred from c. 400 BC, during the traditionally termed Ceramic Age.

Middle to Late Holocene Archaic Colonization

That the earliest dates for a human presence on the Caribbean islands come from Trinidad (c. 6000 BC) is unsurprising in biogeographic terms given its size and proximity to mainland South America (Boomert, 2000); contemporary sea-levels suggest a much shorter crossing and even a vestigial physical connection is conceivable. The other islands in the Southern Caribbean, running parallel to the South American coast, are smaller and more distant (c. 25–150 km) from the mainland, and were settled much later than Trinidad. Within this southern archipelago, there does seem to be a relationship between colonization date and island size. The larger island of Margarita has the earliest dates (c. 5000 BC) beyond Trinidad and the mid-sized islands of Aruba, Curaçao, Cubagua, and Tobago have considerably later dates (c. 3200–2400 BC), while several of the smallest and/or most remote islands were only ever seasonally occupied, or fully settled much later, or indeed never colonized at all (Hofman & Antczak, 2019).

Turning to the Greater Antilles, the earliest radiocarbon dates are also Middle Holocene and derive from Cuba, Hispaniola, and Puerto Rico (Cooper, 2010; Fernandes et al., 2020; Naegele et al., 2020; Napolitano et al., 2019; Rodríguez Ramos, 2010; Ulloa Hung & Valcárcel Rojas, 2013). The approximate date ranges for the initial colonizations of these three islands are broadly comparable (c. 4200–3200 BC), and consistent with an initial colonization of Cuba followed by Hispaniola and Puerto Rico, so plausibly from west to east. This sequence corresponds to biogeographic expectations, assuming a direct crossing from the Central American mainland first to Cuba (the largest island) and then following the islands' configuration to Hispaniola (second largest) followed by Puerto Rico, although the scarcity of archaeological sites from this period means that the chronology is subject to debate (Ulloa Hung & Valcárcel Rojas, 2013). Current evidence indicates a strikingly later colonization (c. AD 550–950) for Jamaica (Allsworth-Jones, 2008; Callaghan, 2008), although several factors may have obscured earlier evidence (Keegan & Hofman, 2017); the likely origin points are neighboring Cuba and/or Hispaniola. In this regard, Jamaica displays similarities with the Bahamian archipelago, which also seems to have been initially peopled by colonists from both Cuba and Hispaniola in the region's Late Ceramic Age (c. AD 700–1100) (Berman & Gnivecki, 1995; Keegan et al., 2008).

The earliest dates for the Lesser Antilles cluster on several Leeward Islands, notably Antigua, Saba and St Martin (c. 3500–2500 BC), and indicate a later Middle Holocene Archaic colonization (although Napolitano et al. [2019] would down-date this horizon). Ostensibly, this might represent an eastward extension of the aforementioned Greater Antillean processes ultimately originating in Central America (Hofman & Antczak, 2019). However, somewhat later dates for initial colonization of most of the other Leeward Islands (c. 2800–1000 BC) and several of the Virgin Islands (c. 2200–1100 BC) complicate this model. This may suggest that multiple islands were bypassed in such a first peopling of the northeastern Caribbean (Fitzpatrick, 2013; Hofman & Antczak, 2019; Napolitano et al., 2019), with various islands along the way simply visited but not initially settled, leaving little detectable trace (Bérard et al., 2016). Alternative or complementary explanations for the colonization of the Lesser Antilles advocate a separate process originating in South America, either involving a direct open-ocean crossing from the mainland to the Leeward Islands (Callaghan, 2010; Rodríguez Ramos, 2010), or a stepping stone colonization via the intervening Windwards. Regarding this last option, there is admittedly scant archaeological evidence for comparably early activity in the Windward Islands (excepting Tobago [Boomert, 2000] and Barbados [Fitzpatrick, 2011]), and for several islands the earliest dates remain Ceramic Age (Callaghan, 2010; Fitzpatrick, 2013; Giovas & Fitzpatrick, 2014; Napolitano et al., 2019), thus prompting the possibility of their colonization north-to-south from the Leewards (the 'Southward Route Hypothesis': Fitzpatrick, 2013). However, recent multi-island palaeoenvironmental projects provide new evidence to suggest that the initial colonization of the Windwards may have occurred earlier than previously recognized (Siegel et al., 2015, 2018). In some cases (for example, Grenada, Martinique, Marie-Galante) the first dates for landscape modification at c. 3500–3000 BC pre-date the earliest dates from archaeological sites by several thousand years, and may therefore provide support for a south-to-north stepping-stone expansion, with origins in South America (Siegel et al., 2018). In this model, taphonomic and other post-depositional processes are assumed to have destroyed or obscured the archaeological evidence of earliest settlement in the Windwards, contributing, alongside a lack of systematic surveys, coring, and palaeoenvironmental reconstruction, to the problems that bedevil much reconstruction of dynamics across the eastern Caribbean (Hofman & Hoogland, 2018). Clearly, the 'Southward Route Hypothesis' (Fitzpatrick, 2013; Napolitano et al., 2019) and the model proposed by Siegel et al. (2018) are to a large degree mutually exclusive, and this problem requires resolution (complicated further by the impact on radiocarbon assays of high levels of environmental variability: DiNapoli et al., 2021).

Late Holocene Ceramic Age Colonization

The Early Ceramic Age (c. 400 BC to AD 600/800) colonization of the Caribbean differed in several important respects from previous Archaic processes. It is generally agreed that these so-called 'Saladoid' migrations originated from northeastern South America and represent an expansion of Arawakan peoples (Bérard, 2013; Fernandes et al., 2020; Heckenberger, 2013; Rouse, 1992). The current earliest dates for Early Ceramic sites derive, however, from Puerto Rico and the northern Leeward Islands, a situation with strong parallels in the apparent pattern and subsequent distribution of Archaic colonizing populations (Napolitano et al., 2019). This may reflect: (1) direct voyaging from the mainland and/or Trinidad, bypassing the intervening Windwards (Callaghan, 2010; Rodríguez Ramos, 2010); and/or (2) interactions between extant Archaic populations and incoming groups (Hofman et al., 2018; Rodríguez Ramos et al., 2008). In any case, because most Early Ceramic Age sites cluster in the northeastern Caribbean, this colonization process does not correspond closely with biogeographic expectations. That apart, throughout the Early Ceramic Age there is clear evidence for population growth and settlement expansion (Curet, 2005; Rouse, 1992). This general pattern continues into the Late Ceramic Age (c. AD 600/800–1500), during which nearly all the previously unsettled islands were finally occupied, including many of the relatively small members of the Virgin Islands and the Grenadines (Giovas & Fitzpatrick, 2014; Hofman & Hoogland, 2018; Keegan et al., 2008), in addition to Jamaica and the Bahamas.

Summary: The Caribbean

Archaeological and palaeoenvironmental research in the Caribbean over recent decades has generated new data and complicated an already complex suite of processes (Hofman & Antczak, 2019; Napolitano et al., 2019; Reid, 2018; Siegel, 2018). However, at large spatial scales the initial colonization of the Caribbean islands corresponds broadly with the general principles of island biogeography, with sensitivity to the combined variables of area, distance, and configuration. This is exemplified by the first occupation of the larger islands: Trinidad in the far south and three of the four main islands of the Greater Antilles. There are, however, substantial exceptions, and clear differences between biogeographic expectations and the attested colonization of the Caribbean islands as the process later expanded indicate that such factors alone cannot wholly explain the observed patterns. Specific examples are the relatively late colonization of Jamaica and the Bahamas, and the early colonization of several small and distant islands in the northeastern Caribbean, on some models substantially pre-dating the colonization of many intermediate and more substantial islands. One possibility is that the northeastern region was selectively targeted, owing to the specific availability of high-quality lithic and subsistence resources, following on from prior exploration and (is)landscape learning (Hofman et al., 2018; Rodríguez Ramos, 2013). Based on the currently available evidence, the patterns of Ceramic Age colonization are even less consistent with biogeographical factors and appear not to follow a stepping-stone model, with the earliest archaeological dates recorded in Puerto Rico and the northern Lesser Antilles, roughly in the middle of the island chain, and the latest dates occurring nearer the ends of the archipelagoes closest to mainland areas (with the exception of Trinidad). It seems quite plausible that the presence of extant populations, their impacts on island landscapes at multiple scales, and interactions between earlier and later colonists influenced these subsequent colonization processes, alongside other demographic, environmental, social or even cosmological factors (Fitzpatrick, 2015; Hofman et al., 2006, 2011; Rodríguez Ramos, 2010). We address below the intrinsic attractiveness of extant populations (i.e., so-called Allee [1931] effects).

One aspect of island colonization dynamics raised by Keegan and Diamond (1987), to which we return in a more comparative vein in the second half of this paper, especially merits discussion in a Caribbean context, namely the importance of beachhead bottlenecks and of demographic constraints more broadly. 'Beachhead bottleneck' refers to the risk of demographic failure when a small population first colonizes an uninhabited landmass (Keegan & Diamond, 1987; MacArthur & Wilson, 1967), and several scholars have emphasized that continued mobility and maintaining contacts with home communities mitigates this risk, which is potentially amplified by predominantly linear Caribbean geography (Keegan, 1994; Kirch, 1988; Leppard, 2015; Moore, 2001). Apparent high rates of mobility in the Caribbean may reflect such mitigating strategies (Hofman & Hoogland, 2011; Hofman et al., 2011; Rodríguez Ramos, 2010). Strontium isotope analysis of Ceramic Age populations now provides definitive evidence for sustained translocations, including inter-island and mainland–island (Laffoon, 2013), while chronological analysis of the inferred mobility patterns indicates an overall decrease in rates of migration through the Ceramic Age, as expected based on models of demographic growth (Laffoon & Leppard, 2018).

Island Southeast Asia and Near Oceania

Island Southeast Asia (ISEA) and Near Oceania lie between 15 degrees south and 20 degrees north (Fig. 3). They include exceptionally large tropical and subtropical islands lying on the Sunda and Sahul continental shelves (Sumatra, Java, Borneo, and New Guinea), as well as Taiwan and the Philippines to the north. These major islands are surrounded by thousands of smaller islands lying both on the continental shelves and at intervening plate boundaries, many comprising the biogeographically interstitial area of Wallacea. Variable size and topography have implications for the number of ecotones suitable for settlement. For instance, Borneo and New Guinea contain lowland tropical rainforests, savannah, sago palm swamps, high altitude cloud forests, and mountains rising to over 4000 m, while smaller islands and reefs boast much less variation. A further factor that heavily influenced Holocene colonization patterns is the pre-existence of long-established and often enduring HGF populations of Pleistocene origin, for much of this region (which also served as the gateway to Australia) has a deep history of human and earlier hominin insular presence that is unrivalled, in terms of breadth and quality of evidence, by any other island theater (Gaffney, 2021).

Fig. 3 Island Southeast Asia, Near Oceania, and the eastern Indian Ocean: toponyms mentioned in the text

Early to Middle Holocene Settlement

The presence of pre-established HGF populations rendered Holocene island occupation dynamics in this theater unusual in global terms. As seas rose during and after the terminal Pleistocene, extant HGF groups on newly formed islands on the Sunda Shelf (such as Borneo, Java, and Sumatra) increasingly specialized in hunting and gathering resources from rainforests and swamps, habitats that expanded with climatic amelioration (Amano et al., 2016; Rabett et al., 2013). Equivalent persistence of occupation is observed in New Guinea (Roberts et al., 2017). Early to Middle Holocene people in the Philippines, which had remained insular throughout the Pleistocene, responded to similar environmental changes by hunting tropical forest species (Lewis et al., 2008), and continued to practice open sea fishing (Pawlik, 2021). Local forms of agroforestry and cultivation developed across the region, in the case of New Guinea arguably eventually creating an epicenter of indigenous horticultural expansion westward into other islands (Denham, 2018a). Smaller islands, whether shrinking or newly forming as sea-level rose (Williams et al., 2018), were either abandoned in the Early to Middle Holocene (O'Connor, 1992; Shaw et al., 2020), or formed refugia for various biota, including people, who increasingly pursued littoral lifeways (Veth et al., 2017). Higher levels of maritime mobility and exchange over this timespan may have been prompted by the flooding of large tracts of continental shelf (Soares et al., 2008), the greater productivity of warming seas

(Pawlik et al., 2014), and the technological innovation of dugout canoes made with shell adzes (Fredericksen et al., 1993; Shipton et al., 2020). Viewed synoptically, overlapping maritime interaction spheres appear to have emerged at this time around Wallacea (Shipton et al., 2020) and in the Bismarck Archipelago (Summerhayes, 2007).

Late Holocene Settlement

As established, all the large continental islands in ISEA and Near Oceania were already occupied by the Early–Middle Holocene. However, from c. 3500 BC in Taiwan, and c. 2200 BC further south into ISEA proper, ways of life underwent large-scale changes that suggest population mobility and arguably often the arrival of new populations. The most obvious novel characteristics are pottery-making technologies and a degree of reliance on domesticated taxa. Given a parallel step-change in maritime crossing distances across ISEA and Near Oceania, it is widely assumed (though so far not directly substantiated) that this is also associated with new canoe technologies utilizing sails and potentially outriggers, whether developed locally or slightly earlier in the broader East Asian sphere. Populations with these characteristics rapidly colonized smaller islands. Examples include the Batanes Islands in the Philippines, Kayoa and the Banda Islands in Indonesia, along with the Duke of York Islands, and the Arawe, Siassi, Anir, and St Matthias groups in the Bismarcks, as well as New Georgia in the Solomons. These groups also settled the coastal fringes of larger islands; the coastal zones and river valleys of islands such as Luzon, Borneo, and Sumatra experienced colonization in the form of village settlements, often alongside the gradual replacement of HGF communities (Matsumura et al., 2018). These new groups brought with them domesticated animals (Piper et al., 2009) alongside pottery technology in the form of red-slipped earthenware, occasionally with incised, impressed, and dentate-stamped motifs (Carson et al., 2013); they also practiced fishing, arboriculture, and root-crop horticulture (although rice agriculture was probably introduced after these initial dispersals [Alam et al., 2021; Gutaker et al., 2020]). Eastwards, into Near Oceania, initial colonization by the first pottery-producing groups is associated with distinctive dentate-stamped Lapita pottery, first evident in the St Matthias Group (Kirch, 2021), and later moving into the rest of the Bismarck Archipelago between about 1600 and 1300 BC (Rieth & Athens, 2019). Lapita groups, like those in ISEA, targeted islands that were usually small relative to adjacent continental islands, and near key resources (Lepofsky, 1988). Near Oceanic Lapita settlements were densely packed, varied in size between 500 and 80,000 m^2 (Specht, 2007), and were situated on dunes or lagoon margins, in some cases apparently with stilt houses built over the water (Summerhayes et al., 2019).

As suggested above, this Late Holocene patterning in ISEA and Near Oceanic island occupation involved complex migration flows, also well attested via historical linguistics (Gray & Jordan, 2000) and genetics (McColl et al., 2018)—although their routes and nature, and the finer correlations with linguistic, material culture, and subsistence changes, continue to be debated. The 'Out-of-Taiwan' model, arguably the most parsimonious option (purporting to account for correlations in linguistic, genetic, and archaeological evidence) posits mobile, pottery-making communities associated with the Austronesian languages migrating through the region, from Taiwan and (from c. 2200 BC) first to the Philippines and then Indonesia, New Guinea, the Bismarcks, Solomons, and ultimately Remote Oceania (Bellwood, 2017). In contrast, others argue for a broader sphere of inception and interaction around ISEA, wherein correlations in language, technology, and genetics along a west-to-east cline reflect diffusions through extant social networks (Denham, 2018b). The most recent analysis (Cochrane et al., 2021), utilizing a Bayesian framework to assess geographic and chronological patterning in the initial appearance of pottery, suggests that the earliest pottery-bearing deposits in ISEA beyond Taiwan may occur in western Borneo and the northern Philippines. This discrete geography lends support to the suggestion that processes of biological, linguistic, and material-culture change within western ISEA during the Middle and initial Late Holocene may have been more complex, and less linear and neatly correlated, than is often supposed (a conclusion partly supported by recent genetic work; for example, Choin et al., 2021; Larena et al., 2021).

Small reef islands in Near Oceania were colonized substantially after the Lapita horizon, from around two millennia ago. These islands formed more recently through the Late Holocene and represent precarious environments at the margins of horticultural sustainability (McNiven, 2015), although often with reliable marine resources (Bayliss-Smith, 1990). Several tiny volcanic and coral islands, including Takuu, Luangiua (Ontong Java), Nukumanu, Sikaiana, Bellona, and Rennell, were subject to 'back-colonization' from Polynesia (see following section), resulting in the so-called 'Polynesian Outliers' (Kirch, 1984). Irwin (1992, pp. 183–9) suggests that these islands were at the extreme limits of accessibility and utility for permanent settlement and, to mitigate such stresses, their islanders were highly mobile, maintaining widespread contacts within Near Oceania, as well as north into Micronesia and east into Polynesia.

Increasingly, small islands seem to have been selected in the Late Holocene for several reasons, a principal one being that they contained resources suitable for the specialized landscape management and subsistence practices of the colonizing groups. The continental biogeographic zones of the Sunda and Sahul shelves were far more biodiverse than, for example, the smaller circum-New Guinea islands (Roos et al., 2004), but many smaller islands proved ideal for colonists in terms of their access to marine and littoral resources, as well as space for cultivation and foraging. The gradual decline in terrestrial biodiversity as groups moved through Wallacea, the Solomons and Bismarcks did, however, prompt changes to subsistence strategies, including increased gathering from the reef edge (Walter & Sheppard, 2017) and translocations of marsupials and cassowaries from larger islands to ensure protein resources (for example, Heinsohn, 2010; Summerhayes et al., 2009). Access to geological resources was also essential to successful colonization. Potting communities often settled close to clay and temper deposits or had access to more distant sources during initial colonization (Heath et al., 2017). Moreover, after the Mt Witori (W-K2) eruption c. 1300 BC in New Guinea (Machida et al., 1996), modes of obsidian acquisition and exchange altered, following the appearance of Lapita communities. The Bismarck obsidian sources, particularly Talasea, were widely distributed to Lapita communities in Remote Oceania as far east as Fiji (Best, 1987), and as far west as contemporary communities in Borneo (Chia, 2003). Maintenance of long-range movement of such resources was essential to Late Holocene colonization strategies, and mitigated the stresses of occupying new environments.

Mobility and Interaction

The second reason why smaller islands were selected preferentially in the Late Holocene may relate to conflict avoidance or mitigation. As noted above, Late Holocene groups moving into the region often encountered already established long-term populations (Torrence et al., 2009). Thomas' (2008) concept of 'friction landscapes' is helpful here, with much of the friction in this context potentially deriving from interactions with these existing populations. Spriggs (1997, p. 88) identifies a 'defensive posture' in Lapita colonization, whereby settlements were positioned at arm's length from established mainland groups. Subsequent centuries, however, witnessed increasing interaction and admixture (Green, 1991b); on the north and south coasts of New Guinea, Middle to Late Lapita period pottery suggests that Austronesian-speaking groups were active on the mainland (McNiven et al., 2011; Summerhayes, 2019), and pottery finds in the New Guinea Highlands also suggest that potting technology had been adapted to inland clay sources (Gaffney et al., 2015).

Following the initial Late Holocene migrations and subsequent mixing and interaction, long-distance exchange networks linking ISEA with Near and Remote Oceania fragmented into smaller but increasingly specialized trading systems (Allen, 1985; Tanudirio, 2006), certainly by c. AD 1000 and possibly earlier. This saw strategic relocations to monopolize access to resources and the colonization of precariously small islands in critical intermediary locations to facilitate redistribution (Irwin, 1985; Lilley, 1988; Shaw et al., 2016). Along the eastern coasts of New Guinea, a number of tiny uplifted coral islands with limited horticultural capacity were settled within the last millennium and formed the base for mobile canoe voyagers who produced specialty products to exchange for subsistence crops (Gaffney et al., 2020; Gaffney, 2022). Meanwhile, around Halmahera and western New Guinea, maritime groups positioned themselves strategically to exploit bird-of-paradise feathers, raw metals, betelnut, glass beads, pottery, slaves, textiles, bronze axes, and spices (Swadling, 1996), in this case clearly engaging with wider Southeast Asian, East Asian and Indian Ocean trading systems and consumption centers for exotic goods—an extra-insular driving theme to which we will return.

Summary: ISEA and Near Oceania

In global terms, the Holocene colonization of ISEA and much of Near Oceania was unusual, due to the presence of pre-established populations practicing mixed food-acquiring strategies. Broadly speaking—and in part because of the presence of these extant communities—subsequent dynamics in the region were characterized by increasing exploitation of liminal ecological zones and progressively smaller islands. These shifts encouraged novel adaptive responses like the maintenance of long-distance exchange links, diverse settlement strategies, increasing reliance on marine food-webs, and high-frequency maritime mobility. The ultimate mechanisms driving the initial Late Holocene migrations into ISEA may relate to broader contextual factors, as we discuss later. Subsequent island selection seems to have followed culturally-specific practices of rapid migration at first without substantial admixture, selecting for factors like sheltered canoe harbors with proximity to clay and obsidian resources, and at a perhaps cautious distance from pre-existent occupants. Colonization was usually followed by an establishment phase, in which communities gradually refined their subsistence and technological behaviors, and increasingly developed interactions with established populations that variably practiced foraging, cultivation, and agroforestry. As these pottery-making groups moved out into Remote Oceania, however, their options—and behaviors—once again shifted.

Remote Oceania

Remote Oceania covers a significant fraction of the globe, reaching from western Micronesia to Rapa Nui (Easter Island) and from the Hawaiian chain to southern Aotearoa New Zealand (approximately 25 degrees north to 45 degrees south), spanning tropical to (in the south) temperate latitudes (Fig. 4). Most of this area is open

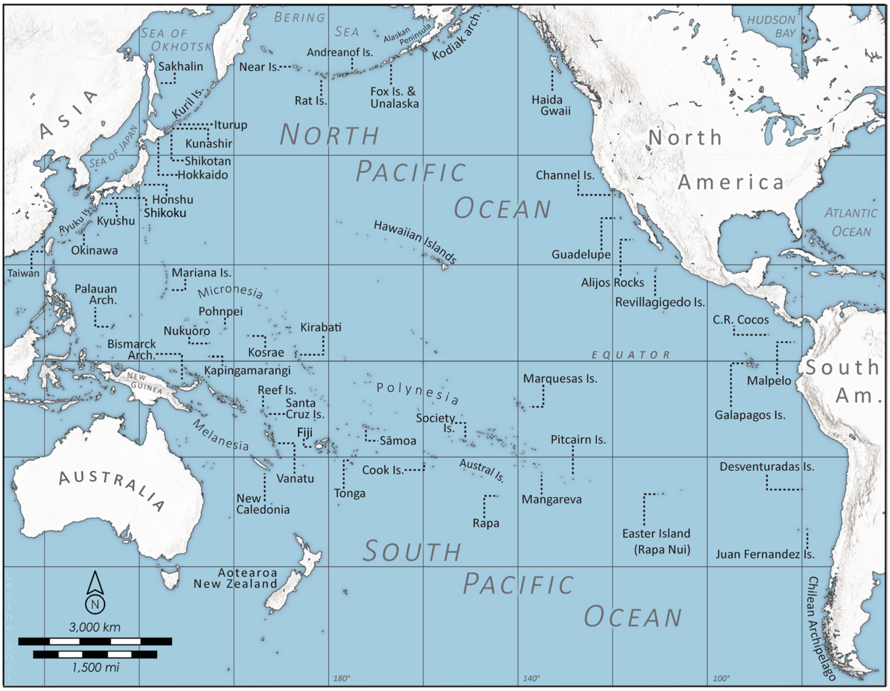


Fig. 4 Remote Oceania and the Pacific Rim: toponyms mentioned in the text

ocean, and the majority of islands within it are small, oceanic (and volcanic) in origin, and separated by substantial distances between archipelagoes. This combination of vast scale and thin distribution has exerted profound influence on the overall biogeography of Remote Oceania; it also effectively precluded any human settlement prior to the Late Holocene (Rieth & Cochrane, 2018), and the availability of sail-driven seacraft alongside sophisticated navigational techniques (Irwin, 1992).

The Late Holocene colonization of Remote Oceania was ultimately the outcome of processes that originated in ISEA and Near Oceania, not least the inferred early development of sailing technology. By 1200 BC, the western Micronesian archipelagos of Palau and the Marianas had been settled from ISEA (Petchey et al., 2016); a century or two later groups from the islands around New Guinea sailed to eastern Melanesia and the West Polynesian islands of Tonga and Sāmoa (Sheppard et al., 2015). This eastward movement stopped in Sāmoa and did not resume for almost another 2000 years, until the colonization of the Society Islands in Central East Polynesia, perhaps as early as AD 1000, and the other major Polynesian islands over the next 350 years. Episodic further colonization occurred in Micronesia, too, with the center and east settled after the western islands, at approximately AD 200 (Weisler et al., 2012). Explanations for the timing and geographic structure of this colonization have typically relied on climatic drivers (Anderson et al., 2006), agricultural expansion dynamics (Bellwood, 2011), culturally specific motivations (Finney, 1996), or some combination of these. Concepts from island biogeography have, by contrast, played a more limited role (Terrell, 1976, 1986; recently Cochrane, 2018).

Lapita Colonization of Remote Oceania

After a pause following their initial appearance in Near Oceania, Lapita settlements appear further east in the Reef and Santa Cruz Islands, Vanuatu, New Caledonia and Fiji, contemporaneously around 1050 BC (Sheppard, 2011; Sheppard et al., 2015), and indicating the first human colonists to cross the Near–Remote Oceania biogeographic boundary (Green, 1991a). Within 150 years of the first Lapita excursions into Remote Oceania, colonists reached Tonga in West Polynesia c. 900 BC and quickly populated the north–south extent of the archipelago (Burley et al., 2015). The only strictly Lapita site in Sāmoa postdates the Tongan landfall, at c. 800 BC (Petchey, 2001), and there are very few additional occupation deposits in Sāmoa for the next few centuries (Clark et al., 2016). The timespan over which Lapita pottery-making populations moved from the Bismarck Archipelago to their farthest eastern extent in Remote Oceania is thus between four and seven centuries. The first Remote Oceanic Lapita sites, with the possible exception of Sāmoa, all appear to be slightly earlier than those of the Northern and Western Solomons or the New Guinea south coast, even though the former are much farther from the geographic origin of Lapita (Sheppard, 2011). The numerous Lapita sites in the westernmost archipelagoes of Remote Oceania suggest successful colonization over a large area, and population continuity to European arrival is indicated by an archaeological record largely without hiatus (cf. Addison & Matisoo-Smith, 2010; Cochrane et al., 2016), although further demographic inputs from the west are likely (Harris et al., 2020).

Additionally, the distribution of Lapita decorative motifs indicates continuing movement between Near and Remote Oceania, and between different Remote Oceanic archipelagoes after colonization (Cochrane & Lipo, 2010; Green, 1979), although this inter-archipelagic sailing practice seems to have ended by approximately 700 BC.

Micronesia

The colonization of the Mariana Islands in western Micronesia c. 1200 BC occurred after the appearance of Lapita pottery in the Bismarcks, but most probably slightly preceded the Lapita expansion into Remote Oceania. One of the earliest and best-dated sites in the Marianas is Unai Bapot, but there is debate about the timing of its occupation. Petchey and colleagues (Clark et al., 2010; Petchey et al., 2016) have shown that dates of 1500 BC or older at the site (Carson, 2008) are derived from a single shellfish species, the dating of which is affected by limestone-derived carbon (Petchey et al., 2018; Carson [2020] does not fully address Petchey et al.'s analysis, and accordingly his conclusions may be erroneous; see now Petchey & Clark, 2021). Although an earlier date cannot be categorically excluded (Petchey & Clark, 2021), all other species of shellfish dated, and all charcoal dates, point to about 1200 BC as the colonization horizon (see also Rieth & Athens, 2019). Multiple sites across the Marianas whose date ranges encompass 1200 BC (Carson, 2014, table 4.1) suggest a successful colonization of some geographic breadth, although many of these sites also suffer from dating issues (Rieth & Athens, 2019, p. 8).

The Palauan archipelago, southwest of the Marianas, was definitely reached by approximately 1000 BC, if not slightly earlier, with evidence for occupation in a variety of environments across the archipelago at this time (Clark et al., 2006; Fitzpatrick, 2018). Admittedly, paleoenvironmental research has revealed a signature interpreted as human landscape modification a substantial 1500 years earlier (Athens & Ward, 2001), but there is a complete absence of similarly aged artifact-bearing deposits. Dickinson and Athens (2007) argue that the discrepancy is caused by subsidence and inundation of early coastal sites, but the existence of unambiguous artifactual signatures around 1200–1000 BC for both the large west Micronesian archipelagoes suggests that these dates are more robust indicators of earliest colonization. In both cases, the colonists almost certainly arrived from ISEA. Linguistically, both modern Palauan and Marianas Chamorro are Malayo-Polynesian languages related to others in ISEA, although not themselves closely related (Pawley, 2018). The earliest pottery in the Marianas, though not in Palau, has clear stylistic affinities with red-slipped and impressed-decorated pottery from ISEA (Carson et al., 2013; Cochrane et al., 2021; Swete-Kelly & Winter, 2022). In short, it is clear that western Micronesia was colonized from the west by groups that were in general terms culturally related.

Linguistic and ceramic affinities collectively suggest that central and eastern Micronesia were colonized from the south, by post-Lapita populations deriving from the former Lapita region, including islands near the Solomons, and not from western Micronesia (Kirch, 1987; Pawley, 2018). Pohnpei and Kosrae, two environmentally rich volcanic high islands, as well as the more environmentally limited eastern atolls such as Kiribati (which had likely only stabilized as islands several centuries before their colonization: Weisler et al., 2012), were colonized between approximately 50 BC and AD 150 (Athens, 2018). Kapingamarangi and Nukuoro atolls were colonized later than the rest of Micronesia and probably in the context of increased two-way voyaging contacts with West Polynesia, beginning about AD 1000 (this is reflected in the atolls' Polynesian languages). Radiocarbon dates from Nukuoro are imperfectly reported; colonization of Kapingamarangi is perhaps better dated at AD 1200–1400, but these dates rely on unidentified wood charcoal and bulk sediment samples (Rieth & Cochrane, 2018).

East Polynesia, Hawai‘i, Rapa Nui, and Aotearoa New Zealand

The increase in voyaging around AD 1000 that led to late colonization of Kapingamarangi, Nukuoro and other ‘Polynesian Outliers’ (Kirch, 1984) closer to New Guinea (discussed in the previous section) also resulted at a more significant scale in the final population expansion eastward, northward and southward into previously unoccupied Pacific islands. The colonization of the Polynesian Triangle, from Hawai‘i in the north, to Rapa Nui in the east, and Aotearoa New Zealand in the south, began about AD 1000, with all the major island groups settled by c. AD 1250 (Allen & Kahn, 2010; Kirch, 2010; Mulrooney et al., 2011; Walter et al., 2017; Wilmshurst et al., 2011). Although there is still debate about the timing of colonization on particular islands, the differences often amount to no more than a hundred years or so, and overall a clear pattern of rapid colonization across a vast region has emerged (although the markedly early colonization of eastern Micronesia also involved prodigious inter-island distances).

In the center of East Polynesia, the Society Islands have previously been beset with dating problems, but dating classification (Wilmshurst et al., 2011), paleoenvironmental (Stevenson et al., 2017), and excavation analyses (Kahn, 2012) have now generally converged on a colonization date of approximately AD 1000, making these islands the earliest colonized in East Polynesia. The Cook Islands, a dispersed set of atolls and small high islands, are closest to the West Polynesian homeland, yet their colonization may postdate that of the Societies: Allen and Morrison (2013), using a Bayesian approach, estimate Cook Island colonization at AD 1050–1270 (95% probability). To the southeast, islands in the Australs have varied colonization dates. The earliest is probably Rapa, estimated to be between AD 800 and AD 1300 (95% probability) (Anderson & Kennett, 2012), and more specifically about AD 1100 as indicated by paleoenvironmental evidence (Prebble et al., 2013). To the northeast, Marquesan colonization occurred shortly after the Societies, likely sometime between AD 1000 and AD 1200 (Allen & McAlister, 2013), while to the far southeast, Mangareva, the Pitcairn group, and Rapa Nui were settled around AD 1200 (Hunt & Lipo, 2006; Kirch et al., 2010; Weisler et al., 2012; Wilmshurst et al., 2011). Recent finds of chicken bones from late pre-Columbian South America indicate occasional onward voyaging even further to the east over the next few centuries (Storey et al., 2007).

The northern and southern extremes of Polynesia have clear colonization chronologies, due to the long history of research in these islands and concerted efforts at accurate and precise dating. In Aotearoa New Zealand, archaeological and paleoenvironmental evidence, including dates from the commensal Pacific rat (*Rattus exulans*) and rat-gnawed seeds (Wilmshurst & Higham, 2004), converge on a colonization estimate in the mid–late thirteenth century, which is also within a recent Bayesian estimate of AD 1270–1309 (95% probability) (Dye, 2015; although see Petchey & Schmid, 2020). In Hawai‘i, a similar Bayesian approach combining archaeological and paleoenvironmental data estimates colonization at AD 940–1130 (95% probability), but most likely between AD 1000 and AD 1100 (Athens et al., 2014).

Summary: Remote Oceania

Although the pattern may become more complicated and nuanced as new genetic data emerge (Matisoo-Smith, 2015; Wilson, 2018), overall the colonization of Remote Oceania is characterized by a sequence of geographically distinct and relatively rapid long-range movements. Cochrane (2018) has used proximate and ultimate evolutionary processes to explain the Lapita colonization of Remote Oceania as a selection-driven range expansion. The proximate trigger for this colonization is thought to be a technological innovation, possibly celestial navigation (Irwin, 1992), a change in climate (Anderson et al., 2006; Sear et al., 2020), or both, that reduced the effective ‘cost’ of voyaging. Lowered voyaging cost, coupled with environmental and subsistence variation between Near and Remote Oceania, generated selective (i.e., fitness) differences between voyaging and non-voyaging behaviors (Cochrane, 2018). Environmental and archaeological data confirm this explanation with, for example, significantly greater numbers of Lapita deposits in Remote, compared to Near, Oceania.

We might expect similar processes to explain other colonization episodes in the Pacific. As dramatically different voyaging capabilities are required for East Polynesia compared to the Lapita region of Remote Oceania (Di Piazza et al., 2007), the colonization of this region from Sāmoa and Tonga might also have been triggered by further innovations in canoe technology and/or navigational skills that lowered voyaging costs. Socionatural environments would also have varied dramatically between Sāmoa-Tonga and East Polynesia around AD 1000 (Sear et al., 2020), the time of East Polynesian colonization. There is increasing evidence that at this time the population of Sāmoa was expanding (Jackmond et al., 2018; Quintus & Cochrane, 2017) and approaching what Burley (2007) has characterized for Tonga as a ‘full-land’ situation. By incorporating a universal selection process based on fitness differences between movement and non-movement oriented behaviors, this explanation builds upon previous colonization research, and also suggests parallels in other contexts.

The Indian Ocean

The Indian Ocean reveals a sharply bimodal distribution between island giants such as Madagascar and Sri Lanka (590,000 km^2 and 65,600 km^2 in area, respectively), and archipelagoes of very small and often (if not exclusively) low coral islands. Although all lie at tropical to subtropical latitudes, the main islands and island groups are widely separated from each other, and most subtend from one or other sector of the immense arc of the continental rim, with few located in the vast reaches of mid-ocean—in contrast to the Pacific (Fig. 5). Perhaps due to these factors, Indian Ocean scholarship has been notably disinclined to approach islands as a coherent focus for investigation. Certainly, alternative spatial classifications, for example exploring all the circum-African islands as an analytical category (for example, Mitchell, 2004, 2022), or including the Bay of Bengal within ISEA, remain insightful. But the accumulating evidence for rapidly expanding Indian Ocean sail-driven interconnections from the mid first millennium BC, revealed by translocations such as the westward transfer of the banana (a native of New Guinea and eastern ISEA), followed by deeper economic integration driven by emergent towns and polities around the oceanic rim during the first millennium AD (Boivin et al., 2013; Fuller et al., 2015; Mitchell, 2022, pp. 132–166; Seland, 2014; Wynne-Jones, 2016), now demands a more holistic approach to Indian Ocean island colonization, within the

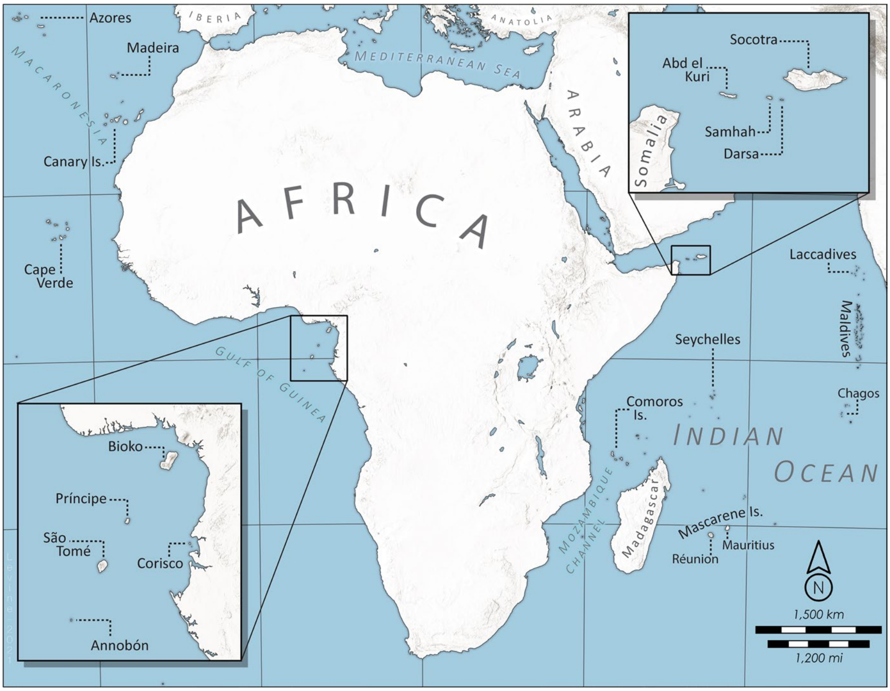


Fig. 5 The western Indian Ocean, Macaronesia, and West Africa: toponyms mentioned in the text

conceptual framework of a broader interactive maritime space. In this context, it is crucial to recognize that the precocious dynamism of maritime and insular activity identified in ISEA (itself usefully envisaged as the Indian Ocean's eastern archipelagic rim) had an impact on early Indian Ocean as well as Pacific-oriented expansion, even if much of the westward lobe currently remains tantalizingly unresolved in terms of definitive data, including dates.

Given the current dearth of reliable chronological resolution, we start with the symptomatic enigma of Madagascar, c. 400 km off the African coast. Much of the uncertainty over colonization dates for islands in the western Indian Ocean revolves around the arrival of humans on Madagascar, and their point of origin (Fuller et al., 2015; NB by virtue of their extreme proximity to the African mainland the Swahili coast islands are not discussed here—see Boivin et al., 2013; Mitchell, 2022, pp. 132–156; Wynne-Jones, 2016). Malagasy is an Austronesian language, a family otherwise confined to ISEA and the Pacific. The existence of this startling outlier, combined with the long-standing model of a late and archaeologically well-attested settlement in the first millennium AD (for example, Dewar & Wright, 1993), has long been taken to indicate initial colonization of Madagascar from ISEA, propelled by a culture of long-distance seafaring not paralleled at an earlier date across the Mozambique Channel (Fleisher et al., 2015; Mitchell, 2022, pp. 65–76). This model has been challenged by purported butchery marks on endemic fauna, radiocarbon dated to the last two millennia BC (Gommery et al., 2011), and more recently on avian megafauna from the Christmas River Site, dated to c. 8500 BC (Hansford et al., 2018). The anthropogenic nature of these traces is hotly disputed, and the temporal gulf between such potential proxies for human activity and the unequivocal first millennium AD horizon certainly presents a challenge (Anderson et al., 2018; Mitchell, 2020a, 2020b, 2022, pp. 65–71; other palaeoenvironmental proxies remain equivocal: Wang et al., 2019). A recent exercise in chronometric hygiene affirms human activity on the island by at least the start of the first millennium AD, but not definitely earlier (Douglass et al., 2019)—a timeframe now supported by additional analysis (Li et al., 2020). This still relatively late date finds support from a regional perspective—a conservative estimate similarly places the colonization of the Comoros group, in the Mozambique Channel, within the first millennium AD, and certainly by the ninth century (Allibert, 1989; Boivin et al., 2013; Mitchell, 2022, p. 72).

Madagascan processes assuredly need to be contextualized still more broadly. As alluded to above, the period c. 500 BC–AD 1000 saw societies around the Indian Ocean rim becoming more inter-connected, with growing indications of circum-oceanic (if perhaps not truly trans-oceanic) voyaging. As a large landmass on the fringes of this world, Madagascar's late, possibly initially patchy colonization may have been a product of burgeoning long-distance interactions rather than local demographic or indeed biogeographical factors (Mitchell, 2004, pp. 243–44; 2020a, 2022). In this sense, a first millennium date (whether BC or AD) remains, at least at present, the most likely for the island's colonization.

To the north, in the Arabian Sea, the timing of colonization on Socotra and its arid archipelago is equally unclear. Despite well-established second millennium BC connections between the Nile Valley and the Gulf of Aden in the form of Egypt's trade with ‘Punt’ (Lucarini et al., 2020), the earliest plausible Socotran dates fall in the first millennium BC, on the basis of megalithic burials with striking parallels on the Arabian Peninsula (Naumkin & Sedov, 1993). This timing would support an intriguing reference, apparently to Socotra, made by Pliny the Elder (*Natural History* VI, 153). By the first millennium AD there is substantial evidence for human activity, with cosmopolitan connections (Seland, 2014). Socotra’s smaller, arid neighbors appear on current evidence to have been uninhabited until relatively recently.

Further east, and at a pivotal point for movement around the Indian Ocean rim, the big island of Sri Lanka fortunately has a much more securely established colonization history, at least in outline. At the lowest Pleistocene sea-level stands Sri Lanka was simply a promontory of South Asia; at other times it has variously been tenuously connected via the Bridge of Rama (a chain of uplifted coralline limestones joining it to Tamil Nadu), or separated by modest distances across shallow continental shelf. As such, the Upper Palaeolithic occupation identified from 45,000 years ago at Fa-Hien Lena (Wedage et al., 2019a), is not necessarily proof of over-water dispersal (though equally, it could be on a minor scale). HGF groups continued to live on Sri Lanka until the Late Holocene (Roberts et al., 2015; Wedage et al., 2019a, 2019b), with gradual insularization probably beginning earlier (Banerjee, 2000). Archaeobotanical evidence then signals a major change in the first millennium BC, with the arrival of mixed rice and millet farmers, associated with developing urbanism and long-distance contacts (Murphy et al., 2018; Roberts et al., 2015). Once again, this marked shift, together with greater connectivity, is best understood alongside the burgeoning contemporary development of Indian Ocean maritime connections.

Further from the South Asian mainland, Buddhist monks arriving in the Maldives in the first few centuries AD (and well attested archaeologically: Forbes, 1987) reported an already present population (Maloney, 1980, pp. 49–75), but the antiquity and derivation of the latter is uncertain. The earliest radiocarbon dates, from Nilandhoo Foamathi, fall in the third to fourth centuries AD (Litster, 2016) and are most parsimoniously associated with the Buddhist colonization horizon. The Laccadives, closer to the mainland and Sri Lanka, were perhaps colonized at around the same time (Forbes, 1979).

The Andamans and Nicobars are relatively isolated archipelagoes that separate the Bay of Bengal from the Andaman Sea (Fig. 3). Ethnographically famous as the Andamanese undoubtedly are (Radcliffe-Brown, 1922), the archaeology and population origins of both island groups remain obscure. In the case of the Nicobars, less than 200 km at the nearest point from Sumatra, solid genetic affinities with modern mainland populations suggest a relatively recent colonization (Thangaraj et al., 2003), presumably post-dating the third millennium BC initial expansion of farming into ISEA, and quite possibly associated with an early stage of westward maritime expansion from the latter. The Andaman Islands, however, stand out as a potentially extraordinary prospect within global island colonization patterning. The earliest known archaeological data derive only from the Late Holocene, prompting Cooper (1993, 1996) to posit a late arrival. Yet the circumstantial evidence for an earlier colonization is increasingly persuasive. Firstly, documentary sources suggest little or no contact between the Andamans and the Malay Peninsula over the last two millennia (Cooper, 1989). Secondly, despite supposed phenotypic similarities to mainlanders, recent analysis suggests that there is in fact substantial divergence in morphological and genetic terms between the Andamanese and mainland Malay groups (Stock, 2013). Thirdly, modern genomic data now indicate a marked divergence between the Andamanese and mainland Asian genetic material that can be convincingly associated with early farming dispersals (McColl et al., 2018; Thangaraj et al., 2003, 2005). Collectively, these observations hint at colonization by HGFs well before the spread of farming through Southeast Asia, whether in the Late Pleistocene or Early Holocene, followed by sustained isolation. During the lowest glacial sea-level stands, water gaps would have been substantially narrower between Cape Negrais on the southeastern coast of the Bay of Bengal, the midway island of Preparis, and the northern Andamans, perhaps c. 100 km apiece (Curray, 2005)—distances provocatively comparable to those separating Wallacea from Sahul. Shortened distances, favorable currents, and maybe vegetation-rafting on the outflow of the palaeo-Irrawaddy river may help to explain this intriguing colonization, followed by long-term isolation as crossing distances extended through the Holocene.

Lastly, the few truly remote mid-ocean archipelagoes, namely the Seychelles, the Mascarenes (Mauritius, Réunion, and minor outliers), the Chagos, and the Cocos Islands (plus Christmas Island), have witnessed little archaeological work aimed at establishing their date of colonization, and were certainly empty at European contact. On current evidence it is assumed that Europeans were the first to discover all these groups (Boivin et al., 2013; Mitchell, 2004, 2022).

Summary: Indian Ocean

In contrast to the patterns of island colonization so far identified in other theaters, Indian Ocean processes stand out as driven by rather different factors, with most island settlement developing in tandem with the expansion of long-range maritime networks involving a variety of participants from the continental rim as well as islands. Conversely, yet equally exceptionally, in the now small and remote Andaman Islands a unique combination of circumstances may have enabled the survival into the present of an HGF island population with very deep origins. Only in the case of the Ocean's two 'matchbox continents' do more familiar explanatory approaches involving distance from the mainland gain potentially primary traction, with divergent and in one case instructively negative results. While Sri Lanka was intervisible with Asia, reached possibly dryshod in the Pleistocene, never subsequently abandoned, and then newly peopled by farmers across a Holocene strait, Madagascar's 400 km from Africa still appears on balance to have proved insuperable until well into the Late Holocene, and the island appears to have then been colonized from a quite different direction. Finally, the emptiness of the mid-ocean archipelagoes, in contrast to the widespread peopling of Remote Oceania, furthers the impression that the main thrusts of long-range maritime activity (whether primarily or secondarily island-colonizing in terms of intent), were fundamentally circum- rather than trans-oceanic—undoubtedly employing open-sea shortcuts across indentations, but largely avoiding the formidable central sea desert. This presumably reflects both the sparseness of mid-oceanic islands (especially in the almost empty eastern half of the open Indian Ocean, closest to ISEA, where even the tiny Christmas Island and the Cocos Islands, directly down the prevailing wind from the maritime hub of the Sunda strait, were undiscovered until a few centuries ago), and the driving agency of interactions by continental and insular actors around the rim.

The North Atlantic

During the Early and Middle Holocene, shifting conditions created by rising sea-levels along the maritime façade of northwest Europe encouraged short-range relocations to and from emergent or submergent islands along the continental margins. One example is the cessation of HGF occupation on Doggerland in the North Sea, which was inundated shortly before 6000 BC (Gaffney et al., 2009). The British Isles provide an equally instructive contrast between initially dry-shod re-peopling by HGFs during the Late Glacial to Early Holocene (Pettitt & White, 2012), and the maritime arrival of farming, around 4000 BC, via short-range southern and longer-range western seaboard axes (Brace et al., 2019; Garrow et al., 2017; recent genetic evidence indicates substantial later demographic turnovers and influxes: Patterson et al., 2022). The British Isles stand out in global terms as a comparatively early instance, at least beyond the Mediterranean, of island colonization by agropastoralists.

A hiatus of several millennia then ensued before an advanced Late Holocene surge outward into the North Atlantic islands scattered between Europe and the North American mainland (Fig. 6). This theater is circumscribed to the north by the Arctic Circle, with its glaciated landmasses and seasonal pack ice grading northward into polar sea ice (for this reason we do not address further Jan Mayen, Bear Island, and Svalbard, the first known to the Norse but never settled: Hofstra & Samplonius, 1995; Hultgreen, 2003, pp. 305–307). Here, the high latitude disadvantages of cold were in part offset by immensely rich maritime ecosystems. To the south, the region is edged by open ocean, excepting Rockall and other miniscule skerries (leaving to one side hints, discussed below, that the Norse may have reached the northern fringes of Macaronesia: Mitchell, 2022, p. 63).

Maritime sailing technology and skills that developed in Scandinavia in the later first millennium AD, perhaps associated with favorable sea conditions during the Medieval Climate Optimum (Dugmore et al., 2010), played a key role in the settlement of the North Atlantic. This process is known as *Landnám* (Old Norse for 'the taking of land': McGrail, 1980; Smith, 1995), although a complementary motivation to the carving out of farmland was the search for, and exploitation of, valuable Arctic trade goods for continental markets, notably walrus ivory and furs (for example, Barrett et al., 2020). From the eighth century AD onwards, Norse settlers of Scandinavian origin migrated to the Faroes, Iceland, and Greenland, an expansion that culminated in their arrival on the archipelagic fringes of North America by the eleventh century AD (Wallace, 2003). This predominantly east–west route, latitudinally constrained by the need for a viable if short growing season for crops, is described

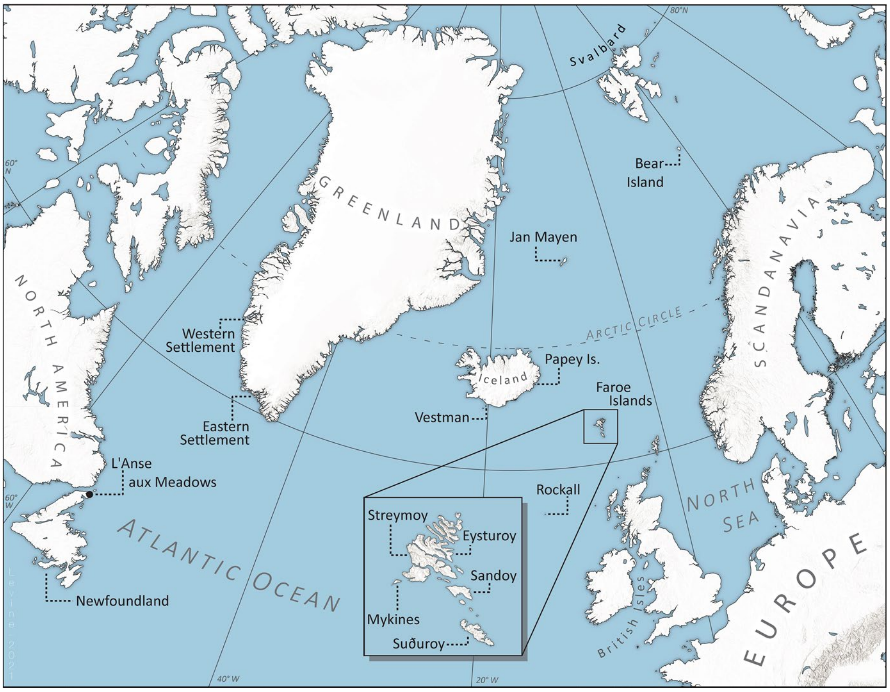


Fig. 6 The North Atlantic: toponyms mentioned in the text

in medieval texts and amply affirmed by archaeological finds, radiocarbon dating, as well as, in the case of Iceland, volcanic ash (tephra) layers at settlement sites. Although as a colonization process it is rarely set within global patterns, it reveals striking similarities to independent Remote Oceanic processes of not dissimilar date, albeit with culturally specific differences.

The Faroe Islands and Iceland

The Faroe Islands lie roughly midway between Norway and Iceland (respectively c. 600 and 440 km distant), and constitute the first stepping stone for a diaspora across the North Atlantic. The eighth-century Irish monk Dicuil suggested that anchorites had lived on certain North Atlantic islands before the Norse arrived (Tierney, 1967), and although the identification of the Faroes in his writing has been questioned (Arge, 1991), the earliest palaeoenvironmental dates do suggest small-scale human landscape modification between AD 400 and 600 (Jóhansen, 1979; Hannon et al., 2005; Edwards et al., 2005). Moreover, a pre-Norse presence has been directly confirmed by the earliest dates of non-native barley grains from Á Sondum on Sandoy (Church et al., 2013). Initial Norse settlement of Sandoy and Eysturoy is evident in the ninth century (Church et al., 2005; Stumman Hansen, 2013). Permanent early (AD 800–1000) sites are located on the coast, while seasonal later (AD 1000–1100) sites are also found inland (Malmros, 1990). The large islands were rapidly settled; the scarcity of data from smaller islands means that it is uncertain whether they were seasonally occupied, or never settled at all.

Iceland, too, presents the vexed issue of anchorite activity prior to the Norse arrival (Tierney, 1967). A few putative sixth to eighth century AD dates come from the small island of Vestman, off the south Icelandic coast (Hermanns-Auðardóttir, 1989), and from the southwest around Reykjavík (Nordahl, 1988). However, these derive from wood charcoal with inbuilt age and none lie stratigraphically below the *Landnám* Tephra Layer (LTL) of AD 877 ± 1 (Schmid et al., 2017). The earliest short-lived materials, by contrast, are consistent with tephrochronological evidence and support an initial colonization horizon in the mid–late ninth century (Ascough et al., 2007; Schmid et al., 2021). This mid–late ninth century colonization is also attested in literary sources. *Íslendingabók*, composed in the twelfth century (Grønlie, 2006), pinpoints the timing and speed of earliest Norse settlement, and indicates that all the medieval administrative divisions of Iceland were settled within 60 years (AD 870–930). This timeframe is further confirmed by ice-core data and historically dated tephra layers (Schmid et al., 2017). A recent comprehensive reassessment of the Icelandic evidence indicates that 550 archaeological sites can be assigned to three consecutive periods of settlement (Schmid, et al. 2021); only two seasonal sites in the southwest date to the pre-*Landnám* period and can be interpreted as residues of exploration. The earliest palaeoecological data from the same area suggest that non-native barley was cultivated before the deposition of the LTL, approximately between AD 830 and AD 880 (Schmid et al., 2018a). However, occupation evidence becomes far more extensive (Schmid et al., 2021) during the *Landnám* and post-*Landnám* periods (AD 877–938/939; AD 938/939 to 1104). Pre-*Landnám* sites are situated coastally, while early *Landnám* sites are located both in coastal and inland areas, including less optimal ones, and spread from the southwest to the north and then the east.

Overall, Iceland's settlement was extremely rapid, homogeneous, and continuous, with all inhabitable parts occupied before AD 890 (Schmid et al., 2018b, 2021; Vésteinsson & McGovern, 2012). This speed relates in part to the scale of the process, perhaps involving as many as 24,000 initial settlers in less than 20 years (Vésteinsson & McGovern, 2012), although there was also later immigration (Vésteinsson & Gestsdóttir, 2014). Moreover, this explosive colonization was successful in the long-term; most settlements were not abandoned and indeed persist to this day. Smaller satellite islands were also settled; Vestman (regardless of the uncertain earlier dates) in the late ninth to tenth century AD (Hermanns-Auðardóttir, 1989), and Papey in the late tenth to eleventh century (Eldjárn & Sveinbjarnardóttir, 1989). In northwestern Iceland a strong correlation between a farmstead's size and its establishment date can be discerned, suggesting that the largest and wealthiest farms were founded by the first settlers (Steinberg et al., 2016).

Greenland and Newfoundland

Grænlendingasaga and Erik's *Saga Rauða* (written in c. AD 1190 and 1260 respectively) describe the voyages of the Norse to Greenland (whose nearest landfall lies c. 300 km distant from northwest Iceland) around AD 985 (Gilbert et al., 2008; Rasch & Jensen, 1997), during the Medieval Climate Optimum (AD 950–1250 [Jackson et al., 2019]). Unlike Iceland, Greenland was already occupied, thanks to prior expansion by circum-polar HGF groups across land, ice and sea. The Norse settlement unfolded east to west; the current evidence indicates that the larger Eastern and Middle Settlements (between 60 and 61 degrees north, and with 560 recorded farms), began before the smaller Western Settlement (around 64 degrees north, with some 75 farms) (Arneborg et al., 2012).

The earliest sheep, goat, and cattle (unequivocal evidence for Norse translocations) in secure contexts are from large *Landnám* settlements in the Eastern Settlement and, in radiocarbon terms, fall within a late eighth to tenth century AD range compatible with the textual tradition (Edwards et al., 2008). Other early permanent settlements are dated to the late tenth century (for example, Arneborg et al., 1999, 2012). Clarifying the initial colonization of the Western Settlement is more challenging. The earliest reindeer, harp seal, and walrus bone samples from Niaquusat in the Western Settlement also fall between the late eighth and tenth centuries. However, their contexts are most likely connected to the indigenous Dorset occupants, and might suggest Norse–Dorset interactions as readily as a small number of early Norse arrivals (Arneborg et al., 2012). Aside from these culturally ambiguous dates, permanent Norse settlements in the west date to the early eleventh century AD (Arneborg et al., 1999, 2012).

Greenland Norse sites were located in fjords or near rivers and lakes. As in Iceland, there is a strong correlation between site size and establishment date; initial settlers founded larger and ultimately wealthier farmsteads than later settlers (Arneborg et al., 2012). Estimated total peak populations for the Greenland Norse settlements range from 2250 to 6800 people (Lynerup, 1996), yet all were abandoned before the mid fifteenth century AD, potentially due to climatic deterioration caused by the Little Ice Age, which may have triggered resource stress and competition between the Norse and indigenous groups (Dugmore et al., 2010). It has also been suggested that storm frequency intensified around AD 1425–1450, disrupting vital long-range interaction networks.

Newfoundland, a large island in the Canadian maritime archipelago, lies c. 1100 km south of Greenland. *Grænlendingasaga* and Erik's *Saga Rauða* describe several Norse expeditions around AD 1000 to Vínland, widely understood to be Newfoundland, where they encountered indigenous people. So far only one Norse site (L'Anse aux Meadows) has been extensively excavated. The settlement persisted for only a short time before it collapsed, potentially due to competition between Norse and local American-Dorset groups (McGhee, 1984). The radiocarbon dates from peat, twigs and charcoal with inbuilt age do not provide narrow ranges, but indicate a short occupation (Wallace, 2003), according to recent Bayesian analysis beginning c. AD 910–1030 and ending AD 1030–1145 (Ledger et al., 2019).

Summary: North Atlantic

Given the reproductive limitations associated with an eremitic lifestyle, the first anchorites of the Faroes, even if accompanied by a few other settlers, probably struggled with demographic bottleneck conditions. Permanent settlement of the North Atlantic islands also required sustained maritime activity to maintain contact and population flow over long distances. Unsurprisingly, it was the subsequent Norse colonization that succeeded over the longer term. The Norse explored Iceland and established seasonal bases in the southwest before large-scale, permanent settlement, suggesting that the scoping of new territory was a necessary first step to equip settlers with the knowledge essential for the ensuing explosive and permanent *Landnám*. The latter involved rapid relocations of a large number of people that retained connections to Scandinavia via trading networks (Frei et al., 2015). Norse voyaging expansion was strikingly fast and cumulative, with the Faroes settled in the early ninth century AD, Iceland in the late ninth century, the Eastern Settlement of Greenland in the late tenth century and the Western Settlement and Newfoundland in the early eleventh century. Rapid population relocation and continuous occupation of all inhabitable parts of Iceland by the mid tenth century triggered expansion to Greenland two generations later. The scale of settlement in Iceland ensured that demographic momentum was maintained, resulting in around 500 years of settlement in Greenland and a brief Newfoundland foothold. It is also interesting to note that recent radiocarbon dates within the Faroes and on Iceland give little support for island size being a determinant of relative antiquity of colonization.

The Norse *Landnám* in the North Atlantic is a classic example of a self-reinforcing iterative process of voyaging and discovery by people technologically increasingly adept at maritime dispersal. Success in the Faroes encouraged the discovery in turn of Iceland, Greenland, and Newfoundland. Yet while the settlement of Iceland was permanent, that of Greenland and Newfoundland was ultimately not, illustrating the interacting effects of distance, climate, and competition. The long-term success or failure of colonization clearly related in part to distance, and more precisely to 'rescue effect'—the closer an island was to a large source population, or indeed the larger its own population, the less likely it is to experience local extinction. Beyond distance, however, both competition and climate are additional key factors in understanding the patterning of *Landnám* colonization, and its failures. The fact that interior and coastal areas in Iceland were rapidly fully settled, with farm properties delineated by the construction of large earthwork systems (Schmid, 2018), suggests the need for excess offspring or newcomers to acquire land further afield, prompting onward movement—and an analogous model applies to the (over-) exploitation of ivory and fur resources. Last but not least, the eventual closing of the optimal climatic window by the Little Ice Age, and resultant sharper competition from indigenous people (comparatively advantaged as conditions grew more inimical to farming), undercut the sustainability of Greenland's demographically fragile Norse settlement.

Other Theaters

Finally, we explore a variety of other islands scattered around the Pacific's continental rim and in the mid-latitude Atlantic that lie outside the major theaters as often defined, but that nevertheless provide further intrinsic and comparative insights. The presumption, reasonable if admittedly not proven, is that colonization events in all these contexts were effected without sail-powered seacraft, with the exceptions of the remarkably tardy agricultural expansion into Japan and equally late settlement of the Canaries.

The North and East Pacific Rim: Ryukyus to Chile

Tectonic activity to the north of ISEA and Oceania has generated numerous islands, notably but not exclusively in the form of island arcs and chains (Fig. 4). The Japanese archipelago and surrounding islands, including the Ryukyus (between Kyushu and Taiwan) and Kurils (between Hokkaido and the Kamchatka Peninsula), have a particularly long and complex settlement sequence. Several saw Pleistocene occupation, in some instances continuing into later times. The four main Japanese islands, today totaling some 380,000 km^2 in area, all boast a robust Upper Palaeolithic. During the Last Glacial Maximum, the deep strait between Korea and Kyushu endured, but those between mainland Asia and Sakhalin, and between Sakhalin and Hokkaido, were closed by eustatic drawdown, while that between Hokkaido and Honshu was either drastically narrowed or turned into a tenuous land bridge (Oba & Irino, 2012). There is, accordingly, little or no need to invoke maritime colonization for the initial Japanese Palaeolithic, nor for the succeeding Jōmon Palaeolithic and its Holocene HGF successors, assuming that local cultural processes rather than new influxes are responsible for the latter (much the same applies to Sakhalin's enduring HGF population). Palaeolithic and later Jōmon maritime activity is, however, implicated in the offshore activity on fringing islands (Ikeya, 2015; Kaifu et al., 2020), as well as the colonization of smaller true islands to the north and south. In the Ryukyus, following a maritime Upper Palaeolithic occupation but subsequent abandonment, a renewed Holocene HGF colonization of much of the chain (excepting the southernmost islands) began around 7000 BC (Takamiya, 2006). The most plentiful evidence comes from large (but distant) Okinawa; and interestingly, despite early evidence from intervening islands, by around 2000 BC settlement appears to have contracted southwards, with smaller islands such as Yaku abandoned (Takamiya et al., 2015). North of Hokkaido, the southern Kurils likewise appear to have been settled around 6000–5500 BC (Fitzhugh et al., 2016). The earliest evidence derives from Iturup, with later settlement from neighboring Kunashir and Shikotan (Kuzmin et al., 2012), all notably among the largest of the Kurils, as well as the most southerly of the islands and closest to Hokkaido.

The appearance of agropastoral lifeways in the Japanese archipelago during the first millennium BC (the Yayoi phenomenon) is usually attributed at least in part to a population influx from mainland East Asia, bringing rice agriculture (for example, Crawford, 2011; Hudson, 2013; Hudson et al., 2020). The initial Yayoi is now redated to c. 1000–900 BC (de Boer et al., 2020; Shoda, 2010), and initially farming was limited to Kyushu, Shikoku, and southern Honshu. This distribution probably reflects the axis of expansion and latitudinal constraints on rice cultivation rather than a preference for larger islands per se; for example, northerly Hokkaido, an enduring HGF bastion, is twice as large as Kyushu. In contrast to much of ISEA and Near Oceania, where horticulturalists entering regions with already established HGF occupants at first tended to avoid or skirt the latter populations (focusing on small islands or moving rapidly through), in much of the core of the Japanese archipelago HGF lifeways rapidly disappeared, save in northern Honshu, Hokkaido and off-shore islands, plus the more distant Kurils and Ryukyus (de Boer et al., 2020; Hudson et al., 2020).

Island colonization of the circum-Pacific east of the Bering Sea is ultimately a function of the arrival of people in the Americas, yet substantially postdates the primary phase of this process (as it does to a still more pronounced degree on the Caribbean flank). The eastern Aleutians (the Fox Islands) appear to have been reached by HGFs, presumably from Alaska, around c. 7000 BC (Knecht & Davis, 2001). Moving westward and out to sea, island size decreases from the Fox to the Andreanof, Rat, and Near groups, and both this and increasing distance correspond tightly with later colonization. The first settlement on Unalaska dates to c. 7000 BC, on the Andreanofs to 4000–3000 BC, on the Rat Islands to 1500 BC, and on the Near Islands to 500 BC (Veltre & Smith, 2010)—a globally rather rare example of human colonization patterns mapping onto simple biogeographic expectations without appreciable 'noise'. From the Aleutians southwards, there are no substantial oceanic islands off the coast of the Americas, excepting the small eastern Pacific remotes such as the Revillagigedo Islands, the Alijos Rocks, the Galapagos, and the Juan Fernandez group, none of which were colonized prior to European arrival. The majority of the inshore islands situated on the continental shelf, from the Pacific Northwest to the Chilean archipelago, are so close to the American mainland that crossings are mostly trivial, though arguable exceptions include the HGF intakes of the Kodiak, Haida Gwaii, California Channel and Panamanian Pacific islands. In the Kodiaks, earliest settlement is now dated to c. 5500 BC at the Rice Ridge Site on Kodiak itself, the largest of the group (Kopperl, 2012). Further south, the Haida Gwaii archipelago appears to have been occupied (or seasonably exploited) from the early Holocene, c. 9000–8000 BC (Mackie et al., 2018). Initial activity on the California Channel Islands is even earlier, lying at the Pleistocene/Holocene boundary (Erlandson et al., 2011), when the archipelago was probably united into the palaeoisland Santarosae. The islands off Pacific Panama were first settled by HGFs slightly before 4000 BC, followed after a long hiatus by pottery-using groups from the last centuries BC (Martín et al. 2017). The similarity between the earliest dates here and in the Greater Antilles raises the intriguing possibility of a common stimulus in the changing lifeways and demographics of the early Archaic in continental Central America.

Macaronesia and West Africa

Among the Atlantic's Macaronesian islands (Fig. 5), the remote Cape Verdes, Azores and Madeira were probably unknown prior to Portuguese expansion, although there are hints on Madeira (in the form of *Mus musculus* as a proxy for human arrival) that Norse voyages may have reached this far into the ocean at southerly latitudes (Mitchell, 2022, p. 63), perhaps as a consequence of voyages around the Iberian peninsula and into the Mediterranean. The Canaries, by contrast, lie only c. 90 km off the West African coast and were certainly colonized by agropastoralists prior to this, though precisely when has long been disputed. A recent synthetic analysis convincingly narrows the likely timeframe to between the later first millennium BC and the early first millennium AD (Nascimento et al., 2020), and Mitchell demonstrates that reliable radiocarbon dates become more plentiful in the latter half of this window (2022, pp. 76–82). The admittedly equivocal genetic evidence may suggest that this colonization derived from source populations in the Maghreb or perhaps further east (Fregel et al., 2019). That this timespan also witnessed a step change in economic integration and urbanization in the western Mediterranean and 'Mediterranean Atlantic' beyond the Gibraltar Strait, associated with Punic and later Roman maritime activity (Broodbank, 2013, pp. 561–575), is unlikely to be coincidental. There is an intriguing parallel for this co-development of maritime integrative processes and island colonization in the potentially contemporary settlement of Socotra, on the far side of the continent.

Further south, in the Gulf of Guinea and Bight of Biafra, stratified sequences and robust dates are largely absent. Indeed, São Tomé and Príncipe has recently been identified as the only modern nation that remains essentially devoid, to date, of archaeological investigation (Mitchell & Lunn-Rockcliffe, 2022). That said, Bioko (at 2000 km^2 the largest island in the Gulf) and smaller Corisco (only c. 20 km from the mainland) provide evidence for settlement by farming groups well within the timeframe of this study. On Corisco, a review of radiometric dates indicates likely settlement around 100 BC (Sánchez-Elipe Lorente et al., 2016). Bioko presents a more complicated situation: the Bantu-speaking Bubi (genetically similar to other Bantu-speaking groups: Gelabert et al., 2019) appear to have colonized the island at around the same time as Corisco (Clist, 1998), but Bubi mythohistoric accounts recall an extant indigenous people, the Balettérimo, who may conceivably be implicated in an otherwise unusual and archaeologically identified chipped stone tradition. Príncipe, São Tomé, and Annobón, lying increasingly far out into the Gulf (Annobón lies a considerable 350 km from the mainland), all appear to have been free of human settlement at the point of European arrival (Mitchell, 2022; Mitchell & Lunn-Rockcliffe, 2022).

Summary: Other Theaters

Some trends can arguably be discerned in the structure and dynamics of colonization among this disparate set. For pragmatic purposes, the minor theater islands can be divided into three groups: island chains and arcs; off-shore islands implicated by the colonization of the Americas; and oceanic super-remotes.

The island chains exhibit an unsurprising tendency for colonization dates to reflect biogeographic expectations. In the southern Kurils (from 6000 BC to 5500 BC), eastern Aleutians (from 7000 BC), northern Ryukyus (from 7000 BC), and on Bioko (1000 BC–AD 1), the larger, closer islands were colonized before smaller, more distant ones (or the latter not at all, in the case of Annobón). In this calculus, size appears to have trumped distance, at least within certain ranges: Okinawa, for example, is more distant from Kyushu than the northern Ryukyus, but large enough, at tropical latitudes, to have maintained a population over the long term, whereas the intervening islands apparently lacked this capacity.

Questions over the axis of Pleistocene human entry into the Americas south of Alaska complicate the study of island settlement in this region. The kelp highway model, involving coastwise movement rather than via an interior corridor between the ice sheets (Erlandson et al., 2007), would provide a neat context for terminal Pleistocene to Early Holocene activity on coastal islands surrounded by rich marine ecologies (for example, the early dates from the California Channel Islands, and possibly Haida Gwaii). The slightly more remote Kodiaks, by contrast, may not have been implicated in this initial coastal corridor, and their markedly later settlement may reflect a separate process.

Lastly, Macaronesia (except the Canaries) and the eastern Pacific islands share small size, great distance from continental landmasses, and a lack of stepping stones readily leading to them. These factors combine to render them highly unlikely candidates for colonization within our timeframe. The Canaries are likewise small, but only moderately remote and, like Socotra in the Indian Ocean, they lay crucially close to emergent Late Holocene zones of sail-driven networks and long-range trade, which can be convincingly implicated in their colonization dates.

Discussion: Structuring Factors in Global Island Colonization

Preliminary Observations

The foregoing has outlined at an empirical level the spatial and temporal patterning of Holocene island colonization, theater by theater. Figure 7 presents the resultant consolidated global pattern, distinguishing between broadly HGF and farming populations, and providing the baseline for much of the interpretative discussion that follows. It is apparent that certain aspects of the pattern observed by Keegan and Diamond (1987) remain robust, while others need revision. On the former front their focus on three great nurseries of maritime mobility as engines of global island colonization remains justified. The Mediterranean, Caribbean, and ISEA with Near

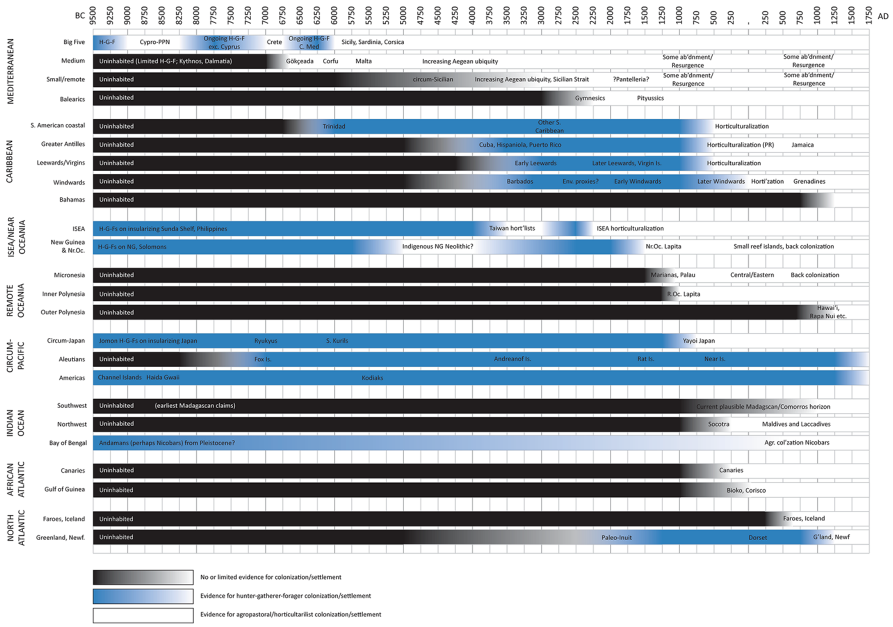


Fig. 7 Schematic of regional processes in Holocene island colonization

Oceania—the first and third with particularly densely interwoven continental and insular geographies—each witness exceptionally early island colonization, led off in all instances by HGF occupation that in the Eurasian examples stretches back unevenly into the Pleistocene, followed by variably later farming colonizations. Truly oceanic spaces were breached last, often only with distance-busting sail-based technologies, although the vectors differ; *trans*-(North) Atlantic, *circum*-Indian Ocean, and directly out into Remote Oceania, the last unmediated by continental contact until end-of-the-line landfalls in South America. Remote Oceania remains the theater in which island colonists demonstrably traveled furthest, although some Indian Ocean distances, if they could ever be shown to be unbroken, might rival these. Conversely Africa, with a long yet largely unindented coastline furnished with few offshore islands, still appears to come relatively late to the insular game, as Keegan and Diamond observed.

On the other hand, subsequent data have undoubtedly altered and complicated the picture since 1987, by bringing entirely new sequences to light, and challenging the previous pattern for certain long-known theaters. Major examples of the former include several Indian Ocean and other circum-African island groups, as well as the surprisingly early dates for a Holocene HGF presence on islands around the northern

Pacific rim from Okinawa to the California Channel Islands. The latter is especially pertinent in the Caribbean, where the chronological data are slowly resolving into a seemingly irreducibly complex set of dynamics. It also obtains in Near and Remote Oceania, where Lapita has been temporally clarified and spatially expanded, including south towards the Torres Strait, while broadly contemporary starts in parts of Micronesia are now well documented and a clear, late signal has been affirmed for much of eastern Remote Oceania. Likewise, the North Atlantic theater has benefited from a major radiocarbon-driven tightening of chronological focus. Even in the Mediterranean, overall the most stable among the previously well-investigated theaters (cf. Broodbank, 2006), ultra-early Holocene dates on Cyprus and the case for an anomalously late arrival at the opposite end of the basin, in the Balearics, prompt reevaluation.

One ongoing challenge to establishing colonization dates that applies across several theaters also deserves note. This involves circumstances where the earliest dated cultural deposits and evidence for environmental perturbations or other ambiguously anthropogenic signatures do not chronologically align. When the temporal gap is small, this can satisfactorily be explained by taphonomic or recovery effects obscuring the earliest cultural evidence; this, for example, is probably the case in Malta, with a divergence of perhaps three or four centuries between large-scale environmental change and dated cultural deposits (Malone et al., 2019; Marriner et al., 2019). Where there is a more pronounced divergence, but more solid underpinning of the lower-dated, cultural horizon, we might well conclude that the antecedent environmental signature was non-anthropogenic, as for example on Palau (Athens & Ward, 2001; Clark et al., 2006). In at least two cases, however, dissonance between the archaeological and palaeoenvironmental data creates an interpretative impasse. First, in the Lesser Antilles dates from archaeological deposits support a 'Southward Route Hypothesis' (Fitzpatrick, 2013, 2015; Napolitano et al., 2019), but dated environmental disruption supports a northward 'Stepping Stone Model' (Siegel et al., 2018). Secondly, on Madagascar, where the earliest unambiguous archaeological deposits date to the first millennium AD (Anderson et al., 2018; Mitchell, 2020a, 2020b), purported butchery marks on avifauna are dated several millennia earlier (Hansford et al., 2018). These questions cannot currently be clarified or resolved without improved data, although broader informed contextualization of the kinds attempted here may be helpful in provisionally selecting the most plausible scenarios.

Interpreting the Patterns: Biogeographical and Wider Environmental Approaches

How much of the structure and variability now established do models grounded in biogeography capture? And how much instead requires recourse to other—cultural and social—modes of explanation? We begin with an exploratory quantitative analysis to assess the continued importance of biogeographic factors, employing a statistical evaluation of the impact of several quantifiable physiographic, geometrical, or configurational (sensu Keegan & Diamond, 1987) variables—plus one readily identifiable cultural variable—on colonization dates for a substantial sample of islands for which robust chronological data are available, and which span our main theaters. We follow this by considering the role of certain other broadly environmental factors that are harder to evaluate in strictly quantitative terms, yet which potentially served to shape global as well as distinctive regional patterns.

The quantitative analysis uses a sample of 49 islands selected for robust and chronologically refined data for first Holocene settlement (i.e., in cases like Okinawa, we ignored preceding Pleistocene occupation) and that span the theaters under discussion. Six variables were used to describe each island: size; latitude; elevation; coastal complexity index; isolation index; and the presence or absence of sailing technology as a readily measurable cultural variable (see Supplementary Information for data and R code). Coastal complexity index is generated by length of shoreline divided by area (essentially a measure of smoothness versus roughness). This variable is relevant in that degree of coastal indentedness has been convincingly associated with autocatalytic sequences (sensu Keegan & Diamond, 1987) in some contexts (for example, Broodbank, 2006), with a 'flat' configuration discouraging maritime experimentation—Atlantic Africa is a good example. Obviously, this attribute applies primarily to the source area, rather than target, of colonization; but as indented littorals tend to co-occur within associated coastal and insular regions, this variable provides a useful and justifiable cipher. The isolation index is defined as the sum of the square roots of the distances to the nearest continent, the nearest island group or archipelago, and the nearest equivalent or larger island (Dahl, 1991). This measure is preferable to raw distance from the nearest continent (for example, Itescu et al., 2019). For the present purpose, dates BC/AD were converted into time before present (BP), the dependent variable in our analyses.

A graphic exploration (Fig. 8) of independent variables and colonization time BP suggests that, of our six variables, the isolation index and known or presumed

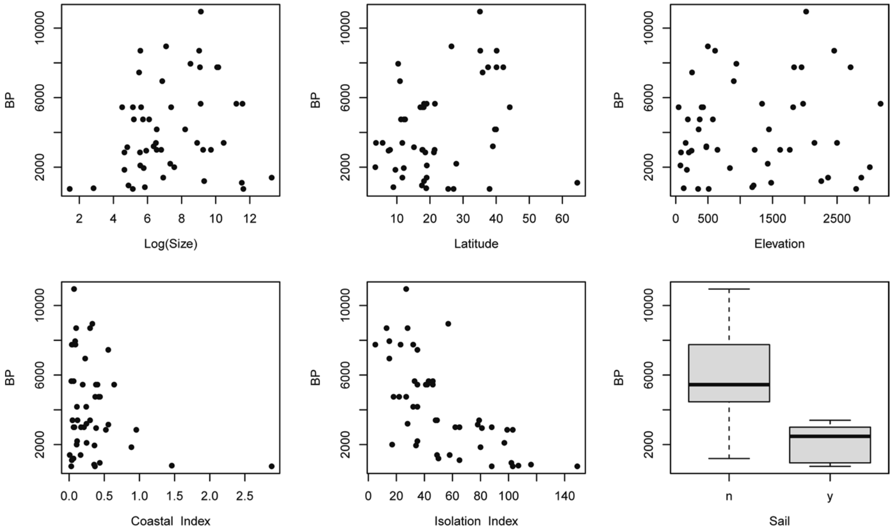


Fig. 8 Independent variables and colonization time BP

Table 1 Top three models by AIC

Model	df (n of parameters)	AIC	Delta	Weight
Isolation Index	3	874.8	0	0.134
Isolation Index + Size	4	874.9	0.11	0.127
Isolation Index + Size + Latitude	5	875.3	0.48	0.105

Table 2 Top three models by BIC

Model	df (n of parameters)	BIC	Delta	Weight
Isolation Index	3	880.5	0	0.449
Isolation Index + Size	4	882.5	2.0	0.166
Isolation Index + Size + Latitude	4	883.8	3.33	0.085

presence of the sail are the best predictors of colonization time. That is, the presence of sails (in Remote Oceania and the North Atlantic) is associated with very *late* colonization episodes. This is perhaps not surprising, but nevertheless useful as a formal affirmation that, beyond certain spatial thresholds, particular technological conditions were fundamentally necessary for oceanic colonization. Given the characteristics of the independent variables (which are not normally distributed), non-parametric tests of correlation were generated with the Mann–Whitney U test for the presence of sail and Kendall's tau for all other variables. These tests indicate there are significant correlations between the sail's presence/absence and BP ($p < 0.00$), isolation index and BP ($p < 0.00$), and a possibly significant correlation between size and BP ($p = 0.10$). All other p-values are between 0.15 and 0.39.

Generalized linear models (GLMs) allow the examination of the effects of more than one continuous dependent variable on BP. This can determine, for example, if a model that includes *both* isolation index and other variables better predicts BP than isolation index alone. GLMs are like multiple linear regression (but do not have the strictures of a normally distributed response variable—here, BP—among others: McElreath, 2020). They compare the regression of the response variable on various combinations of independent variables, with each combination considered a separate model. The efficacy of different models can then be determined using Akaike's information criterion (AIC) and a Bayesian information criterion (BIC), which are used to rank models in terms of information loss (Symonds & Moussalli, 2011). The AIC for each model is calculated from the number of fitted parameters (independents), the residual sum of squares of the model or maximum likelihood estimate, the intercept as an additional parameter, and the variance estimate as a parameter. In general, lower AIC values are better considering a parsimony criterion where less complex models (e.g., with fewer parameters) are preferred over more complex ones. Twenty-six models were constructed of all possible combinations of independents (i.e., an all sub-set approach). The top three models by AIC are presented in Table 1.

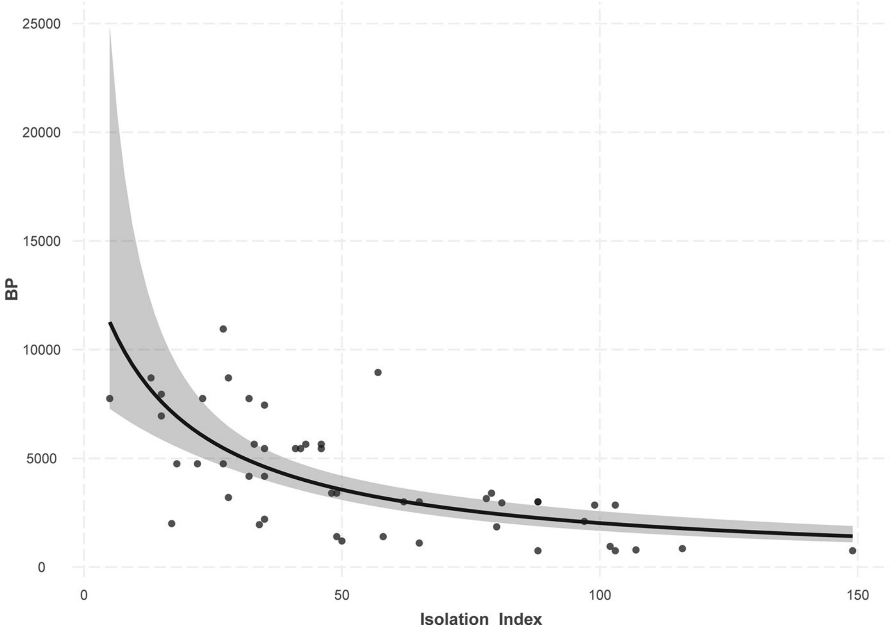
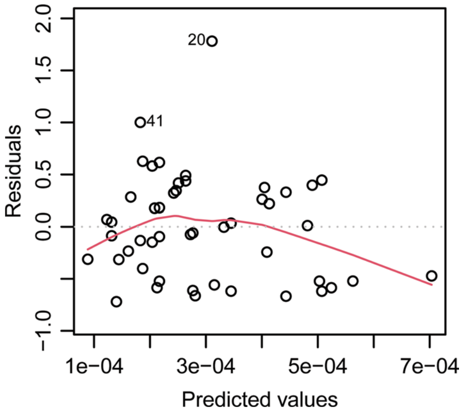


Fig. 9 Isolation Index model fitted to the data with a 95% confidence envelope

Fig. 10 Isolation Index model: residuals versus fitted



Here, delta is the difference between a model's AIC and the top model's AIC. AIC is not just a function of the number of parameters (although it might look like it in this case). There are other models within the 26 evaluated that have lower AICs than either the second or third ranked models, but with greater degrees of freedom. The calculated weight (Akaike weight) allows us to compare how effectively the best-fitting model predicts the data, relative to other models (Symonds & Mousalli, 2011). Weight is a value between zero and one with the weights of all models evaluated summing to one, and is analogous to the probability that a model is the best approximating model. Thus—for example—the Isolation Index model only has about a 13% probability of being the best approximating model.

We can also use BIC to rank our models. BIC is very similar to AIC but is calculated in a slightly different way (Johnson & Omland, 2004), from several terms: (1) a formula using the value of the maximum likelihood function computed from the parameter values that create the highest likelihood of realizing the response variable value; (2) sample size of the response variable; and (3) the number of parameters. The top three models by BIC are shown in Table 2.

Again, the Isolation Index model seems to be the best. In a Bayesian framework weight is not akin to a probability such as for interpretations of AIC, but is an estimation of Bayes Factors, part of a method for determining support amongst competing Bayesian models (McElreath, 2020; Raftery, 1995). Figure 9 shows the Isolation Index model fitted to the data with a 95% confidence envelope, and the actual values. The data are very noisy, hence the low AIC and BIC weights.

Examining the residuals (Fig. 10) reveals two outliers with z-scores greater than 1 standard deviation, Okinawa (case 20), and Cyprus (case 41), both—interestingly—colonized earlier than predicted by the model. Intriguingly, both these large islands witness preceding HGF settlement and therefore present opportunities for knowledge feedback to later colonists.

In summary, the quantitative analyses suggest that the presence of sailing technology predicts late colonization time, for reasons associated with theater-specific adoption of technological innovations that facilitated open-ocean travel; a useful observation at regional but not global scales, and a reminder of the importance of building local specifics into any explanation of patterning. In a generalized linear model framework, isolation alone is the best predictor of colonization time. However, the associated scores are not high, and the data are very noisy. As a result, we suspect that the variables utilized in these models (although clearly important) are not the only ones that account for structure in global island colonization. So the explanatory net will, indeed, need to be widened beyond the purely physiographic, geometrical, or configurational properties we examine here.

The preceding analysis clearly demonstrates an explanatory role for degree of isolation and, to a lesser extent, island area—two variables, along with configuration, that are central to island biogeography. Our broader exploration further bears out the importance of these factors cross-culturally. This is especially the case in the Caribbean and Mediterranean (see now Plekhov et al., 2021), where a handful of very large islands (the Greater Antilles and the Mediterranean 'big five'), or smaller islands with very low isolation indices (Trinidad; the Dalmatian islands), witness much earlier colonization than smaller, remoter islands. Distance, area, and configurational effects also seem relevant in the Gulf of Guinea, and the Ryukyus, Kurils and Aleutians, but less so in the open-ocean contexts of Remote Oceania, the Indian Ocean and the North Atlantic, as discussed further below.

These factors combine to make islands attractive in multiple ways. Accordingly, harder questions need to be asked as to exactly why, for example, big, reasonably easily reached islands were attractive. Was it because they were simply easier to discover; because they could support robust populations; or because they tended to have more varied environments and greater biodiversity? Again, in closely packed theaters (where most outsized islands are found, unsurprisingly given their continental geological origins), sheer distance does not seem to be an insurmountable barrier, with crossings of seldom much over 50 km (a day or two's paddle) in the Mediterranean, to take one case. In this kind of context it does not seem to be their intrinsic discoverability that renders such larger islands attractive, as argued by the first applications of island biogeography to human colonization (Cherry, 1981, 1984; Keegan & Diamond, 1987). Rather, the key attractor was area and (in less abstract terms) area's typical implications for demographic capacity, environmental diversity and sustainability (including of edible or otherwise exploitable animal and plant resources), geological and pedological variety, and maximum elevation (ensuring more varied ecozones, as well as, especially for farmers in semi-arid theaters, orographic rainfall). A big island, once colonized, also brought 'commuter effect' benefits to its neighbors (Keegan & Diamond, 1987, p. 59), in terms of larger overall populations and social networks on which to draw in adversity, or from which to recolonize after an abandonment.

The significance of area may offer insights into divergences between HGF and farming dynamics on islands. Food-acquiring strategies should be more sensitive to area than food-producing strategies, in that they are dependent on non-anthropogenic trophic systems (though this is not a binary division, as these strategies can co-mingle, especially in the tropics). As a result, we should expect insular area to impinge more severely on the colonization dynamics of HGFs. Food-producing communities should be released from these constraints, and yet, critically, still demonstrate preference for larger environments (Cherry & Leppard, 2018a) (we ignore here, to limit an otherwise lengthy discussion, the complicating factor of latitudinal effects on carrying capacity: Freeman et al., 2020). This general observation may be central to building a global account of the relative paucity of HGF versus farming settlement of islands.

Beyond biogeography, but still relating to the environmental and spatial contexts in which islands existed, two further points are worth emphasis. First, although intriguing regionally specific cases have been made that certain climatic conditions might have played a significant role in easing maritime travel to islands (notably a putatively less violent North Atlantic during the Medieval Climate Optimum, and the effect of El Niño events on facilitating eastward voyaging in Remote Oceania: Anderson et al., 2006), the sheer variety seen in the chronology of colonization sequences denies any global-level patterning beyond the overall identification of the Holocene as an island-colonizing window—certainly, Fig. 7 shows no inter-regional correlation of positive or negative activity with, for example, the well-known 8.2 kya climate event.

Second, and more positively, although our exploratory quantitative analysis suggests that absolute latitude has little impact on the timing of colonization at a global scale, several unrelated colonization episodes do display a preference for extension within a given latitudinal envelope. In the Mediterranean, earliest Caribbean, Lapita, initial Remote Oceanic, and Norse cases colonizers moved readily with the latitudinal grain, but less frequently across it, at least beyond broad bands of similarity. Why should this be the case? Coincidence is far from impossible: the Mediterranean has a pronounced east–west orientation, as do the first-colonized Greater Antilles. North Atlantic expansion operated between open ocean to the south and polar environments to the north; and the orientation of equatorial winds in the Pacific, prior to innovations in sail technology, may have militated in favor of west–east movement. Yet latitudinal gradients may equally have been culturally favored, whether for cosmological reasons (the comfort zone within the rising and setting of a key celestial navigation aid?), or, at least for island farmers, due to the limited tolerance of their domesticates for different growing conditions, and the time required to breed adapted strains. As Vander Linden and colleagues (2022) have pointed out, genetic lag in mutation rates (and consequent variation in hardiness or tolerance) of various European Neolithic staples may be relevant to explaining discontinuous range expansion, with the development of landraces increasingly tolerant of latitudinal difference enabling subsequent north–south expansion of farming. Considering the generally late dates for expansion across latitudinal bands in Near and Remote Oceania, such a model could perhaps be most effectively explored in this theater, as the genetic analysis of early Oceanic crops develops. Further possible explanations for the pulse-like nature of certain island colonization sequences are offered below.

Interpreting the Patterns: Social and Cultural Drivers of Island Colonization

Clearly, island biogeographical and broader environmental patterning can explain part but far from all of the behavioral patterning observed. One key point to note is that although successful in addressing the relative timing within regions (i.e., in which approximate order islands were colonized), purely environmental models are less able to shed much light on absolute timing at larger scales—especially given the limited degree to which inter-regional climate fluctuations and island colonization seem to be correlated. As we shall see, absolute timings, regionally and globally, owe more to wider social and cultural factors.

But first, what of autocatalysis, Keegan and Diamond's explanatory model drawing upon both island configuration and human cognitive responses to shed light on why certain island colonizing sequences take off so spectacularly? This model seems exceptionally insightful, with clear relevance not only to the extraordinary take-off of island expansion from ISEA through to Remote Oceania, but also to the Norse *Landnám* across the North Atlantic, where earlier discovery of islands in relatively benign sailing nurseries (the Baltic and North Seas), allied with enormous dispersal range, led to the type of long-distance open-ocean exploration described in Erik's *Saga Rauða*. As Cochrane (2018) argues, expansion through Near Oceania led to iterative colonizing behaviors; aided by innovations in canoe technology, this behavior brought into range Remote Oceania, with its sparser, more far-flung insular geography. In the sense that this exploratory behavior had been 'selected for', it was maintained, honed and enhanced, driving expansion far into the Pacific. Once the actual nature of the island and coastwise expansion that brought an Austronesian language to Madagascar is better understood, autocatalyzing processes may also find purchase in Indian Ocean explanations. At a much more modest level, local autocatalyzing sequences can be identified in many other island groups, including those of the Mediterranean and Caribbean.

It will be self-evident that the most spatially ambitious dispersals just discussed also involved the use of advanced seafaring technology, and specifically the greater speed, cargo-carrying capacity and (in terms of propulsive energy) calorie-light locomotion of sail-driven seacraft. Indeed the initial adoption and progressive refinement of such technology to meet ever-greater challenges in the world of islands can itself be understood as one element of autocatalysis, rendering distance more plastic in terms of human experience and capabilities (Broodbank, 2000, pp. 105–106; 2010). The impact of technology-dependent perceptions of maritime distance was such that, for example, in the absence of the sail little Annobón may have been as, or more, remote from the African mainland as Sāmoa from Tonga. It is unfortunate that our knowledge of the seacraft in which people reached islands is extremely uneven, and for many theaters, especially during the earlier Holocene, based on little more than inference. The minimal assumption is an environmentally suitable subset from a potential range of paddle-driven canoes, reed craft, skin boats or rafts, adequate for short-range and short-term crossings to and between islands. But as we have seen, later colonization dates are strongly associated with the existence of sailing technology, a function of the relatively recent global emergence and development of the sail and associated innovations in select, probably independent regions in western and eastern Eurasia from the third and second millennium BC onward, including modes of navigation suitable for oceanic space and the capacity to sail to windward (Anderson, 2010). This interrelated group of innovations was central to the Late Holocene island colonizing phases in ISEA and Near Oceania, plus the entirety of the Remote Oceanic, North Atlantic and (assuredly, if less directly evidenced) Indian Ocean expansions, though it proliferated too late to have an impact on initial island colonization in the Mediterranean and appears not to have existed in the Caribbean before AD 1492—an observation perhaps in implicit tension with claims for direct long-range colonization events into the heart of the islands from the South American mainland.

It is interesting to note that dramatically increased dispersal capacity did not release island colonists from the impacts of other physiographic variables. In consequence, easing access to remote and/or small islands may paradoxically have increasingly exposed such colonists to the greater risks associated with decreased size and increased remoteness. If so, we might expect exceptional long-range colonizing abilities to co-exist with higher frequencies of localized failures—as is indeed borne out by the examples of Henderson, Pitcairn, Kirimati, Norfolk, and other ‘mystery islands’ in the Pacific (Anderson, 2001), as well as larger islands (Greenland)—or higher rates of subsistence and social crises (for example, Rapa Iti and Rapa Nui: DiNapoli et al., 2018). This ‘bridge-too-far’ effect may account for other less spectacular instances of failed or unsustainable colonization on the outer edges of island worlds.

Trouble at the extremities of expansion apart, one key element of seafaring technology was not simply to enable people to reach islands but to sustain networks of mobility and connection that would allow such ventures to be sustained. Many episodes of island colonization by farming populations are, during their earlier phases, associated with apparently high degrees of interconnectivity. This is evident in the material record, where Lapita (and pre-Lapita in ISEA: Cochrane et al., 2021), Saladoid, and Impressed wares in the Pacific, Caribbean, and Mediterranean respectively index broadly shared potting traditions, as well as long-distance circulation of lithic resources (especially obsidians and cherts: Best, 1987; Çilingiroğlu & Çakırlar, 2013). That this cultural homogeneity reflects deeper inter-community mobility is now supported by various bioarchaeological datasets from the Caribbean and Remote Oceania (see references in Laffoon & Leppard, 2018), as well as by a similar diachronic meta-study from the Mediterranean (Leppard et al., 2020). Paleogenomic studies from the Caribbean, Mediterranean and Pacific suggest this mobility operated at very large scales (e.g., Fernandes et al., 2020; Mathieson et al., 2018; Nägele et al., 2020; Olalde et al., 2015; Skoglund et al., 2016). However, soon after the earliest phases of colonization, inter-island mobility appears to contract in these theaters (if sometimes only temporarily). Interaction networks in the Caribbean become more localized over time (Hofman et al., 2011), as also in the Mediterranean (Broodbank, 2000, pp. 163–164). Inter-island connectivity in the Pacific seems to become less frequent in the aftermath of local colonization horizons, and trading networks in the small fringing islands of New Guinea and Wallacea also operated at reduced spatial scales, albeit highly intensively, starting in the first millennium AD.

The initial pattern of extensive material inter-connections is most readily explicable in terms of the need for small, potentially fragile groups dispersing over extensive areas to maintain long-distance ties to avoid demographic crunches, for example through long-distance exogamy (Jordan et al., 2009; Leppard, 2015). Such marital residence mobility might express itself materially as broad areas of cultural homogeneity if craft production was at least in part a gendered activity. As populations grew after initial colonization, the need to offset the fragility of small populations via exogamy relaxed, long-distance mobility waned, and material culture reflects more parochial patterns.

The broader issue of the distribution of populations (both pre-existent and incoming) is otherwise relevant to some of the regional sequences. Specifically, extant populations may have rendered some options unattractive to newcomers, a factor recognized by Keegan and Diamond (1987) under the banner of ‘competition’ (distribution models in human behavioral ecology predict comparable effects, for example, Jazwa et al., 2019). Norse interaction with indigenous populations, for example, can be understood in these terms. In ISEA, as we have seen, previously established populations on the largest islands seem to have influenced the directions and spatial patterning of incoming maritime groups, who maintained spatially discrete settlement (even if pre-existing exchange networks became potentially attractive to newcomers).

Elsewhere, however, the situation appears to have been rather different. Allee (1931) demonstrated that in a low-density demographic environment an extant population may in fact be an attractor, and some established populations indeed appear to have been an attractive factor. In the Caribbean, the otherwise perplexing spatial overlap between long-established Late Archaic and incoming Early Ceramic Period settlement in the Leewards might be explicable in these terms. Recently established colonizing populations may have been equally attractive. In the Mediterranean, we have suggested that big islands were partly favored due to their capacity to support large, stable populations. Iceland also witnessed rapid in-filling, as did parts of Aotearoa New Zealand and optimal niches in the Hawaiian group.

Allee effects wane rapidly, however, as populations grow beyond the point that optimal habitat is fully occupied, and accordingly lower-ranked habitats start to fill. The North Atlantic is again instructive, with prime settlement sites in Iceland occupied first, and the rapid settlement of the whole island—including marginal regions—prompting further onward movement westwards (Schmid et al., 2021). This process of self-reinforcing growth, followed by increasing demographic pressure that renders the risk of further long-distance colonization increasingly tolerable, should have a discontinuous spatial and temporal signature. It is therefore interesting that temporally discontinuous aspects of island colonization have long been noted: the Remote Oceanian 'long pause' (cf. Keegan & Diamond, 1987, p. 67); highly discontinuous movement through the Caribbean (i.e., the Saladoid/post-Saladoid interface: Fitzpatrick, 2015); and arrhythmic (Guilaine, 2001) farming expansion through the Mediterranean. There are other viable explanations for this discontinuous pulsing, as discussed above, including climatic changes and latitudinal constraint—but its broad incidence may indicate some cross-cultural effects of growing island demography in the aftermath of colonization (cf. Leppard, 2014).

A Final Perspective: Island Colonization and Continental Dynamics

Our focus in this synthesis has been on islands, globally. However, as colonizing populations ultimately derived from neighboring continents, it is also instructive to relate processes in these maritime worlds back to those unfolding within continental cores. Our analysis suggests that, in addition to biogeography, and insular and wider maritime social and cultural factors, a range of large-scale processes within the Americas and Afro-Eurasia may be more closely implicated than is broadly recognized in the processes along and beyond their coasts that we witness archaeologically as island colonization.

Firstly, and most obviously, several regional episodes of island colonization should be understood as extensions of bigger, continental Neolithization processes. For reasons we do not address in detail here—although the insular data may hint at the nature of the process—the emergence of food-producing economies was often followed by spatial expansion (Bellwood, 2011; Diamond & Bellwood, 2003). In the Mediterranean, earliest island settlement by agropastoralists should be understood within this broader outflux around the basin (Broodbank, 2013; Leppard, 2021), and in the Gulf of Guinea early activity on Corisco and Bioko aligns well with the Bantu expansion. In the Caribbean, the arrival of more fully horticultural (food-producing) and Arawakan-speaking communities is arguably the outstretched limb of gradual processes of domestication and growth originating deep within the South American continental interior. The expansion of food-producing lifestyles on the coast and islands of East and Southeast Asia is admittedly more complicated and less fully understood, but again there is a suggestive similarity in timing with the terminal Mid and early Late Holocene island colonization horizon in ISEA.

Continental dynamics may be relevant in other ways too, most notably on several of the maritime margins of Eurasia. For example, 3000–1000 BC witnessed the florescence of large and sometimes urban polities in central East Asia (Liu, 2009). This period saw increased maritime mobility, including pelagic fishing and voyaging, in the East and South China Seas, and the initial Yayoi farming colonization of the Japanese main islands is now dated to at least 900 BC. Increased coastal activity in and after state formation on the continent finds parallels in the terms of the growth of maritime and specifically island networks in the Mediterranean world over a similar timespan, driven in part by reorientation of island resources towards new continental consumption centers (Broodbank, 2013). In both cases, targeted archaeological exploration of the critical deltaic junction points might shed light on the translation of continental practices and new riverine transport technologies to maritime and ultimately insular conditions. In ISEA further evidence for maritime mobility and reconfiguration of maritime networks in the early first millennium AD—perhaps linked to Indian Ocean activity of the kind glimpsed in settlement of Madagascar and the Nicobars—occurred in the context of the integrative processes immediately prior to the emergence of Iron Age states by mid millennium (Stark, 2006). In a similar way, the dry, northern circum-African islands of the Canaries and Socotra witness first colonization in the wake of the rise of Iron Age imperial states to their northeast and north, respectively, and the emergence of economic links between these and adjacent areas of Africa. Last but not least, the Norse expansion occurred in the wake of political centralization and integration within Scandinavia, a process that, as Barrett (2008) emphasizes, had ramifications for the negotiation of social status and that created not only winners but also losers, potentially liable to seek their fortunes elsewhere.

These temporal connections are probably too nebulous to demonstrate an unambiguous causality, but are nonetheless suggestive. Several island colonization episodes in the low–mid latitudes certainly correspond approximately with the emergence of large-scale continental societies (although there are clear exceptions, for example the lack of discernable impact of the emergence of the first Mesoamerican states on the Caribbean); and these episodes may be related directly or indirectly. In direct terms, these expansions away from burgeoning centers of political power may reflect Scott's observation (2009, 2017) that state-making tends to be convulsive. Institutionalization and territorialization demand co-option, and rejection or avoidance of these processes in turn drives mobility. Increased mobility on the fringes of state-making may, then, represent flight away from incipient centers of power. In indirect terms, marginal colonization (i.e., movement into lower-ranked environments) is one in a suite of responses to the types of demographic packing widely attested in complex societies—that is, a common type of ecodemographic pressure is resolved along two distinct pathways with nonetheless comparable archaeological outcomes. Conversely, the new types of wealth and demand often attendant on urban/state societies, alongside expanding economic networks and the comparative ease of bulk water transport, may provide an impetus for the long-range exploitation of marine and insular environments and resources that simply did not exist in the absence of formalized social hierarchies.

These points are far from intended to reduce patterns in global island colonization to functions of mainland process, but adopting a global and deep-historical perspective undoubtedly encourages an evaluation of certain island colonizations in the light of transformative continental dynamics during the Middle to Late Holocene. Equally, it enables a productive move beyond both localized ('insular') and generalized (for example, purely biogeographic or environmental) models.

Conclusions

We have synthesized the available global data relating to the colonization of islands during the Holocene, updating and building on previous work at this scale. At a global level, the outcome reinforces observations on patterning implicit in Keegan and Diamond's paper: that the global maritime mobility 'nurseries' in the Mediterranean, ISEA, and the Caribbean fostered early offshore colonizing activity; that the emergence of the sail within the former two contexts generated the dispersal capacity necessary for open-ocean colonization; and that, at this global scale, climate dynamics have no obvious pan-regional explanatory capacity. Beyond such broad-strokes conceptualization, however, our goal in analyzing the shape and tempo of colonization was—as well as an appreciation of the intrinsic richness of global variation—to understand how common factors beyond the local have shaped such behavior cross-culturally, and to assess how islands and islanders contributed to macro-scale historical trends during the last ten thousand years. In pursuit of this, we undertook an exploratory quantitative analysis, which demonstrated the enduring relevance of major environmental variables in accounting for spatial and temporal patterning in global island colonization, while also recognizing that global analysis can obscure behaviorally relevant regional patterns. On the strength of this latter observation, we have drawn upon regional results to consider which extra-environmental factors may have contributed to evident patterning.

This process has resulted in some expected observations and affirmations of the importance of various structuring effects in island colonization. Variables including area, distance effects, and configuration demonstrably were important during the colonization of islands during the Holocene, and probably prior to that. Additionally, autocatalytic effects encouraged colonization processes, reaching their apogee in selection-driven range expansion in Remote Oceania. Recognizing that certain types of behavior in certain types of novel environment can become iteratively established, we see the concept of selection (and parallel concepts) for long-distance dispersal behaviors (Cochrane, 2018) as globally useful. What renders such increases in fitness possible are types of pressure in particular populations, and here various demographic dynamics (including 'competition' broadly conceived) play a role.

Our observations include the recognition that various types of environmental variability probably constrain HGF colonization processes, constraints not experienced by communities more reliant on produced, rather than acquired, calories. This, we suggest, has global explanatory capacity for the occurrence, structure and timing of HGF colonization activity (while recognizing that food acquisition and food production can co-exist in mixed economies, especially in the lower latitudes). We have also, when it comes to agropastoralist or horticulturalist island colonization, identified a ‘bridge-too-far’ effect as dispersal capacity increases but ability to tolerate environmental intransigence does not; and we have shown that arrhythmic, pulsing dynamics characterize island colonization processes globally. This last may potentially be explained by latitudinal constraint, but a role for demographic processes (of the type, perhaps, described by Ideal Distribution Models) seems likely.

Despite vast differences in spatial scale, patterning in different theaters can indeed be understood as part of more generalized processes, and the above combination of factors explains why discrete episodes of island colonization may exhibit comparable structure. Yet our analysis also implicitly suggests why such processes occurred at all. Relative to size and other physiographic factors, islands can represent sensitive and risky types of environment, and human occupation of them may require distinct motivating forces, and pressures within the source community (of whatever scale). At an abstract level, our review suggests that demography can be a proximate cause of movement: how a population is distributed in a landscape, and how resources are distributed within that population, seems broadly relevant to understanding the deep causes of Holocene maritime dispersals. Our final novel observation, then, is continental. We suggest that the most likely contexts for explanation involve: (1) initial Neolithization and subsequent horizontal movement of farming lifestyles; and (2) the dynamic processes that lead to the emergence of large-scale, integrated, and urban continental societies. The former is largely predictable, in that many island colonization events can be considered more generally as specific types of dispersal by food-producing or ‘mixed’ regime groups. The latter is surprising, and suggests that we now need to grasp how early transitions towards large-scale societies can, in different types of context, drive deeply divergent behavioral process—both centripetal and centrifugal.

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Authors' Contributions CB and TPL conceived the study. TPL, CB, EEC, DG, CLH, JEL, and MMEB researched, wrote, and edited the manuscript. EEC prepared the code, performed the statistical analysis, and prepared the supplementary materials.

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Data Availability Supplemental materials for this paper include a detailed RMarkdown document outlining all steps of analysis. Alongside the RMarkdown document are additional files necessary to replicate this study.

Declarations

Conflict of interest The authors declare no conflict of interest.

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