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Anthracology in a relict forest in the South Pacific: An archaeobotanical approach on wood charcoal assemblages from Mocha Island☆

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A B S T R A C T

Mocha Island is located in the South Pacific Ocean (38°22′ S) only 30 km off the coast of Southern Chile. The first Europeans set foot on the island in 1544 CE, and the reports left by navigators between the 16th and 17th centuries inform of a well populated island, where the natives grew maize, beans and kept “sheep” with long necks (camelids). The Spaniard conquerors, who never settled on the island forced its depopulation between 1685 and 1687 CE. The island was uninhabited until 1850 CE, when the Chilean state started a colonization program in Southern Chile.

The last decades of archaeological research on the island show that pre-Hispanic groups visited it sporadically during the Archaic Period (1500 BCE), and more regularly from the Early Ceramic Period (100 CE). But around the year 1000 CE (Late Ceramic Period) the archaeological sites show continuous and regular use of the space around domestic units; mound and platform complex has also been dated to this period.

This paper presents the wood charcoal analysis results of three archaeological sites from Mocha Island, dated between the 850 CE and 1685 CE. The aim is to discuss the forest environment over 500 years of Pre-Hispanic and early Historic inhabitation that involved crop cultivation, camelid husbandry and population growth in this insular territory of 52 km^2. The anthracological results indicate the presence of lauriphyllous and sclerophyll taxa, suggesting ecotonal zones where different types of taxa can coexist, and in which the development of woody taxa with edible parts might have been promoted.

1. Introduction

The broad ecological context of this study is the temperate forests of South America, globally known for high biodiversity and for hosting a significant percentage of endemic plants. Because of their diversity and available resources, the temperate forests of Southern Chile (western slopes of the Andes, 36°S – 42°S) have been exploited since the arrival of the first hunter-gatherer groups in the region ca. 15,000 years ago (Dillehay et al., 2008). The ethnographic and ethnobotanical studies among the Mapuche indigenous people evidenced this long tradition of forest knowledge (Aldunate, 1996; Aldunate and Villagrán, 1992; Gumucio, 1999; Wilhelm de Möesbach, 1992). Today forest resources are still collected, traded, and consumed at broader rather than just local scales. Unfortunately, traditional forest practices are threatened by territorial constraint's that have been imposed by the Chilean state since the 19th century (Ley de Colonización 1823 and 1845, and Ley de 1883 that created the Comisión Radicadora de Indígenas) as well as by the ecological loss associated with the introduction of forestry plantations in the region (Di Giminiani, 2015, 2016).

In spite of the long occupation history and archaeological evidence to the contrary, it is commonly assumed that major landscape and forest transformation occurred only after the European colonization (1550 CE). In the traditional archaeological discourse the idea prevailed of small-scale agricultural or horticultural subsistence that did not significantly modify the forest environment, which was described later as pristine by the naturalists of the 18th century (Camus and Solari, 2008). Environmental history and ecological data indicate that the vegetation of Southern Chile has been shaped by anthropic action over many centuries (Lara et al., 2012). Nevertheless, there is still scarce data regarding woodland burning during the pre-Hispanic period (Armesto et al., 2010), including its real extend and timing. Although anthracology provides a great proxy with which to study people and forest interactions (Asouti and Austin, 2005), in the regional context of Southern Chile wood charcoal analysis is still an underdeveloped discipline.

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Given the potential of wood charcoal analysis, it was incorporated into the archaeobotanical analysis of Mocha Island to explore the pre-Hispanic forest dynamics in an insular context. Recent archaeological projects have provided a background in relation to human-environment interactions in the island, for example, that show since the Archaic Period small deer (*Pudu puda*) and nutria or coipo (*Myocastor coypus*), along with other terrestrial mammals (*Pseudolapex* sp., *Oncifelis* sp., and *Galictis* sp.) were intentionally transported and/or translocated to the island (Campbell, 2015). Although there is no archaeobotanical data from the Archaic Period, the later evidence from the Ceramic Period indicates the transportation of crops (quinoa, maize, beans), as well as camelids (Roa et al., 2021).

The general aim of this paper is to contribute to the knowledge of the temperate forest, especially in relation to the pre-Hispanic groups who inhabited the territory long before any of the ecological descriptions of Southern Chile were written. In specific terms, this paper provides direct evidence about the anthropic factor that for centuries modelled what today is known as the native or natural forest of Southern Chile.

2. Mocha island geographical and ecological context

Mocha Island is located in Southern Chile, to the west of the coast of the Araucanía Region (Fig. 1), but geo-politically is part of the Biobío Region. The island is in the Pacific Ocean (38°22′ S) only 30 km off the coast and it has an area of around 52 km^2. Geomorphological studies indicate that the island emerged during the Pleistocene due to an abrupt tectonic uplift and it was probably completely exposed by the end of this period (Prieto, 1997). It is unknown whether or not the island was connected to the mainland in the past, but it has been an insular territory since at least the 4000 BCE, after the stabilization of the sea level (Campbell, 2015).

For the last 6000 years the island has experienced rapid rates of tectonic uplifting (Nelson and Manley, 1992). Today the central part of the island corresponds to elevated Pleistocene marine platforms of around 340 m ASL covered by native forest and surrounded by Holocene marine terraces, where most of the archaeological sites and modern population are concentrated (Campbell & Pfeiffer, 2017).

The island hosts more than a hundred species of birds, but there are few native species of terrestrial vertebrates that correspond to amphibians, reptiles and rodents (Pefaur and Yáñez, 1980). These terrestrial vertebrates could represent relict populations possibly from where the island was connected to the continent, or they could have arrived by marine drift, since they are of small size (Jackson et al., 2013).

The vegetation of Mocha Island has been described as a lauriphyllous temperate coastal forest dominated by *Aextoxicon punctatum* Ruiz & Pav. (Luebert and Pliscoff, 2006). This type of forest shares similarities with the coastal forest on the western slope of the Nahuelbuta Coastal range (Biobío and Araucanía regions), however due to the geographic isolation of the island there are significant differences. The absence of conifers and the *Nothofagus* genus on the island is one of the most noticeable, since both are quite abundant on the mainland (LeQuesne et al., 1999). The forest of the island is believed to be a remnant of the vegetation that existed in the continental coastal region before the diversification of the associations observed today in the evergreen forest of Southern Chile (Villagrán and Armesto, 1980).

The most relevant reference that gives a detailed account of the botanical species present and absent on the island is the publication of K. Reiche (1903) which he wrote after a summer visit to the island in 1902. Later, in 1958 there was a "Mocha expedition" during which the botanist G. Kunkel (1968) participated and subsequently added more species to the initial list made by Reiche (especially in relation to lichens and ferns). Both publications were the basis for the later ecological studies (LeQuesne et al., 1999; Pefaur and Yáñez, 1980), and they provide a historical perspective of vegetation changes on the island during the last hundred years.

Today, the forest is concentrated in the middle mountain of the island and most of it is confined within a Nature Reserve created in 1988 (Reserva Nacional Isla Mocha). According to the vegetation studies (CONAF, 2006; LeQuesne et al., 1999), the different woody associations of the island vary according to height (meters above sea level). For

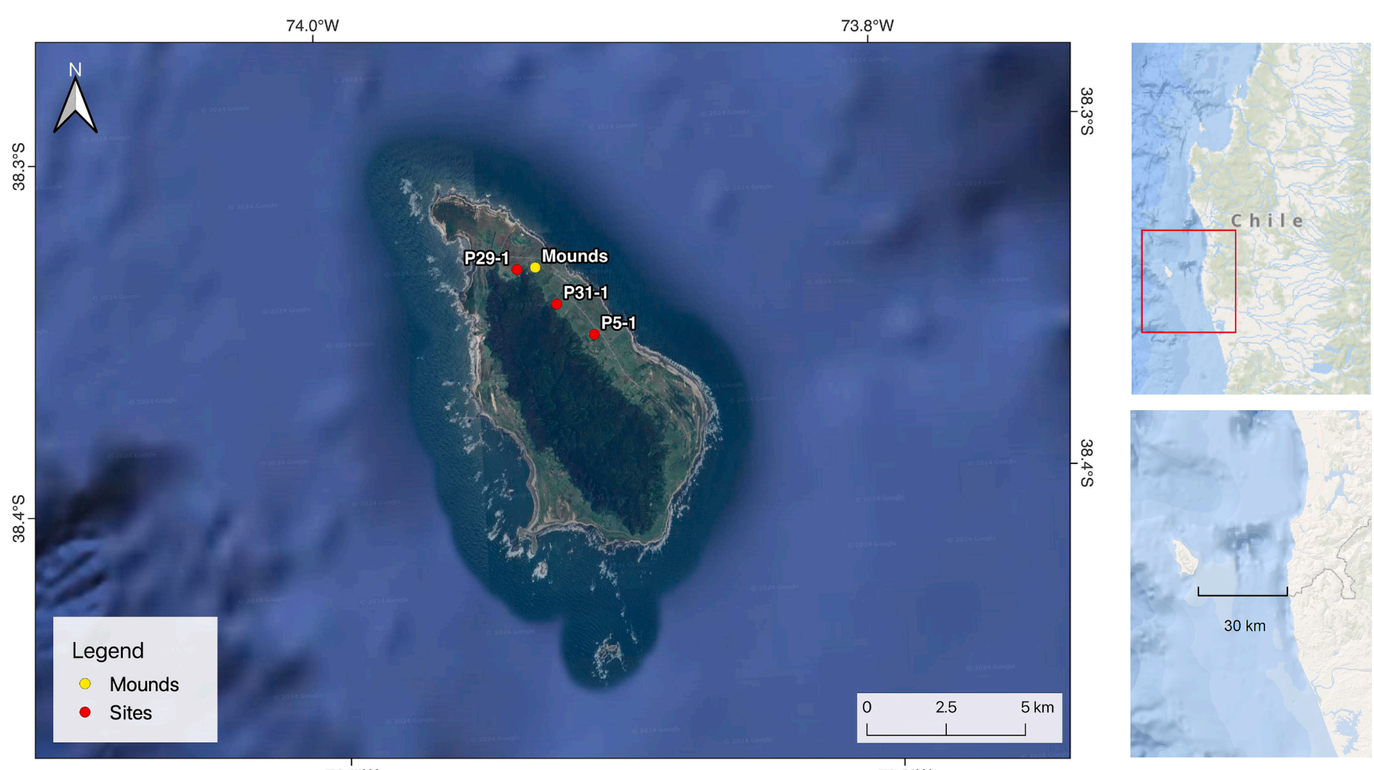

Fig. 1. Mocha Island map showing location of archaeological sites.

example, in the highest parts (between 50–300 m ASL), there is a closed canopy forest of *Aextoxicon punctatum*, with other shade tolerant species such as *Amomyrtus luma* (Molina) D. Legrand & Kausel, and *Laurelia sempervirens* (Ruiz & Pav.) Tul. (Figs. 2 and 3). Then in the middle part (slopes) we find secondary shrubs such as *Fuchsia magellanica* Lam. and *Aristotelia chilensis* (Molina) Stuntz. In the terraces (15–60 m ASL), there are forest patches of *Peumus boldus* Molina, a sclerophyllous tree that grows in more open and sunny areas and which could represent remnants of larger sclerophyllous formations in the past. In water saturated areas of the terraces (never over the 10 m ASL), there are also hualve or swamp formations where Myrtaceae species predominate such as *Myrceugenia exsucca* (DC.) O. Berg and *Blepharocalyx cruckshanksii* (Hook. & Arn.) Nied. (Donoso, 1993).

3. Archaeological and Historic context.

Since pre-Hispanic times there has been discontinuous human occupation on the island, and all human presence before the 20th century implies the use of navigation technologies. The earliest occupation dates to the Archaic Period 1450 cal. BCE /3400 cal. BP, (Campbell, 2015), followed by a 1500-year hiatus with no evidence of human presence until the Ceramic Period (100 CE). This paper focuses on the Late Ceramic Period, which in the regional archaeological chronology for Southern Chile corresponds to the period before the Spanish arrival (1000 to 1550 CE). An estimated population growth and presumed agricultural intensification differentiates the Late Ceramic Period from the previous pre-Hispanic Periods (Roa et al., 2018). Evidence of mound construction and other large scale landscape modification are characteristic of the period (Campbell and Pfeiffer, 2017; Dillehay et al., 2007), and they have been related to social aggregation dynamics and public feasts. Another relevant aspect of this period is the management or taming of camelids or chillihueques, which according to the limited evidence, probably involved a tamed guanacos (*Lama guanicoe*), rather than domesticated species like llamas or alpacas (Westbury et al., 2016).

The archaeological sites have been studied as autonomous economic units. The evidence indicates that crops such as maize (*Zea mays* L.), quinoa (*Chenopodium quinoa* Willd.), and beans (*Phaseolus* sp.) were brought and cultivated in the island, and animals such as camelids, were also transported to and kept on the island (Roa et al., 2021). The sites also show evidence of foreign elements such as turquoise beads and raw lithic materials, like obsidian from continental volcanic sources hundreds of kilometres away (Campbell et al. 2018). This suggests that the island was not isolated and participated in wider social interaction networks.

In terms of subsistence, the archaeobotanical record shows consumption of cultivated and wild resources. Along with cultivated plants such as quinoa and maize, wild berries such as *Aristotelia chilensis* and *Rubus* cf. *geoides* are the most ubiquitous taxa in the island (Roa et al., 2021). The isotopic analysis of some Late Ceramic individuals from the island shows a mixed diet that incorporated crops and terrestrial animals, e.g., camelids (Campbell et al., 2020). Consumption of marine resources has also been evidenced through the artefactual and zooarchaeological record (Roa et al., 2021), and organic residue analysis from pottery sherds shows that marine products were processed in pots in which C_3 plants were also cooked (Montalvo-Cabrera et al., 2024).

The Late Ceramic Period sites are the most ubiquitous archaeological contexts on the island. They show a dense habitation deposit indicative of an intensive and reiterative use of the space and suggesting occupation continuity until the depopulation of the island (1687 CE). The evidence indicates that the construction of the mounds started around the 1000 CE and that they were completed by 1300 CE. The dates on preserved plant material indicate that maize was present in the island as early as 1000 CE and maize, beans, and quinoa become ubiquitous in all the sites by about 1300 CE (Campbell, 2020). Although the end of the Late Ceramic Period has been established at the time of the European contact (1554 CE in the mainland,1544 in Mocha Island), it is almost impossible to distinguish stratigraphically between the Late Ceramic Period and the Historic Period. Since 1553 the Spaniards started to establish forts and settlements on the mainland, but Mocha Island was never a Spanish settlement. Because it was not properly incorporated to the Spanish territory, there was not prohibition preventing Dutch and British ships from landing on the island. European ships were able to obtain water and food in exchange of iron knifes and other goods. The archaeological data and the written records indicate the absence of European historical settlements on the island (excepting few glass beads), and following the previous publications (Goicovich and Quiroz, 2008; Campbell, 2020) the brief post contact Period will be considered as a continuum of the Late Ceramic Period.

The testimonies left by the Europeans navigators from 1544 CE mention a well populated island with an abundancy of crops and animals, including castillian sheep and the *chilihueques,* known as the sheep of the land (Fletcher, 1652; van Noort, 1602). The Spanish authorities forced the depopulation of the island in 1685–1687 CE. At the time of the depopulation, more than 600 people were moved from the island to the mainland. The island was deserted for 140 years and in 1840 started to be repopulated by farmers from the continent. Today the estimated population is around 400 people.

4. Materials and Methods

4.1. Archaeological sites and sampling strategy

The analysed wood charcoal was obtained from three archaeological sites: P5-1, P29-1 and P31-1. These sites were excavated between the summers of 2010 and 2015, and each of them was archaeologically assed using a test-pitting grid system (Campbell, 2011). The sites are located at the north east of the island that faces the continent (Fig. 1); they are between 8 and 15 ha of areal extent (details in supplementary material). Each of the sites has been considered as an independent domestic unit separated by at least 1.5 km from other neighbouring sites.

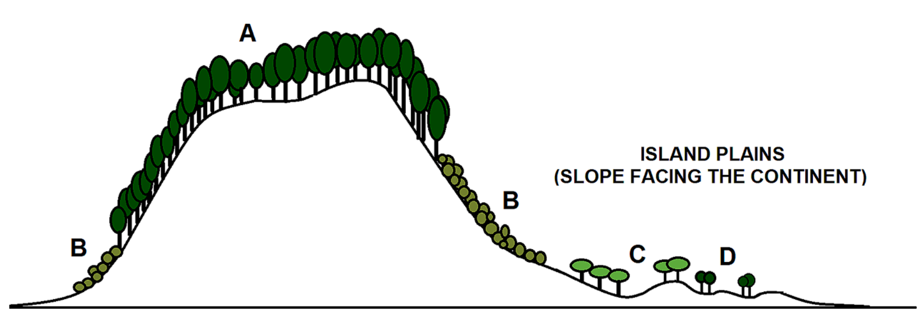

Fig. 2. Schematic representation of Mocha Island vegetal formations, based on Donoso (1993) and (Pefaur and Yáñez, 1980). A: *Aextoxicon punctatum* forest, presence of shade tolerant species such as *Amomyrtus luma* and *Laurelia sempervirens*. B: Secondary shrubs, presence of *Fuchsia magellanica* and *Aristotelia chilensis*. C: *Peumus boldus* forest. D: hualve or swamp forest, presence of *Myrceugenia exsucca* and *Blepharocalyx cruckshanksii.*

Fig. 3. Mocha Island vegetal formations. Left: inside of *Aextoxicon punctatum forest*, corresponds to A in Fig. 2 (2015, courtesy of Hugo Carrión). Right: maize cultivation among half burned *Aextoxicon punctatum* trees (2014, courtesy of Pablo Arenas).

The three sites are placed in the island pains (elevated Pleistocene platforms), with easy access to forest and marine resources (nowadays the tide line less is than 1 km away and it could have been nearer in the past due to the constant tectonic uplifting).

The contextual information and radiocarcon dates indicate that the three sites were occupied during the Late Ceramic Period, between the 1000 CE and depopulation of the island in 1687 CE (Campbell and Pfeiffer, 2017). The archaeological deposit shows evidence of domestic activities carried out in each of the sites, such as food preparation and consumption, as well as processing of fermented drinks (Godoy-Aguirre, 2018). The sites show over a metre of archaeological deposit containing ceramic sherds, lithics, bones, shells, and vegetal remains. The artefactual assemblage of each site shows evidence differentiation strategies but no significative contrasts in terms of wealth or resources accessibility (Campbell, 2020). The three sites can be considered contemporary to each other and comparable in terms of the activities carried out in each of the sites.

The samples analysed comprised charcoal fragments dispersed in the archaeological layers that were recovered from stratigraphic flotation columns of the mentioned domestic sites. In accordance with anthracological analysis, scattered wood charcoal fragments most likely represent several collections of firewood and burning events that are the product of activities carried out over long periods (Kabukcu and Chabal, 2021; Théry-Parisot et al., 2010). While one flotation column per site was obtained in P29-1 and P31-1 respectively, two columns of the P5-1 site were extracted. The sediment samples were obtained systematically according to the archaeological layers recognized in each of the excavation units and the individual stratigraphical features (detailed information provided in supplementary materials). Each of the samples were floated separately, using an assisted flotation machine.

4.2. Charcoal analysis

Before the analysis of the wood charcoal samples the first task was to create a reference collection of modern wood taxa from Mocha Island. Wood samples were collected on the island during the fieldwork between the years 2013 and 2015 and they were later charred, following the protocol proposed by Solari and Lehnebach (2004).

Wood charcoal analysis was then conducted in accordance with the standard anthracological methodology (Chabal et al., 1999, Solari, 1993). Each wood charcoal fragment was analysed by observing the three anatomical sections of the wood under an optical microscope (Olympus BX60, Institute of Archaeology, UCL). Taxonomic identification was achieved through direct comparison with the modern reference specimens from the island, which was complemented with a more comprehensive charcoal reference collection from Southern Chile, as well with wood atlas and relevant publications (Rancusi et al., 1987; Solari, 1993; Wagemann, 1949).

Following Solari and Lehnebach (2004), the wood charcoal results are presented in terms of frequency rather than weight or volume. The taxonomic identification uses the nomenclature from the catalogue of vascular plants of Chile published by Rodriguez and collaborators (2018).

5. Wood charcoal results.

From the three sites a total of 4,665 charcoal fragments were analysed (Table 1), of these, a 63.9 % were taxonomically identified, a 9.6% were classified as an unknown angiosperm, and a 26.4 % as non-identifiable fragments. In terms of provenience 48.7 % of the analysed fragments were recovered in P5-1, 32.6 % in P29-1, and the remaining 18.6 % was obtained from P31-1.

A total of 34 woody taxa were identified in the samples from the Ceramic Period of Mocha Island (Figs. 4 and 5, complete taxa list in supplementary material). These taxa represent 25 families of angiosperms (including one monocot taxon), and one gymnosperm taxon. All the identified taxa correspond to native taxa of Southern Chile, but among them, there are taxa described as non-native to Mocha Island (gymnosperms and the *Nothofagus* genus, Fig. 5: A to D, LeQuesne et al., 1999). The few fragments identified as gymnosperms were classified at class level as Pinopsida. Considering the ecology and geographical distribution of the three native families of conifers (Araucariaceae, Cupressaceae, and Podocarpaceae), the taxon could correspond to the Podocarpaceae family. Unfortunately, most of the fragments identified were small, so they could only be assigned to a broad taxonomical category.

P5-1 shows the highest taxa richness value with a total of 31 different

Table 1
Summary of analysed wood charcoal fragments per site.

Identification categories	P5-1 TP 05.02.03	TP 06.01.01	P29-1 TP 29.01.02	P31-1 TP 31.02.01
Identified	615	665	1084	620
Unknown	132	108	124	86
Non-identifiable	204	549	315	163

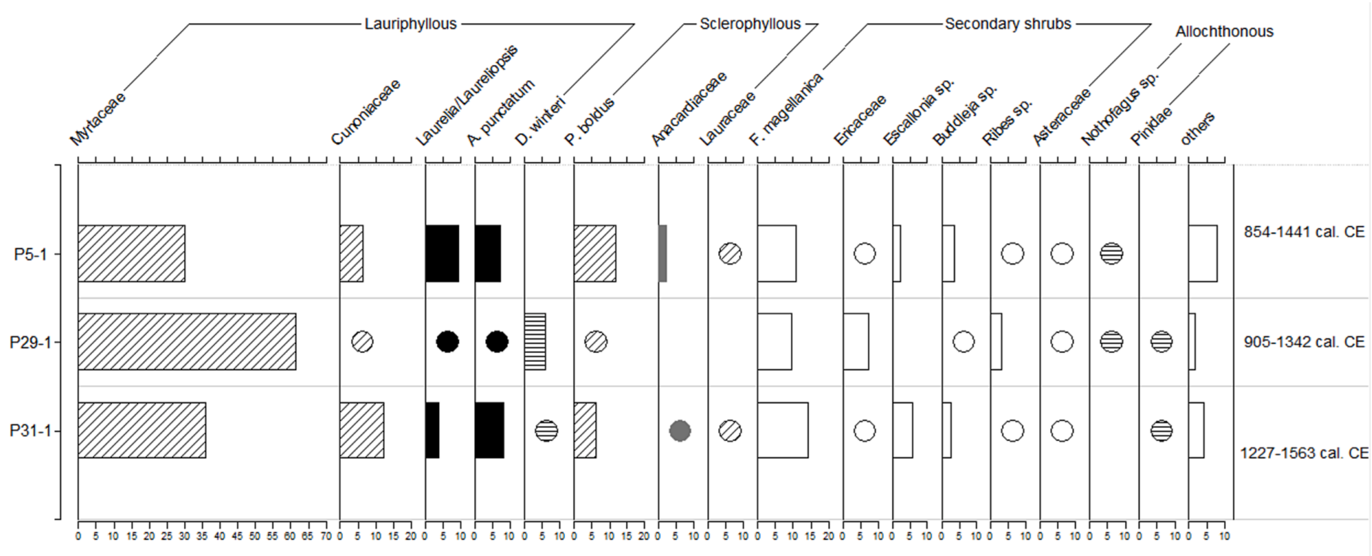

Fig. 4. Summary of identified woody taxa from P5-1, P29-1 and P31-1 according to ecology. Black filling indicates shade tolerance, striped diagonal filling indicates shade tolerance to medium tolerance, striped horizontal filling indicates shade intolerance to medium tolerance, and grey filling indicates shade intolerance. Unfilled or white colour indicates no specific shade/light tolerance. Circles indicates values under 2%.

identified taxa (24 angiosperm families), followed by 24 different taxa identified in P31-1(23 angiosperm families), and 20 taxa identified in P29-1(16 angiosperm families).

The most frequently identified taxon in the three sites was the Myrtaceae type A. According to the catalogue of the vascular plants of Chile (Rodriguez et al., 2018), the Myrtaceae family compromises 8 genera and 22 species in Southern Chile, with 13 of the species catalogued as endemic. Some of the cellular features characteristic of each of the species (such as type of punctuations, or number of bars in the perforation plates, or quantity of vessels/ rays per mm^3), were not always visible in the wood charcoal fragments due mainly to taphonomic alterations. As methodological caution the Myrtaceae family was only identified to sub family level, distinguishing two types; the Myrtaceae type A corresponds to diffuse porous wood (Fig. 5: K to L) with small vessels (around 30 μM), heterogenous rays, and presence of scalariform plates (Rancusi et al., 1987). The taxa grouped in this type includes the genera *Luma, Myrceugenia* and *Ugni,* while Myrtaceae type B comprises the *Amomyrtus*, *Blepharocalyx* and *Tepualia* genera. Most species of both types have edible berries that can also be used as dyes (Hoffmann, 2005).

Among the other frequently identified taxa there is *Fuchsia magellanica* (a shrub and part of secondary vegetation, Fig. 5: G-H), the Cunoniaceae family (lauriphyllous tree taxa), and *Peumus boldus* (a sclerophyllous tree, Fig. 5: I-J) and *Laurelia/Laureliopsis* (lauriphyllous trees).

The relative frequency of the identified taxa was calculated in order to explore the similarities among the sites and are presented in Fig. 4. For comparison purposes some species were grouped together under the family identification. As example, *Cryptocarya alba* (Molina) Looser and *Persea lingue* (Ruiz & Pav.) were grouped under Lauraceae, and Myrtaceae type A and B were grouped together as Myrtaceae. Although this helped to uniform the taxa categories among the different sites, it has the disadvantage of enabling a less accurate environmental interpretation. But since most of the assemblage was identified at sub-family level (Myrtaceae type A), this limitation was one that already existed in the data set. The taxa were differentiated according to their ecology (lauriphyllous or sclerophyllous), shade tolerance and primary or secondary status in forest succession using relevant published literature (Donoso, 2006; Gutiérrez and Huth, 2012; Luebert and Pliscoff, 2006; Lusk, 1996; Lusk & Del Pozo, 2002). Most of the secondary shrubs have a broad ecological spectrum, so they were not classified under sclerophyllous or lauriphyllous types.

The lauriphyllous taxa dominates the assemblage in the sites: 71 % in P29-1, 61 % in P31-1, and 54 % in P5-1. Secondary shrubs follow in representation reaching 26 % in P31-1, 23 % in P29-1, and 20 % in P5-1, and sclerophyllous taxa correspond to 16 % in P5-1, 7.7 % in P31-1 and 1.4 % in P29-1.

In terms of shade tolerance and forest succession, the pioneer taxa are usually shade intolerant and able to grow in poor soils while late successional taxa are shade tolerant and require fertile soils (Gutiérrez and Huth, 2012; Lusk and Contreras, 1999). The shade tolerant taxa (*A. punctatum*, *Laurelia/Laureliopsis*, and *Persea lingue*), represent a 19 % of the identified taxa in P5-1, 13.4 % in P31-1, and 2.3 % in P29-1. More than half of the taxa of each site correspond to shade tolerant to medium tolerance taxa like *P. boldus,* and the Myrtaceae, Cunoniaceae and Lauraceae families. At the other end of the shade tolerance spectrum, we find two shade intolerant taxa (Anacardiaceae and *Maytenus* sp.) and three shade intolerant to medium tolerant taxa (*Drimys winteri* J.R. Forst. & G. Forst., *Nothofagus* sp. and Proteaceae). Altogether these taxa represent between 7.5 % to 2.5 % in each of the sites.

6. Discussion: Wood charcoal results and the other lines of evidence

The only pollen study for Mocha Island has a single ^{14}C date obtained at the beginning of the Laguna Huairavos sequences (126–525 cal. CE, LeQuesne et al., 1999). The dated pollen zone fits into the Early Ceramic Period of the island and is characterized by the predominance of woody taxa such as *A. punctatum*, Myrtaceae, *Hydrangea serratifolia* (Hook. & Arn.) F. Phil, an *Azara* sp. type, and some traces of *Eucryphia cordifolia* Cav. Later pollen zones show a lower percentage of woody taxa with a significative presence of grass like plants, all indicative of a disturbed environment. But since there are no dates for the other pollen zones or columns, it is difficult to link these changes to the archaeological periods.

Because there is no environmental data for previous periods, there is uncertainty about the forest composition before the Early Ceramic Period (100–1000 CE). For instance, gymnosperms and the *Nothofagus* genus were identified in the pollen record (*Podocarpus nubigena* Lindl. and *Nothofagus* type *dombeyi)*, but it was interpreted as pollen from the

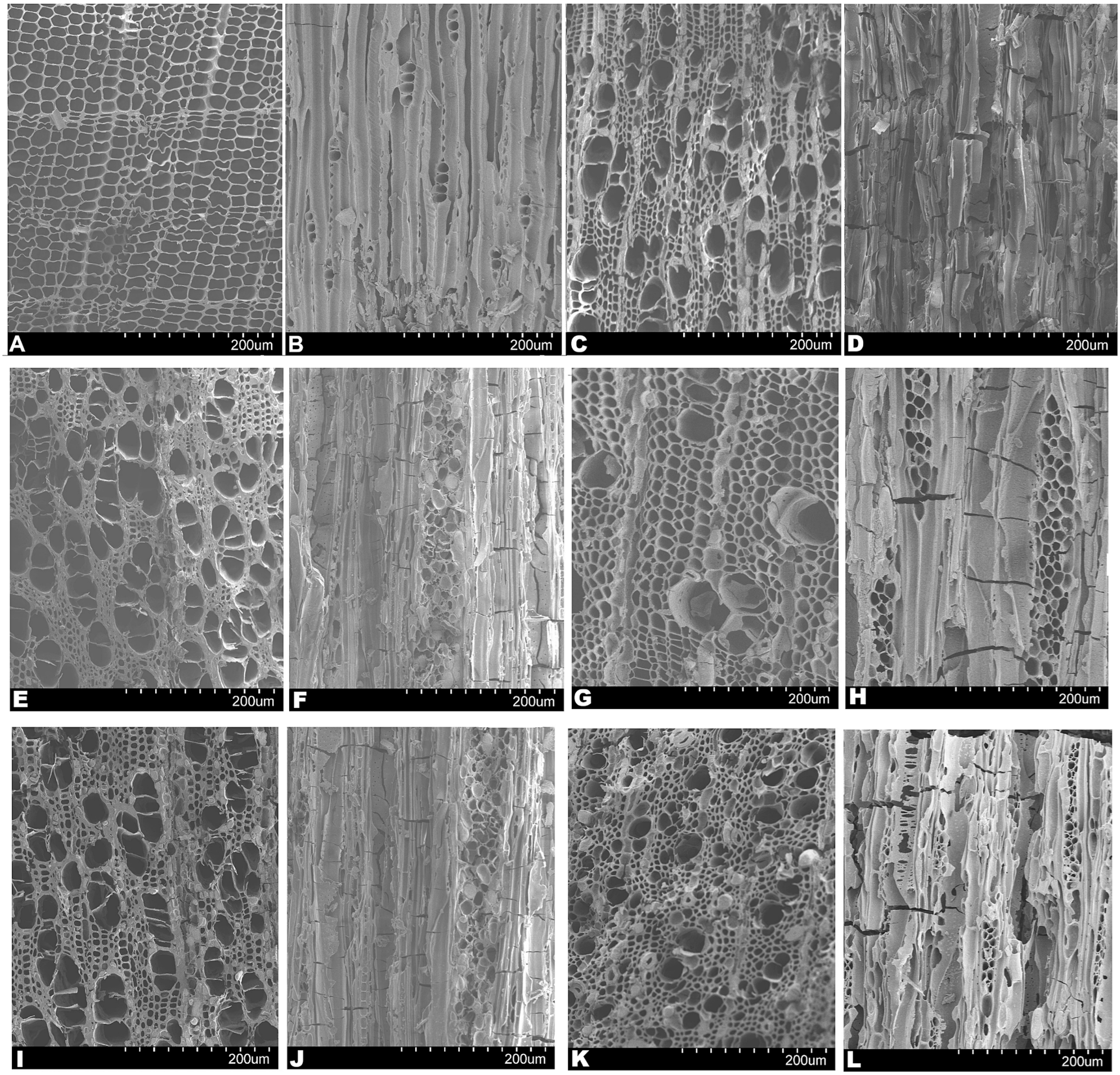

Fig. 5. SEM images of identified wood taxa from Mocha Island showing Transversal (TS) and tangential longitudinal sections (TLS), all under 200X magnification. A-B: Conifer; C-D: *Nothofagus* sp.; E-F: Anacardiaceae, G-H: *Fuchsia magellanica*; I-J: *Peumus boldus*; K-L: Myrtaceae type A.

continental coast by LeQuesne and collaborators (1999). Due to the low number of allochthonous wood charcoal fragments identified in the archaeological sites (altogether 11 for Pinopsida and 13 for *Nothofagus* sp.), the evidence should be interpreted with caution. The allochthonous wood charcoal could then correspond to driftwood, or wood artifacts carried to the island during pre-Hispanic times. Considering that pre-Hispanic groups introduced animals (like *Pudu puda* and camelids, among others), and plants (*Zea mays*, *Phaselous* sp., *Chenopodium* sp.), and though more evidence is needed, at the present it is not possible to discard the introduction of woody plants to the island.

Some of the identified wood charcoal taxa, for example the Anacardiaceae family and *Cryptocarya alba*, were not registered in the island descriptions of Reiche (1903) and were categorized as absent in the posterior descriptions of Kunkel (1968). In the Anacardiaceae family, the genus *Schinus* was identified among the wood charcoal, charred seeds identified as cf. Anacardiaceae were registered in the P5-1 site (Roa et al., 2021), and *Lithrea caustica* (Molina) Hook. & Arn. was found in the pollen record (LeQuesne et al., 1999). In addition to the wood charcoal identified as *Cryptocarya alba, Persea lingue* and indeterminate Lauraceae, *C. alba* seeds were identified in P3-1 (Roa et al., 2021). This suggests the presence of two different genera of the Anacardiaceae family (*Lithrea* and *Schinus*) and two of the Lauraceae family (*Persea* and *Cryptocarya)* in the island during pre-Hispanic times. The descriptions of Reiche (1903) and Kunkel (1968) only mention the presence *P. lingue* and absence of *C. alba,* and in later descriptions *P. lingue* is mentioned to be a non-frequent species (Pefaur and Yáñez, 1980).

The previously published archaeobotanical data from Mocha Island recorded 16 families of woody taxa identified from the charred seed record (Roa et al., 2018, 2021). By considering both lines of evidence, wood charcoal and charred seeds, the archaeobotanical records of

Mocha Island accounts for 30 angiosperm families (36 different taxa), and one gymnosperm taxon. According to the ethnographic and ethnobotanical literature from the Mapuche culture (Gumucio, 1999; Muñoz et al., 1981; Wilhelm de Möesbach, 1992), all the identified taxa have reported traditional uses, indicating that part of them could have been used as firewood or timber, but also as food, medicine, dyes and other purposes (details and references in supplementary material). Among the identified taxa, 25 of them have different edible parts (fruits, nuts, tender shoots, and even bark is considered starvation food), of which berries stand out as the most ubiquitous and frequent wild food recovered in the charred seed record (Roa et al., 2021). Among the woody taxa with edible berries identified from wood charcoal fragments are the Myrtaceae family, *Aristotelia chilensis*, Polygonaceae, Ericaceae and *Ribes* sp. These last two taxa were not recovered among the charred seed record and in the same manner, not all wood taxa identified from the charred seed record were identified as wood charcoal. Although there are a series of issues that need to be considered, for example taphonomy and social practices regarding wood collection, it is relevant to highlight the complementarity among the results obtained by anthracology and carpology.

The ethnographic sources indicate that trees and other types of plants are important not only in economic terms for the native populations of Southern Chile (Aldunate, 1996; Gumucio, 1999). The current evidence indicates that the groups who inhabited Mocha Island were actively collecting forest resources for firewood, food and possibly for other purposes. Most likely they were also burning patches of forest to open areas for habitation and cultivation purposes, which according to the data presented here did not transformed the island into a deforested area. The data we have to date is concentrated in a few centuries (1000–1500 CE), however the archaeobotanical record of the island shows a diversity of woody plants that differs from what was recorded in the early 20th century and from what can be observed nowadays.

7. Conclusions

From three archaeological sites representing the Late Ceramic Period of Mocha Island, a total of 34 native woody taxa were identified that include trees, shrubs and other minor wood-like plants. Although they are all native to southern Chile, two taxa have been described as non-native to the island *(Nothofagus* sp. and gymnosperms). The most frequent and ubiquitous taxon in all the sites is Myrtaceae type A, a family that includes trees and shrubs with edible berries. In ecological terms, some species of the Myrtaceae family have been described as components of the intermediate stage of forest succession (Lara et al., 2014).

The identified taxa indicate a combination of lauriphyllous and sclerophyllous types, where shade tolerant and shade intolerant species are found, as well as secondary species. There is no evidence to suggest a predominance of a closed canopy forest but neither a completely deforested landscape during the Late Ceramic Period in Mocha Island. Even though the people from this period cultivated plants and managed camelids, the data suggest that shade tolerant species were present throughout the entire occupation of the sites.

It seems likely that in the central part of the island an old-growth forest could have persisted (providing seeds, wood, and other resources from shade tolerant species), while in the plains, where all the residential units were concentrated, a more open type of vegetation could have been established (Fig. 3, right). Previous wood charcoal analysis in Southern Chile has suggested a link between ecotonal zones and archaeological sites (Solari, 2008). The development and maintenance of ecotonal zones could have been promoted by the Late Ceramic People of Mocha Island, especially because these areas can potentially concentrate species with edible and other useful properties.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2025.105126.

Data availability

No data was used for the research described in the article.

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