



# The maternal ancestry of the Kavaratti islanders and the last glacial maximum aftermath

Alnoman Mundher Tayyeh<sup>1,2</sup> · Jaison Jeevan Sequeira<sup>1</sup> · Lomous Kumar<sup>3</sup> · Idrees Babu<sup>4</sup> · George van Driem<sup>5</sup> · Mohammed Shafiu Mustak<sup>1</sup>

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## Abstract

The prehistoric human settlement of the Lakshadweep islands remains a mystery for various reasons. Uncertainty about the existence of indigenous tribes in these islands and the lack of folklore records present major obstacles to the reconstruction of Lakshadweep ancestry. However, with extant population data, we seek to understand the maternal ancestry of the Kavaratti islanders. Mitochondrial control region variation analysis of 80 individuals from this island shows maternal links with the populations in the northwestern region of the South Asian mainland. The founder clade R30b2, observed in the Kavaratti islanders, is so far present only in the Scheduled Castes from the Punjab region, Jat Sikhs and Nairs. All other mainland populations carry basal R30 or R30a subclades. The presence of a specific Uralic U4 lineage in our samples, in addition to the Indo-European affinity observed in the phylogeny tree, substantiates a northwestern maternal ancestry of the Kavaratti islanders and implies an ancestral admixture with early humans in the Near East at the time of the last glacial maximum (LGM). Based on our Bayesian analysis, we furthermore propose that a group bearing mostly R30b2 during the LGM recovery, moved eastward and southward, where they received Indian-specific M haplogroups. Hence, the maternal ancestry of the Kavaratti islanders is evidently a consequence of the demographic changes in the northwestern region of the Indian subcontinent caused by the Last Glacial Maximum. The haplogroup distribution pattern and nucleotide sequence data produced in this study will enrich the forensic database of the Lakshadweep islands.

**Keywords** Kavaratti · Lakshadweep · Maternal ancestry · Mitochondrial DNA · R30 haplogroup

## Introduction

The prehistory and settlement of the Lakshadweep (Lakṣadvīpū) islands, long known in English and other Western languages by the *tadbhava* form of the native name for the archipelago as the Laccadive Islands, has interested numerous researchers and historians. However, the question as to who the earliest settlers of this archipelago were still awaits an answer. We seek to solve this puzzle with genetic data. Even in the decade of high-throughput next generation sequencing, mitochondrial DNA remains an important tool for identifying and dating deep maternal lineages of antiquity that are present in extant populations. Studies rely on haplogroup frequency distribution and the divergence times of haplogroups in order to understand the clustering patterns within and between populations. In this study, we identify haplogroups prevalent in the Kavaratti islanders ( $n = 80$ ) of the Lakshadweep archipelago. We then use the haplogroup frequency distribution pattern as well as the control region

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✉ Mohammed Shafiu Mustak  
msmustak@gmail.com

- <sup>1</sup> Department of Applied Zoology, Mangalore University, Mangalagangothri 574199, India
- <sup>2</sup> Department of Biosciences, Biotechnology Unit, Mangalore University, Mangalagangothri 574199, India
- <sup>3</sup> CSIR-Centre for Cellular and Molecular Biology, Hyderabad, Telangana 500007, India
- <sup>4</sup> Department of Science and Technology, Lakshadweep Administration, Kavaratti 682555, India
- <sup>5</sup> Institut für Sprachwissenschaft, Universität Bern, Länggassstrasse 49, 3012 Bern, Switzerland

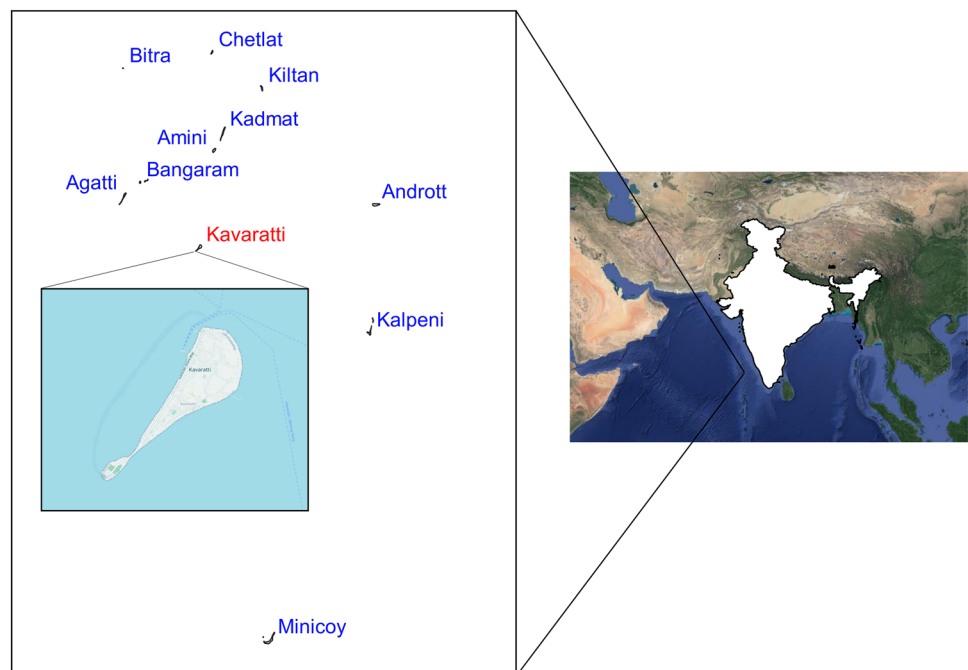
sequence variation information obtained from various datasets to perform multivariate analysis. In addition, we construct maximum likelihood and Bayesian phylogenetic trees to date the coalescent age of these clusters. Interestingly, all our analyses point towards the northwestern region of the Indian subcontinent and date the maternal ancestry of the Kavaratti islanders to the Last Glacial Maximum. This study will provide an important direction for future research emphasising the repercussions of the LGM in shaping the gene pool of both northern and southern ancient populations.

The Lakshadweep Islands are located off the southwest coast of the Indian subcontinent. Kavaratti Island is one of the 36 islands of this archipelago. Kavaratti Island is surrounded by Agatti and Amini in the north and Āndrōttū and Kalpēni in the east (Fig. 1). The nearest distance from the city of Cochin (Kocci) on the Malabar Coast is 404 km. Kavaratti is the capital of the Lakshadweep Union Territory. In the 2011 census, the population was 11,221. Socio-culturally, all the islands except Minicoy are similar, with the majority following Islam and mostly involved in coconut plantations, jute trade and fisheries. Minicoy, which is closer to the Maldives, has undergone the greater influence of Maldivian customs. The Lakshadweep population comprises four tribes, i.e. Aminidivi (Aminidīṭṭṭ), Kōya, Mālumi and Mēlāccēri. However, the aboriginal tribes are believed to have gone extinct with the arrival of the ancestors of the present-day inhabitants, who have characteristics of the Malabārīs of Kerala. The Kōya take pride in tracing their ancestry to Nambūdīri Brahmins and occupy the highest stratum on the islands, whereas the Mālumi and Mēlāccēri provide services to the Kōya. The Mēlāccēri

dominate the northern islands. The Mālumi are believed to have descended from the seafaring Urukār ‘boatmen’ class of the Malabar Coast. The Mēlāccēri are believed to be descendants of the Tīyyar tribe (Gabriel 1988).

*The Periplus of the Erythraean Sea*, dating from the first century AD, mentions the Laccadives as ‘islands off the Malabar coast’ (τὰς νήσους...αὐτῆς τῆς Λιμυρικῆς) as a source of tortoise shell, and mentions the two islands Αἰγιδίον (Aigidion) and Καίνειται (Cæneitæ) as a hideout for pirates (Arrian and Strabo 1533; McCrindle 1878; Schoff 1912). Gray (1889) identified the islands Αἰγιδίον (Aigidion), Κάναθρα (Canathra), Μονάχη (Monachè) and Ἀμμίνη (Amminè), mentioned in the second century AD by Claudius Ptolemy in his *Geography*, with the Laccadive islands Kavaratti, Agatti, Amini and Minicoy, respectively. The Καίνειται (Cæneitæ) of the Periplus and Ptolemy’s Κάναθρα (Canathra) may both represent Occidental renderings of the name of Kavaratti, and we also suggest that Ὀρνέων (Orneorum) and Καλαδαδρούα (Calandadrua) in the same archipelago may have represented Ptolemy’s Graeco-Roman renderings of the original names of the islands known today in modern Malayālam as Baṁkaram and Kiltān, respectively (Moletius 1562; Nobbe 1845). The Kavaḍidivīpa mentioned in the twelfth century inscription at Narendra (Barnett 1915) and in another contemporaneous inscription of the Goan Kādamba dynasty as Kāpardikadvīpa (Fleet 1870) is probably Kavaratti (Tripathi 2006). Human settlement on the Laccadives no doubt dates back to antiquity. Forbes (1979) contends that a wave of Hindu immigrants from the Indian mainland settled on the island in or around the seventh century AD. The older inscriptions on

**Fig. 1** Map showing Kavaratti island in the Lakshadweep archipelago located off the southwest coast of India



the Laccadives are in the Vaṭṭeluttu script and are anterior in date to the inscriptions in Arabic script. The dating of the introduction of Islam to the Laccadives remains problematic, but the formerly Buddhist island realm of the Maldives, including Minicoy, were not converted to Islam until the middle of the twelfth century AD.

Not many genetic studies have been undertaken on the population of the Laccadives. Mustak et al. (2019) studied the maternal and paternal ancestry on eight islands. The study concluded that the maternal ancestry of the islanders was related to South Indian populations, whilst the paternal lineage derived overwhelmingly from North Indian and West Eurasian haplogroups. Kavaratti island was not included. In the present study, we address this gap by generating forensic data for an important island from the Lakshadweep archipelago in the form of mitochondrial DNA sequences. A recent study that focused on the Mēlāccēri tribe (Anthropological Survey of India 2021) found only two haplogroups, viz. M30 and R30, each with very low nucleotide diversity, confirming a strong bottleneck event. In order to understand the cause for such a founder effect, in the present study, we emphasise the R30 and M2 haplogroup distribution. We also assess the impact of the Last Glacial Maximum (Malyarchuk et al. 2010; Silva et al. 2017; Shamooun-Pour et al. 2019) as a possible cause for the change in population dynamics in the Near East.

## Materials and methods

### Population sample

Blood samples were randomly collected from 80 unrelated males residing on Kavaratti Island. Informed consent was obtained from the participants. The study was conducted after obtaining the approval of the Institutional Human Ethics Committee of Mangalore University in accordance with the guidelines in force.

### DNA extraction and genotyping

DNA was extracted using the standard Phenol Chloroform method. Non-coding hypervariable segments in the control region were amplified using ABI Veriti 96-well Thermal Cycler (Applied Biosystems). For improved resolution, the coding region (11,948–12,772 and 14,856–15,978) covering 2028 bp was also amplified. Primer details are given in ESM\_1 Table 1. PCR products were sequenced using Sanger sequencing technique (ABI 3130xl Genetic Analyser, Applied Biosystems). The mtDNA sequences were aligned against the reverse Cambridge Reference Sequence (rCRS) in Ugene Unipro Software (Okonechnikov et al. 2012). Variations were scored, and haplogroups were assigned according to Phylotree 17 FU1 (Dür et al. 2021), using Haplogrep

**Table 1** Haplogroup distribution in Kavaratti Island

Haplogroup	Frequency (%)	Subclade	Count	Frequency (%)
A	1.3	A14	1	1.3
G	1.3	G3a1'2	1	1.3
M	1.3	M	1	1.3
<b>M2</b>	<b>19.2</b>	M2	1	1.3
		<b>M2a'b</b>	<b>14</b>	<b>17.7</b>
M21	1.3	M21b1a	1	1.3
<b>M3</b>	<b>10.3</b>	M3	1	1.3
		<b>M3a1 + 204</b>	<b>7</b>	<b>9.0</b>
<b>M30</b>	<b>7.7</b>	M30	3	3.8
		M30 + 16,234	3	3.8
<b>M33</b>	<b>10.3</b>	<b>M33a</b>	<b>8</b>	<b>10.3</b>
M4'67	2.6	M4'67	2	2.6
M9	1.3	M9a4a2	1	1.3
<b>R30</b>	<b>32.1</b>	<b>R30b2</b>	<b>25</b>	<b>32.1</b>
U2	1.3	U2c	1	1.3
<b>U4</b>	<b>10.3</b>	U4	2	2.6
		U4b1a1	2	2.6
		<b>U4b1a1a1</b>	<b>4</b>	<b>5.1</b>
			<b>78</b>	

Haplogroups with higher frequencies are in bold

2.4.0 software (Weissensteiner et al. 2016), followed by a EMPOP database query check (Huber et al. 2018). Two samples showing ambiguous results were excluded from the analysis. Data generated during this study are available in the supplementary file ESM\_2.

### Statistical analysis

DnaSP6 software (Rozas et al. 2017) was used to calculate nucleotide diversity, haplotype diversity and Tajima's D indices, based on sequence variation. For comparative analysis, pairwise  $F_{st}$  among different populations was calculated using Arlequin Software (Excoffier and Lischer 2010). The same software was used for AMOVA (Analysis of Molecular Variance). PAST4 software (Hammer et al. 2001) was used for multivariate analysis, such as Principal Component Analysis (PCA) and Neighbour Joining (NJ) Tree clustering. M2 and R30 haplogroup network analysis was performed using the POPART package in R (Leigh and Bryant 2015). The Phylogeny Tree was constructed using Mega 11 software (Tamura et al. 2021).

### Bayesian analysis

Bayesian age estimation was performed using BEAST v2.7.4. Samples were filtered based on the haplogroups. Ancient mitogenomes (with higher coverage and C14 dates) from AmtDB were used for calibration (Ehler et al.

2019). The L2c2 mitogenome from a Moreno individual (PaMOR16007) was used as an outgroup. BEAST runs were performed using the non-coding region sequences. Trees were linked, and runs were performed with the HKY substitution model. A strict molecular clock was chosen with mutation rates of 1.292 and 0.369 mutation/site/million years for the HVS1 and HVS2 region, respectively (Connell et al. 2022). A consensus tree was generated using Treeannotator with the following settings: 50% burnin, Common Ancestor Heights. Consensus tree was pruned in iTOL. In Figtree, the tree was rerooted to L2c2 outgroup. Median Heights with 95% HPD (High Probability Densities) were considered as TMRCA and reported. All the runs were performed with 5,000,000 burnin and 50,000,000 iterations, drawing samples at intervals of 10,000 MCMC (Markov chain Monte Carlo) steps (Olivieri et al. 2017; Brandini et al. 2018; Capodiferro et al. 2021).

## Results and discussion

### Genomic diversity in the Kavaratti islanders

Haplogroups R30b2 (32.1%), M2a'b (17.7%), M33a (10.3%), M3a1+204 (9.0%) and U4b1a1a1 (5.1%) account for about 70% of the total mtDNA variation on Kavaratti Island (Table 1). The abundance of macrohaplogroup M (51%) in this population resembles mainland populations of the Indian subcontinent (Anthropological Survey of India 2021). Macrohaplogroup R accounted for 32% of the total distribution. The U4 haplogroup occurred at 10% frequency. Viewed at the macro-level, this population carries Indian-specific M and ancient N in relatively equal proportion. These two haplogroups contrast with the mainland tribal gene pool, which shows a significant difference between the two. Interestingly, such equal distribution is also a characteristic of Northern India (Anthropological Survey of India 2021).

Great importance is ascribed to the distribution of M2 in the Indian mainland as far as autochthonous haplogroups are concerned. The frequency of haplogroup M2 in Dravidian tribes is higher than it is in Indo-European speakers (Metspalu 2004). This variation is geographically correlated as well, with a higher prevalence in central and western tribes (Kumar et al. 2008) and traces in eastern tribes like Munda and Mal Pahariya. Betta Kuruba is an exception with the highest M2 frequency (~40 to 60%) in the mainland. On Kavaratti island, haplogroup M2 accounts for 19.2% of the variation, suggesting its deep ancestral link with these ancient tribes (Kumar et al. 2008; Anthropological Survey of India 2021). Our data allow us to resolve the M2 haplogroup up to the M2a'b subclade with mutations at 447, 16,274 and 16,319 (van Oven and Kayser 2009). Earlier studies have

shown a higher prevalence of the M2a subclade in populations in the eastern part of India (Metspalu 2004), whilst haplogroup M2b peaks at 35.65% in Betta Kuruba and is generally absent in tribes of the western region (Kumar et al. 2008; Anthropological Survey of India 2021). Therefore, the two lineages of M2 are evidently unique. Without the coding region mutations, the presence of M2a on Kavaratti Island cannot be confirmed. However, the absence of diagnostic mutations for 'Dravidian' M2b and M2b2 in the non-coding region, i.e. transition at 182 and poly 'A' at 16,180–19,182 followed by 12 'C's and transition at 16,295, respectively (Kumar et al. 2008), hints at a unique ancient lineage of M2 on this island that is different from the one prevalent in southern tribes. To substantiate the uniqueness of the M2 lineage on the island, we performed network analyses of M2 individuals from various datasets. Our analyses of data show a separate cluster for the Kavaratti islanders (ESM\_1 Fig. 4). Furthermore, Bayesian analysis of M2 sequences from the available databases clustered the M2 subclade found in Kavaratti island separately. This Kavaratti M2 cluster shares a common ancestor with the northwestern M2 clade, and appears to be younger (41,611 YBP, 95% HPD: 18,983–68,032) than the other clades found in the Indian subcontinent (ESM\_1, Fig. 5 and Table 4) with coalescence times of 46–57 thousand years. Earlier studies have reported a broader range for the time to the most recent common ancestor for M2 subclades in India (Metspalu 2004; Kumar et al. 2008; Chandrasekar et al. 2009), with M2a dated between 21 and 50 thousand years and M2b dated between 12 and 55 thousand years. Nevertheless, with the exception of M2, which seems to be absent in our samples, the time to the most recent common ancestor for M2a fell in the pre-Last Glacial Maximum period. This time frame for the Kavaratti M2 cluster in addition to its affinity towards the northwestern M2 clade suggests that our samples share M2 ancestry with the northwestern populations.

Another haplogroup that belongs to the pre-LGM is R30. To substantiate this claim, our Bayesian analysis, involving all the available R30 sequences, showed an increase in the population size ~27 kya (ESM\_1, Figure 11). However, the only subclade present on Kavaratti Island is R30b2 (32.1%). Our results are similar to the findings of the earlier studies, which showed a higher prevalence of haplogroup R30 on the Lakshadweep Islands (Mustak et al. 2019; Anthropological Survey of India 2021). Mustak et al. (2019) report R30 frequencies ranging between 60 and 80 percent in some of the northern islands of the archipelago. A control region sequence analysis of R30 samples in the Kavaratti islanders shows very low haplotype diversity ( $Hd=0.417$ ) and nucleotide diversity ( $\pi=0.00152$ ), suggesting a recent population bottleneck or a founder event (Grant and Bowen 1998). All of these pieces of evidence motivates us to conclude that R30b2 is indeed a founder haplogroup for the Lakshadweep



population. The reported coalescent age of the R30b2 subclade is approximately  $16 \pm 8.4$  KY (Chaubey 2013), corresponding to the timeline of the LGM recovery (Clark et al. 2009; Hughes and Gibbard 2015). Based on our Bayesian analysis, we establish a time to the most recent common ancestor of 17,616 (95% HPD: 6661–32,561) for R30b2 (ESM\_1, Fig. 6). Discrepancies were observed in earlier studies (Chaubey 2013; Ranaweera et al. 2014) regarding the distribution of R30 in the Vedda tribe on Sri Lanka. The observed R30 haplogroup distribution is mainly due to the exclusion of the diagnostic mutation at 373, which is one of the diagnostic mutations for R30 (van Oven and Kayser 2009). When these sequences were reanalysed, we found that the Vedda tribe carry only traces of R30 lineages (~3%, unpublished), whereas the Urali Kuruman draw 35% of their ancestry from the R30a1c subclade, with a coalescent age of ~9.4 KY (Sylvester et al. 2019). We report a time to the most recent common ancestor of ~12,000 years for R30a1c, whilst the R30a clade dates back to ~39,000 YBP. While both of these tribes carrying R30a and R30b are from the southern subcontinent, clade R30 is believed to have originated in northern India (Palanichamy et al. 2004), with specific subclades in Nepal (Fornarino et al. 2009) and Iran as well (Derenko et al. 2013). Interestingly, caste groups such as Reddy, Bhargava and Thogataveera (Palanichamy et al. 2004) also carry traces of R30 subclades, strengthening the hypothesis of their ancestral links with the Near East. The R30b2 subclade found in the Kavaratti islanders also occurs in scheduled caste populations in the Punjab and in Jat Sikhs (Singh et al. 2021). All of this suggests that the founder haplogroup R30b2 must have entered the Lakshadweep islands from the mainland during the LGM recovery phase when the sea level was reduced and the island was closer to the Indian subcontinent (Clark et al. 2009; Kim et al. 2023).

Besides M2 and R30, the only other haplogroup found in our samples with a time to the most recent common ancestor anterior to the LGM is M33. Like M2 and R30, the M33 cluster is unique in Kavaratti. Moreover, this clade appears to have separated from the other mainland clades ~50,000 years ago (ESM\_1, Fig. 7). The time to the most recent common ancestor of the M33a clade found on Kavaratti Island is 33,381 years ago (95% HPD: 11,829–56,166). Unlike R30 and M2, the subclades of M33 are spread throughout the Indian subcontinent. A commonality among these three haplogroups is their deep-rooted presence in the northwestern region of the subcontinent. A Bayesian Skyline Plot shows an increase in the population size of M33 carriers ~19,000 years ago. Two other subclades of M, namely M3 and M30, show a post-LGM increase in the effective population size and a time to the most recent common ancestor of ~20,000 YBP (ESM\_1 Fig. 8 and Fig. 9), suggesting that it was indeed the LGM that had driven these haplogroups southward. Haplogroup M33 is

mostly found in central and western populations with the exception of Mal Pahariya. Similarly, haplogroup M30 is predominantly present in western tribes, such as the Kathodi, Mathakur, Kathakur, Khatri, Koraga, Nihal, Bhil and Andh. Haplogroup M3 peaks at between 10 and 30% in the northwestern region of the subcontinent, encompassing Pakistan, Kashmir and the Punjab. The Jenu Kuruba and Koraga tribes from the southern region show a higher frequency of M3 along with the Kamar and Kathodi from the western region. It is plausible that whilst one group reached the Lakshadweep archipelago, ancestors of the other afore-mentioned ancient tribes moved into the Indian peninsula carrying the pre-LGM genetic footprint of the northwestern region of the subcontinent, which included these M subclades. The other possibility is that the M3 cluster, which oddly shows a time to the most recent common ancestor of 1070 YBP (95% HPD: 205–2158), entered Kavaratti island between the second and twelfth century AD, as mentioned in documented history (Forbes 1979).

The western Eurasian haplogroup U4 peaks at 24% in the Volga-Ural region north of the Caspian Sea (Bermisheva et al. 2002). Haplogroup U4 is also found at varying frequencies in Central Asia, the Near East and Anatolia (Quintana-Murci 2004). Based on the comparison of the available U4 sequences, we suggest that our U4 samples, a sample from the northwestern region of the subcontinent (Singh et al. 2021) and a few ancient European samples from AmtDB (Ehler et al. 2019) belong to a lineage with 16356C and 16362C variations that are found in the 'Uralic' lineage of the Eastern European U4 cluster, originating around the LGM time depth (Malyarchuk 2004; Översti and Palo 2022). The time to the most recent common ancestor of the U4 cluster found in the Kavaratti islanders is ~13,000 YBP. One U4a2 sample from Kavaratti shows a time to the most recent common ancestor of ~28,000 YBP. Although these estimates are based on the control region sequences, the time depth of increase in the U4 effective population size in the vicinity of the LGM suggests that the U4 clade found on this island certainly belongs to an older lineage and is not a consequence of recent migration. Also, on the Indian subcontinent, U4 is reported only in the Punjab region (Singh et al. 2021). The rare presence of this haplogroup in the Kavaratti islanders serves as evidence for admixture between the populations from the colder north and the ancestors of this lineage around the Near East and the northwestern region of the subcontinent during the Late Pleistocene, as suggested earlier (Richards et al. 2000; Metspalu 2004; Pala et al. 2012; Silva et al. 2017). These haplogroups with their probable temporal origin in the vicinity of the LGM are an important indicator of population dynamics within the Indian subcontinent. Kavaratti island along with other islands of the archipelago were populated by aboriginals from the mainland who had reached the archipelago during the LGM recovery phase.

What motivated them to move onto an island with limited resources is yet to be established. Nonetheless, it is clear that the migration caused a bottleneck, and since then this population has remained largely isolated.

### Diversity statistics

Nucleotide diversity ( $\pi$ ) in the Kavaratti population is 0.00122, whilst the haplotype diversity (Hd) is 0.993. A lower  $\pi$  index and a higher Hd index suggest a population bottleneck and a rapid population expansion with the accumulation of mutations. A statistically significant Tajima's  $D$  value of  $-1.92469$  indicates a recent population expansion.

### Genetic affinities with island populations

The Lakshadweep archipelago population is distributed over ten islands. To get an overview of the overall Lakshadweep gene pool, we compared average pairwise differences ( $F_{st}$ ) based on haplotype frequencies (ESM\_1 Table 2). The Kavaratti population ( $F_{st}=0.858$ ) is a more diverse group compared to Chetlat (0.324), Bitra (0.564) and Kadmat (0.526). This enhanced diversity is primarily due to the stronger founder effect of R30 on these islands. The R30 frequency on these islands is  $>60\%$ , whilst other more diverse islands including Kavaratti show  $<40\%$ . The Lakshadweep islands are different from each other in area, vegetation and human population. To assess the relationship between founder haplogroups and island area, we conducted a Pearson correlation test. Haplogroup R30 is significantly ( $p < 0.05$ ) negatively correlated with  $F_{st}$  ( $r^2 = -0.80$ ) and island area ( $r^2 = -0.71$ ). The result supports the hypothesis that the earliest settlers had a high frequency of R30 when they reached the Lakshadweep archipelago. Similarly, smaller islands have accumulated this haplogroup in high frequency. Haplogroup M2 shows insignificant positive correlation with  $F_{st}$  ( $r^2 = 0.13$ ) and island area ( $r^2 = 0.20$ ). There is insignificant positive correlation between the island area and  $F_{st}$  ( $r^2 = 0.54$ ,  $p = 0.1$ ). In other words, the greater the area, the more diverse the population.

When Kavaratti was compared with other islands based on Nei's genetic distance (ESM\_1 Fig. 1), the genetic composition of the island turned out to be more similar to Amini ( $d=0.1208$ ), Minicoy (0.1353) and Kalpēni (0.1649). This similarity may be due to the close proximity of these islands with Kavaratti. We also constructed a Neighbour Joining Tree to understand the clustering pattern (ESM\_1 Fig. 2). Besides Amini, Minicoy and Kalpēni, Āndrōttū too clustered closer to Kavaratti. Based on these results, it can be concluded that genetic admixture between Kavaratti and these islands occurred more frequently compared to other more distant islands. Interestingly, being a diverse group, Kavaratti and Amini retained the founder haplogroup R30

at  $\sim 30\%$ , whilst Minicoy and Kalpēni lost this haplogroup gradually. Conversely, it can also be hypothesised that the northern islands including Amini, Agatti, Kiltān and Kavaratti were explored first by the R30 founders, and Minicoy was the latest. Fine structure analysis of all these islands would provide a better understanding of the time depth of migration and settlement.

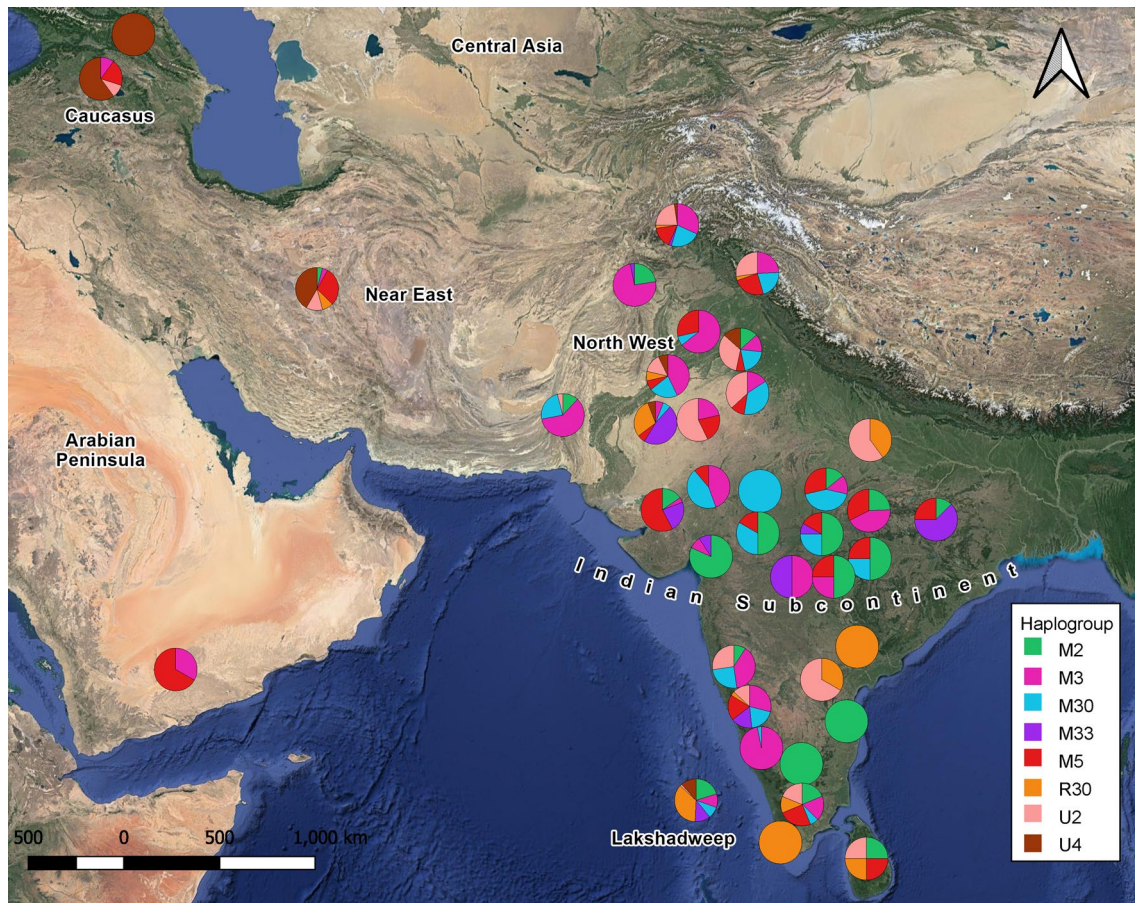
We performed AMOVA grouping of the islands based on geography, founder haplogroup frequency and area (ESM\_1 Table 3). We did not find any notable differences leading towards population differentiation or formation of structured populations. This finding clearly indicates that these islands, though largely isolated from the mainland, had exchanges amongst themselves, and the founder effect is relatively uniform on these islands.

### Genetic affinities with mainland populations

To reconstruct the maternal ancestral lineage of the Kavaratti islanders, we compared their gene pool with that of the mainland populations (Fig. 2). We used Principal Component Analysis (PCA) to visualise the clustering pattern amongst them (Fig. 3). Interestingly, Kavaratti clustered along with the Nair, neighboured by Kodava, Madia, Koraga, Kathodi and the Punjab Scheduled Castes. This cluster lies exactly in between the Western-Central-Eastern cluster and Northern-Northwestern cluster. A similar clustering pattern is seen in the neighbour joining (NJ) Tree plotted, based on Hamming's dissimilarity and an Andamanese root (Fig. 3).

In the neighbour joining tree, Kavaratti clustered with the Punjab Scheduled Castes. This clustering is due to the R30, M2, M3, M30 and L haplogroups present in these populations. No significant affinity obtains between the Kavaratti and Śrī Laṅkan populations. However, the indigenous Śrī Laṅkan tribe called Vedda clustered more closely to Kavaratti than the general population of the island. We observed a similar pattern when larger datasets (1000 genome) were included in the Phylogeny Tree (Fig. 4). In the Phylogeny Tree, the Kavaratti islanders (KAV) clustered with Indo-European speaking language communities.

The multivariate analysis, therefore, suggests that the Kavaratti population belonged to a unique wave of migrants that neither belonged to the earliest Indian-specific M2 carriers nor to the West Eurasian descendants. A peculiar feature in the Kavaratti cluster is the presence of the M3, M30 and U2 clades. Haplogroup U2 peaks in the northwestern and northern region of the Indian subcontinent, like M3, M5 and M30. Out of these, M3 and M30 originated during or after the LGM event. This time depth is important, since the members of the Kavaratti cluster carry M3 and M30, leading us to the assumption that these populations had similar gene pools during the LGM recovery, after which bottleneck events took place.



**Fig. 2** Spatial distribution of major haplogroups found on Kavaratti Island

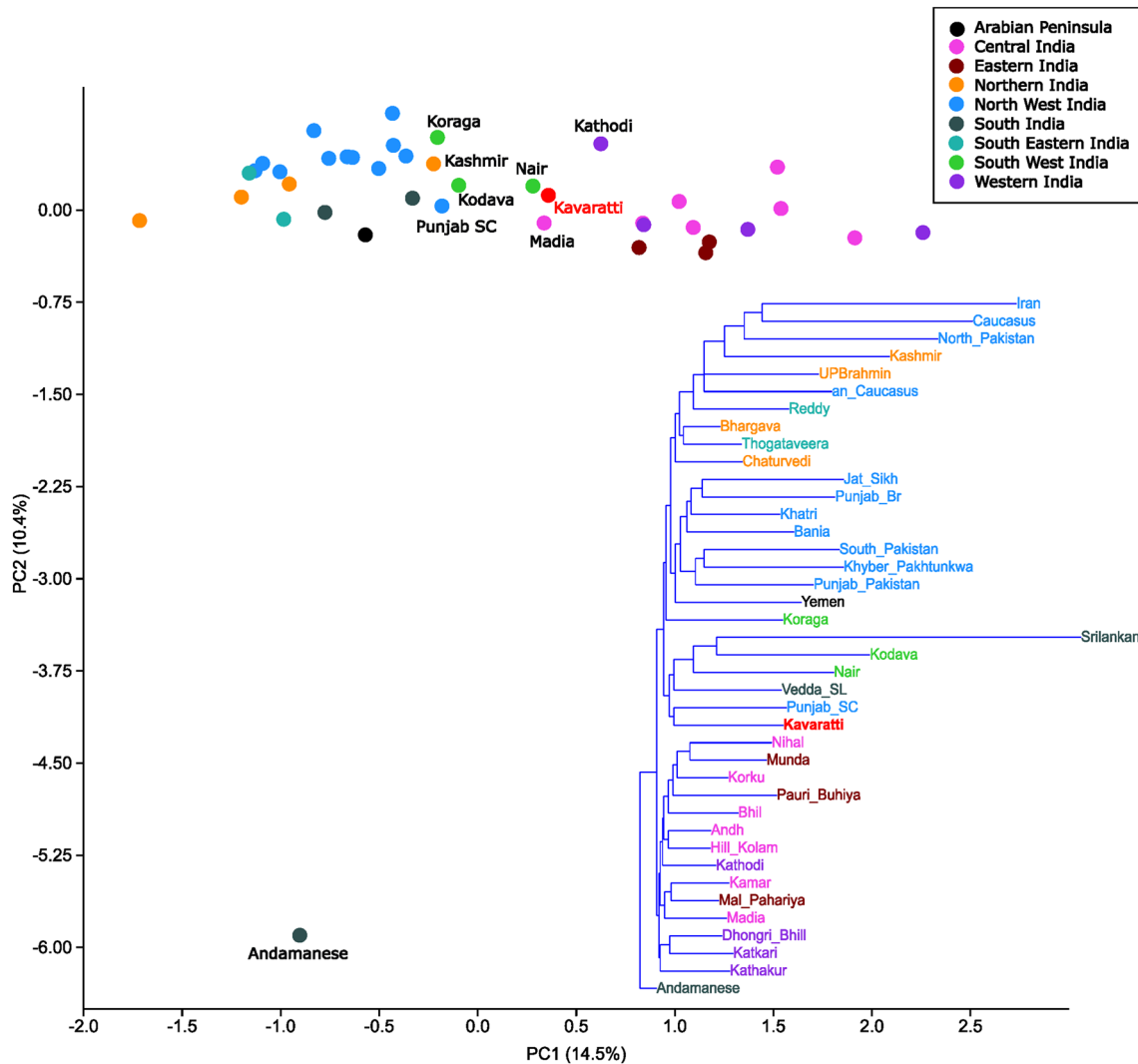
At this juncture, if an R30 bottleneck happened, then it is obvious that the group that migrated to Kavaratti belonged to a bigger group that included the ancestors of the Urali Kuruman, the Punjab Scheduled Castes, Uttar Pradesh Brahmins, Thogataveera, Reddy, Jat Sikh, Nair, etc. Therefore, we hypothesise that the Kavaratti islanders trace their maternal ancestry to the northwestern region of the Indian subcontinent. To resolve this picture further, based on the subclade information available for the R30b2 and R30 haplogroup network analysis (ESM\_1 Fig. 3) and principal component analysis (Fig. 2), we suggest that the Kavaratti islanders are maternally related to Mazhabi Sikhs, Balmikis (Punjab Scheduled Castes) (Singh et al. 2016) and Nairs. All other groups carry R30a subclades. Interestingly, Nairs have two important characteristics which are similar to Lakshadweep islanders, firstly their Malabar roots, as described in oral traditions and documented history, and secondly the high status enjoyed by women (Forbes 1979). However, if the Kavaratti islanders were recent offshoots of the Nairs, then it would most likely have been mentioned in folklore. At present, no record

of any direct Nair lineage to the Lakshadweep islanders, either written or oral, is known to exist (Chib 1985).

Our analyses limit our ability to trace the route of migration, as we do not find any population with R30b2 between the Punjab and Kerala. However, there are two possible routes, viz. (1) The modern route from the Malabar coast, and (2) a hypothetical “non-Malabar route”. The Malabar route is more plausible, because many indigenous tribes with founder haplogroups (Jenu Kuruba, Betta Kuruba, Urali Kuruman, Koraga, etc.) exist along the western coast of India. The lineage of the Kavaratti islanders may have migrated in isolation, following a coastal route until the bearers of this lineage explored the Lakshadweep archipelago. Fine-scale structuring using whole genome data will provide a better understanding of the deep-rooted ancestral links between the Malabar population and the Lakshadweep islanders to confirm lineage sharing between the two.

In conclusion, we identify in the Kavaratti islanders an R30b2 founder lineage arising from the northwestern region of the Indian subcontinent during the Last Glacial Maximum period. The only other populations to carry this lineage are the Scheduled Castes from the Punjab, Jat





**Fig. 3** PCA and NJ Tree showing maternal clustering pattern in mainland and island populations

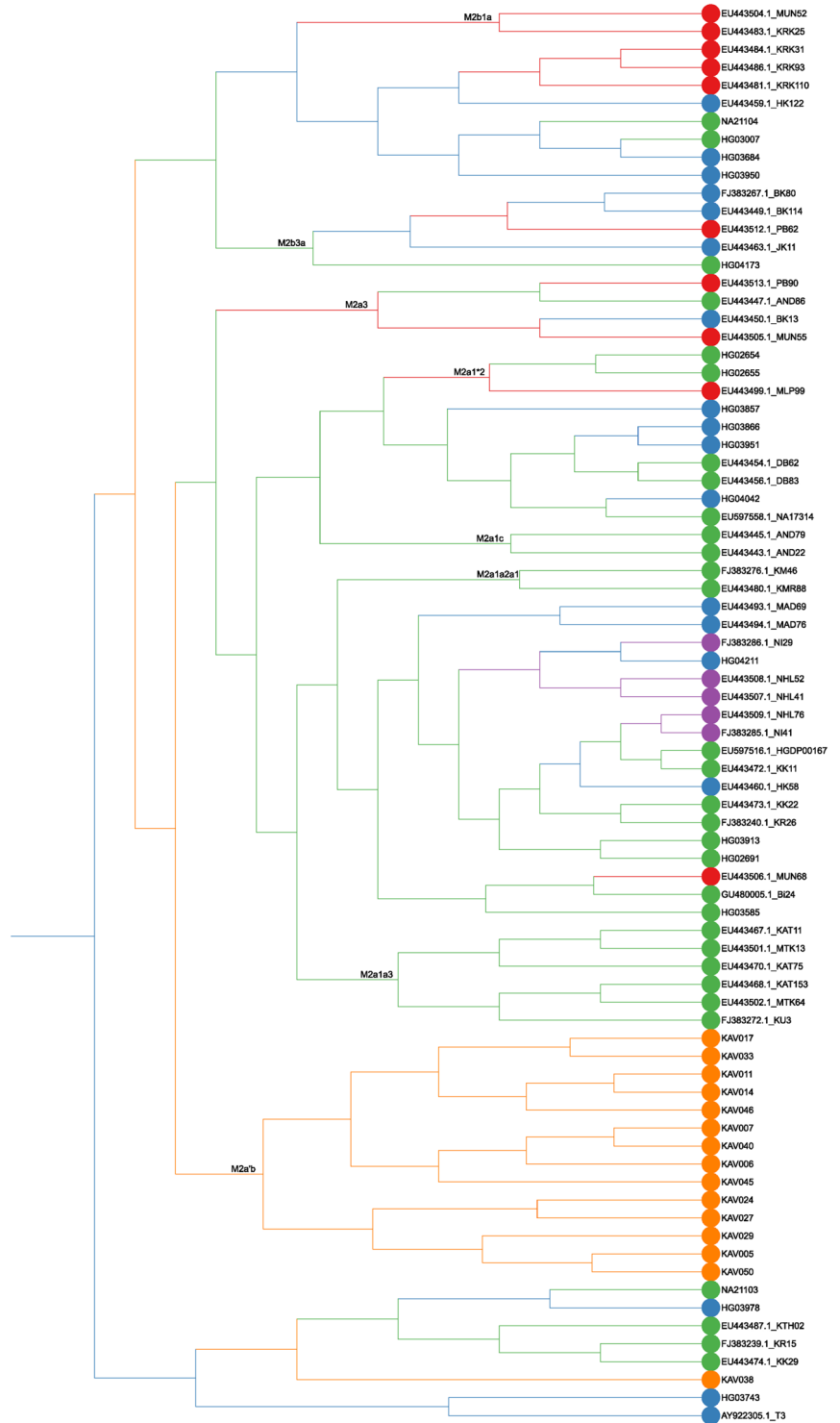
Sikhs and Nairs, who are either found in the northwestern portion of the Indian subcontinent or have recent historical links with this region. In addition, we also find unique clusters of pre-LGM M2 and M33 clades sharing common ancestors with those found in the northwestern populations. A similar trend is seen in the clustering pattern based on the M3 and M30 haplogroups that are prevalent in this region and date to the LGM period. We also report a

rare occurrence of the U4 lineage dated to the LGM period that is otherwise only found in Europe. Its presence in the Kavaratti islanders only suggests that the ancestors of the founders admixed with a diverse group before drastic demographic changes that occurred during and after the LGM. Our conclusions are based on the control region of the mitochondrial DNA and, therefore, must be further substantiated with whole mitogenomes.



**Fig. 4** Phylogeny tree based on maximum likelihood (ML) method

- Austro Asiatic
- Dravidian
- Indo-European
- Isolates
- Kavaratti



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**Authors' contributions** AMT and JJS have contributed equally in conceptualisation, mtDNA analysis, statistical analysis and lab work. MSM and IB has collected the blood samples and outlined the manuscript preparation. LK evaluated the analysis. GvD, MSM and IB have reviewed the manuscript. All the authors have contributed to the manuscript and approved the final draft.

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**Data availability** The datasets generated during and/or analysed during the current study are available in the supplementary file.

## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.

**Ethics approval** This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Human Ethics Committee of Mangalore University (MU/AZ/20/IHEC/2014-15).

**Consent to participate** Informed consent was obtained from all individual participants included in the study.

**Consent to publish** Participants signed informed consent regarding publishing their data anonymously.

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