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PALYNOLOGICAL AND TEMPORAL INSIGHTS INTO THE ATLANTIC FOREST DYNAMICS ALONG THE COASTAL AREAS OF RIO DE JANEIRO STATE: A MINI REVIEW

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Abstract : This mini review synthesizes palynological records obtained from coastal sediments along the coast of Rio de Janeiro State, southeastern Brazil, integrated with paleoenvironmental reconstructions to investigate long-term Atlantic Forest dynamics. Pollen data spanning the late Pleistocene and Holocene reveal alternating phases of forest expansion and contraction, with marked spatial variability influenced by sea-level fluctuations, climate variability, and geomorphological processes. Forested formations were generally restricted to inland areas, whereas coastal lowlands were dominated by restinga, grassland, and mangrove communities. This synthesis contributes to refining the regional paleoenvironmental framework and highlights the importance of palynological records for understanding past and future ecosystem responses along the Brazilian Atlantic coast.

Keywords: Palynology, Atlantic Forest, Paleoenvironment, Late Pleistocene, Holocene

Introduction

The Atlantic Forest is one of the most biodiverse and ecologically significant biomes on Earth. Extending for nearly eight thousand kilometers along the Brazilian coast, it comprises a wide range of vegetation types shaped by complex interactions between climate, topography, sea-level fluctuations, and geological history (Barreto et al., 2024; Barth et al., 2014; Dean, 2002; De Oliveira et al., 2005; SOS Mata Atlântica, 2002; Souza et al., 2005). Despite its ecological importance, the Atlantic Forest has experienced extensive fragmentation and degradation due to centuries of human occupation. Reconstructing its long-term dynamics is therefore essential for understanding past environmental changes and supporting conservation strategies. Palynological investigations conducted over the past decades have generated numerous sedimentary records from lakes, lagoons, peat bogs, mangroves, and fluvial environments, providing valuable insights into vegetation responses to Quaternary climatic and sea-level oscillations and a robust database for reconstructing vegetation dynamics since the late Pleistocene.

The coast of Rio de Janeiro State extends from Campos dos Goytacazes in the north to Paraty in the south, encompassing a coastal plain bordered by the Serra do Mar and Serra da Mantiqueira mountain ranges. (Figure 1)

It comprises a relatively narrow coastal plain, typically 100–200 km wide, with elevations generally around 50 m above mean sea level, occasionally reaching slightly higher. The region spans approximately 22°S to 23°S latitude and 41°W to 44°W longitude. Vegetation along the coastal sector was extensively described by Araujo (1984) and includes ombrophilous Atlantic Forest, restingas, grasslands, and mangroves (Figures 2 to 5). The distribution and structure of these phytophysiognomies are strongly influenced by local climatic conditions, sea-level fluctuations, and underlying geological features. Historically, dense forest covered large portions of the Serra do Mar and Serra da Mantiqueira mountain ranges; however, only about 17% of the state's territory is currently occupied by Atlantic Forest remnants, of which roughly 30% are protected within conservation units.

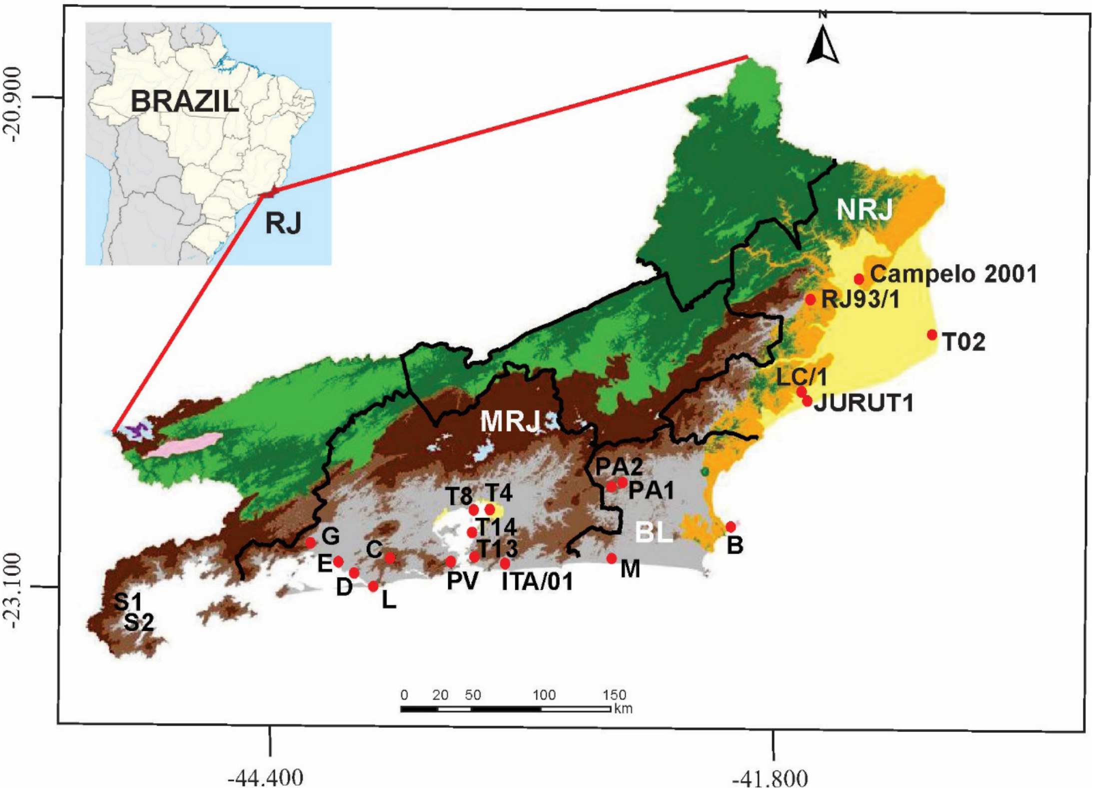

Figure 1. Rio de Janeiro State, mesoregions and localities studied. NF - Northern Fluminense, BL – Coastal Lowlands, MRJ – Rio de Janeiro Municipality. RJ93/1 - Lagoa de Cima; Campelo2001; T02 - Lagoa Salgada; LC1 - Lagoa Comprida1; JURUTI1 - Lagoa Comprida2; PA1 - Poço das Antas 1; PA2 - Poço das Antas 2; B – Búzios; M – Maricá; ITA/01 –Itaipu; T4 – Guapimirim; T8 – Paquetá; T13 – Jurujuba; T14 – São Gonçalo; PV – Praia Vermelha; C – Camorim; G – Guandu; L – Guaratiba; E – Sepetiba1; D – Sepetiba2; S1 - Paraty1; S2 – Paraty2.

Figue 2. Camorim dam, an Ombrophilous Atlantic Forest

Figure 3. Campelo lake border with *Typha*

Figure 4. Poço das Antas. Hill covered by the dense ombrophilous Atlantic Forest and grassland vegetation

Figure 5. Lagoa Comprida, Jurubatiba, restinga vegetation

The largest remaining forest fragments occur in the coastal massifs of Pedra Branca, Tijuca, and Mendanha (SOS Mata Atlântica, 2002). Mangrove ecosystems today are concentrated mainly around Ilha Grande Bay, Sepetiba Bay, Guanabara Bay, the Jacarepaguá lowlands, and the Baixada Norte Fluminense region (Amador, 2013; Schaeffer-Novelli, 2018). Restinga formations extend from the present tideline inland to the first foothills of the Serra do Mar (Rizzini, 1997; Suguio & Tessler, 1984), being particularly widespread along the northern coast (Araujo, 1984; Araújo & Maciel, 1979; Araujo & Henriques, 1984). Human settlement across the region has historically exerted increasing pressure on these ecosystems, contributing to the fragmentation and degradation observed today (Magalhães Correia, 1936).

The ongoing trend of sea-level rise has produced detectable alterations along the coastline and adjacent lowlands, directly influencing local vegetation dynamics. To investigate these changes, sediments collected from multiple sites - via sediment cores and excavations - were analyzed, with pollen grains and spores serving as primary proxies for vegetation reconstruction. Within this framework, the main objective of this study is to examine the oscillations of Atlantic Forest vegetation along the southeastern coast of Brazil from the Late Pleistocene to the present.

Material and Methods

Sediment cores and columnar profiles collected from various microregions of the coastal plain of Rio de Janeiro State were examined (Table 1). Samples were obtained using different coring and sampling techniques, including vibracoring, percussion coring with PVC tubes, and the extraction of sediment blocks in aluminum boxes following manual excavation to expose the stratigraphic profiles.The physicochemical processing of the sediments followed the protocol described by Ybert et al. (1992), with specific adjustments made according to the texture and composition of each sediment type. Palynomorph identification was conducted through comparative analysis using reference slide collections and specialized catalogues. Key literature sources consulted for taxonomic identification included Barth & Misumi (2023), Behling (1995), Garcia (1997, 1998), Hooghiemstra (1984), Lorscheitter et al. (1998, 1999), Luz & Barth (2000), Roubik & Moreno (1991). Palynomorph diagrams were constructed using relative percentages and pollen concentrations with the software packages Tilia and TiliaGraph (Grimm, 1992). Ages of the sediment cores were obtained through radiocarbon (^{14}C) dating by Accelerator Mass Spectrometry (AMS). The AMS-derived ^{14}C ages were calibrated using CALIB v.8.2 and the SHCal20 Southern Hemisphere atmospheric calibration curve (Stuiver et al., 2013; Hogg et al., 2020). The resulting calibrated age ranges and their associated probability distributions are presented in Table 1.

Results

Hereafter, the twenty published palynological sediment studies were analyzed according to the mesoregions of Rio de Janeiro State, arranged from north to south as presented in Table 2.

Mesoregion Northern Rio de Janeiro State (NRJ) (Table 2)

Five sediment cores were analyzed in this mesoregion. The oldest record, from Lagoa de Cima, extends back to approximately 6,500 yr BP and reflects a hygrophilous Atlantic Forest environment that gradually transitioned to grassland communities (Luz et al., 1999; Luz & Barth, 2002; Luz et al., 2011). No sediment from this site is preserved after 3,000 yr BP. Two cores obtained closer to the ocean, from Lagoa Comprida, originate from a palaeolagoon approximately 6,000 yr BP in age (Luz et al., 2022; Misumi, 2020; Misumi et al., 2023). One of these cores is relatively short, while the other shows continuous sedimentation until ~4,000 yr BP, after which deposition ceased. Both records indicate the predominance of restinga vegetation with open-plant communities and hygrophytic elements throughout the period. The ancient coastal palaeolagoon of Lagoa Salgada, with sediments dating from ~2,500 yr BP to the present (Toledo et al., 2009), also shows dominance of restinga vegetation (Barth et al., 2001). Similarly, sediments from Campelo Lake, another former palaeolagoon, are characterized mainly by herbaceous and hygrophytic vegetation and span the interval ca. 2,800–2,300 yr BP (Luz et al., 2006; 2011).

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Table 1. Mesoregions of Rio de Janeiro State, sediment sampling localities, geographic coordinates, and references.

Mesoregion	Locality (material identification)	Geographic coordinates (GPS)	References
Northern Rio de Janeiro State (NRJ)	Lagoa de Cima (RJ93/1 core)	21°46′28″S; 41°31′15″W	Luz et al., 2002
Northern Rio de Janeiro State (NRJ)	Lagoa do Campelo (Campelo 2001 core)	21°40′03″S; 41°11′40″W	Luz et al., 2006
Northern Rio de Janeiro State (NRJ)	Lagoa Salgada (T02 core)	21°54′47″S; 41°00′34″W	Toledo et al., 2009
Northern Rio de Janeiro State (NRJ)	Lagoa Comprida (LC1 core)	22°16′52″S; 41°39′22″W	Luz et al., 2022
Northern Rio de Janeiro State (NRJ)	Lagoa Comprida (JURUT1 core)	22°16′39″S; 41°39′92″W	Misumi, 2020
Coastal Lowlands (CL)	Poço das Antas (PA1 sedimentary column)	22°34′17″S; 42°15′16″W	Coelho et al., 2008
Coastal Lowlands (CL)	Poço das Antas (PA2 sedimentary column)	22°34′80″S; 42°15′05″W	—
Rio de Janeiro Municipality (RJM)	Búzios (RJ92-5 core)	22°48′45″S; 41°54′13″W	Freitas & Carvalho, 2012
Rio de Janeiro Municipality (RJM)	Maricá Lagoon (T2/MAR core)	22°57′34″S; 42°41′41″W	Cruz, 2010; Ishimine et al., 2025
Rio de Janeiro Municipality (RJM)	Lagoa de Itaipu (ITA/01 core)	22°59′53″S; 43°04′38″W	Bartholomeu, 2010
Rio de Janeiro Municipality (RJM)	Guanabara Bay (T4 core)	22°41′10″S; 43°04′56″W	Barth et al., 2006
Rio de Janeiro Municipality (RJM)	Guanabara Bay (T8 core)	22°44′46″S; 43°06′75″W	Barreto et al., 2007
Rio de Janeiro Municipality (RJM)	Guanabara Bay (T13 core)	22°55′26″S; 43°06′35″W	Barreto et al., 2015
Rio de Janeiro Municipality (RJM)	Guanabara Bay (T14 core)	22°50′40″S; 43°07′00″W	Barreto et al., 2017
Rio de Janeiro Municipality (RJM)	Praia Vermelha (PV sedimentary column)	22°57′16″S; 43°09′53″W	Bartholomeu et al., 2014
Rio de Janeiro Municipality (RJM)	Camorim Dam (C core)	23°52′04″S; 43°23′32″W	Barth et al., 2023
Rio de Janeiro Municipality (RJM)	Guandu River (G sedimentary column)	22°71′75″S; 43°18′05″W	Misumi et al., 2014
Rio de Janeiro Municipality (RJM)	Guaratiba (L sedimentary samples)	Without GPS information	Belem, 1985
Rio de Janeiro Municipality (RJM)	Sepetiba Bay (D core)	23°01′50″S; 43°36′03″W	Coelho et al., 2002
Rio de Janeiro Municipality (RJM)	Sepetiba Bay (E core)	—	Santos et al., 2000
Far South of Rio de Janeiro State	Paraty coastal plain (S1 core)	23°12′20"S; 44°43′20"W	Freitas et al., 2025
Far South of Rio de Janeiro State	Paraty coastal plain (S2 core)	23°12′13"S; 44°43′12"W	Freitas et al., 2025

Table 2. Radiocarbon dating (^{14}C AMS) results for the sediment cores and columnar profiles analyzed in this study. The table includes sampling locations (site), sample depth (cm), type of dated material, laboratory code, conventional ^{14}C age (years BP), and calibrated age interval (cal yr BP).

Site	Depth (cm)	Laboratory code	Material	Conventional age (^{14}C yr BP)	Calibrated age (cal yr BP)
Lagoa de Cima (RJ93/1 core)	23-28	*Beta-170237	Mud	3,220 ± 40	3,256 to 3,291
	190-194	**Ly-10310	Organic mud	6,880 ± 65	7,573 to 7,799
	260-272	Ly-10214	Wood fragment	6,985 ± 50	7,675 to 7,869
Lagoa do Campelo (Campelo 2001)	16-23	Beta-157947	Peat	2,320 ± 80	2,083 to 2,496
	204-205	Beta-157950t	Peat	2,790 ± 40	2,761 to 2,953
Lagoa Salgada (T02)	50 – 55	Ly-10216	Carbon lamination	2,540 ± 60	2,405 to 2,741
Lagoa Comprida (LC1)	4 - 6	Beta-500878	Organic sediments	3,780 ± 30	3,980 to 4,185
	12 – 14	Beta-482390	Organic sediments	5,000 ± 30	5,595 to 5,752
	12 – 14	Beta-451038	Organic sediments	5,070 ± 30	5,703 to 5,899
	38 - 40	Beta-451036	Organic sediments	5,120 ± 30	5,736 to 5,917
	69-71	Beta-451034	Organic sediments	5,620 ± 30	6,295 to 6,412
Lagoa Comprida (JURUT1)	27–29	Beta-322813	Clay-organic sediment	5,710 ±40	6,388 to 6,564
	47–49	Beta-399322	Clay-organic sediment	5,890 ±30	6556 to 6,750
	57–59	Beta-322812	Clay-organic sediment	4,700 ±30	5,310 to 5,477
	77–79	Beta-399323	Clay-organic sediment	6,000 ±30	6,675 to 6,715
	87–89	Beta-322811	Clay-organic sediment	6,090 ±40	6,782 to 7,011
	117–119	Beta-399324	Clay-organic sediment	6,350 ±30	7,163 to 7,315
	147–149	Beta-322810	Clay-organic sediment	6,140 ±40	6,853 to 7,085
Poço das Antas (PA1)	38-34	Beta-184063	Organic sediment	1,880 ± 80	1,580 to 1,931
	77-73	Beta-228012	Organic sediment	4,090 ± 40	4,417 to 4,649
	120-116	Beta-182054	Organic sediment	6,080 ± 40	6,779 to7,002
Poço das Antas (PA2)	23-19	Beta-182055	Organic sediment	1,810 ± 40	1,583 to1,750
	122-118	Beta-191406	Organic sediment	3,520 ± 40	3,638 to 3,879
Búzios (RJ 92-5/core)	2	Beta-100116	Organic sediment	100 + 50	160-10
	60	Beta-270654	Organic sediment	3.960 + 40	4.530-4.290
	150	Beta-100112	Organic sediment	4.830 + 80	5.730-5.450
	169	Beta-100113	Organic sediment	4.910 + 80	5.780-5.580
	176.5	Beta-100114	Organic sediment	4.900 + 100	5.900-5.470
	341	Beta-100115	Organic sediment	7.090 + 100	8.060-7.700
Maricá (T2/MAR/core)	168	-	-	3,990	non

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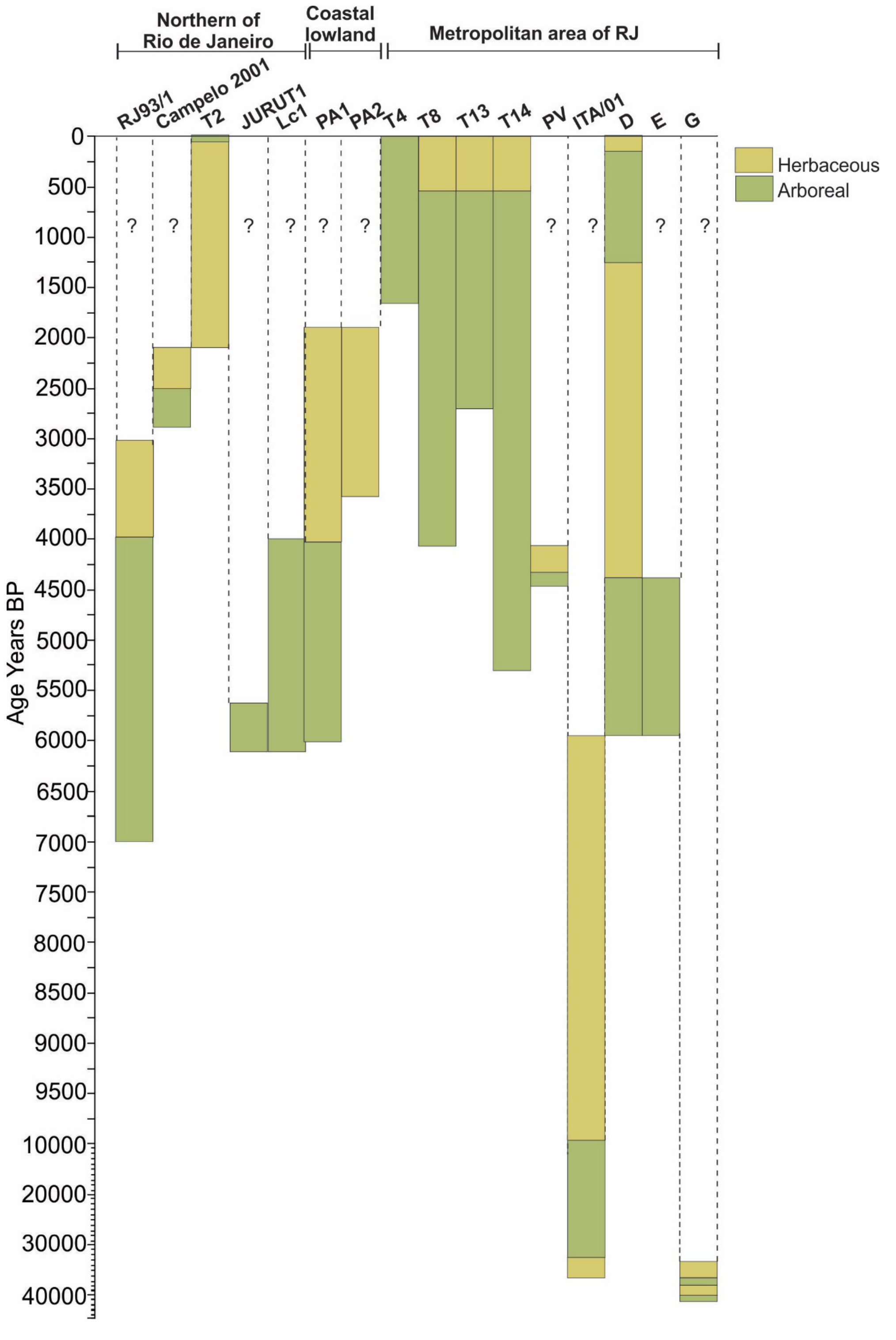

Figure 6. Northern, coastal lowlands and metropolitan área of Rio de Janeiro State.

Mesoregion Coastal Lowlands (CL) (Table 2)

Further inland, at Poço das Antas within the Mico-Leão Reserve (municipality of Casimiro de Abreu), Quaternary vegetation dynamics differed markedly from the coastal sites. Two boreholes were excavated in peat bogs within grassland communities situated among rounded hills covered by Atlantic Ombrophilous Forest (Coelho et al., 2008). Sediments from one borehole span slightly more than 6,000 yr BP, while the other begins at 3,500 yr BP; both sequences end at approximately 2,000 yr BP. The vegetation composition across the analyzed stratigraphic levels was highly consistent. Around 4,000 yr BP, forest cover became fragmented, leaving patches of upper Atlantic Forest interspersed with temporarily flooded grasslands. This mosaic, similar to the modern landscape, facilitated the formation of peat bogs in the area.

Returning to the coastal region, three sediment cores were analyzed: one from a lake on the Búzios Peninsula (Freitas et al., 2012), another from Maricá Lagoon (Ishimine et al., 2025), and a third from Itaipu Lagoon (Bartholomeu, 2010). The Búzios core, spanning ~8,000 yr BP to the present, reveals a persistent predominance of restinga and semideciduous forest vegetation throughout the record, interspersed with mangroves, swamps, and halophytic communities. In contrast, the basal levels of the Maricá Lagoon core date to ~4,000 yr BP (Ishimine et al., 2025; Cruz, 2010). Organic carbon content (COT, %) increased notably in the uppermost 50 cm of the sequence (Bruno, 2013). Restinga vegetation remained dominant, alongside seasonal semideciduous forests, grasslands, and hygrophytic species.

Sediments from Itaipu Lagoon date to approximately 40,000 yr BP, indicating a late Pleistocene environment characterized by humid, swampy conditions. During the Holocene, vegetation transitioned into a mosaic of rainforest, pioneer species, hydrophytes, and open-field communities. Despite this shift, humid conditions were maintained, although grasslands remained dominant. The lagoon itself was definitively established between ~8,000 and 7,000 yr BP (Ireland, 1987; Muehe & Valentini, 1998).

Mesoregion: Rio de Janeiro Municipality (RJM) (Table 2)

Four sediment cores (T4, T8, T13, T14) from the Guanabara Bay region were analyzed, all extending to the present (Vilela et al., 2014). The youngest, the T4 core, begins at ~1,700 yr BP and was collected in the Guapimirim Environmental Protection Area, showing exclusively mangrove vegetation (Barth et al., 2006). Nearby, the T14 core spans ~6,500 yr BP and initially contains abundant ombrophilous forest, which declined around 4,000 yr BP and transitioned to grassland by ~500 yr BP (Barreto et al., 2017), reflecting similar environmental dynamics as observed in the Guanabara Bay cores. North of Paquetá Island, the T8 core (~4,200 yr BP) records a predominance of Atlantic ombrophilous forest, which gradually gave way to open-field vegetation over time (Barth et al., 2004; Barreto et al., 2007). Near the entrance to Guanabara Bay, sediments from Jurujuba Sound (T13 core; ~3,500 yr BP) show an initial dominance of tropical rainforest that later transitioned to predominantly grassland formations (Barreto et al., 2015; Barth et al., 2011).

In other areas of Rio de Janeiro city, recent pollen studies have investigated vegetation dynamics over time. Sedimentary samples were collected near Sugarloaf Mountain, on Praia Vermelha (PV) beach. An old, black-colored sediment block buried beneath the beach sands was dated to 4,520–4,270 yr BP. Pollen analysis indicated the presence of restinga forest vegetation, which was gradually replaced by swamp and peat communities (Bartholomeu et al., 2014). In another location, a short sediment core from the Camorim Dam, constructed within the Tijuca National Forest in 1908, was analyzed. Pollen records from this core show that ombrophilous rainforest persisted throughout the period, despite recurring torrential rainfall events (Barth et al., 2023).

A sedimentary columnar block was collected along the banks of the Guandu River and dated to 42,500–35,200 yr BP. Pleistocene sediments indicate that this period was characterized by a combination of flooded forest and dry lowland vegetation (Misumi et al., 2014). Belem (1985) investigated mangrove vegetation in the Guaratiba area, near Sepetiba Bay, using three sediment cores spanning low- to high-tide sediments; no ^{14}C dates were available. Mangrove pollen grains were consistently present throughout the sequences. Additionally, two sediment cores collected along a mangrove transect in Sepetiba Bay were dated at their basal levels to 6,300–4,650 yr BP. Pollen analysis revealed that, in addition to mangroves, dense ombrophilous forest coexisted with restinga, hygrophytic, and open-field vegetation (Santos et al., 2000; Coelho et al., 2002). Two mangrove sedimentar cores were analyzed recently in the Paraty plain, an extremely Southern area of Rio de Janeiro municipality, one core next the sea tide, the other terrestial (Freitas et al., 2025).

General comments

The northern region of Rio de Janeiro State has undergone continuous landscape changes from the Pleistocene through the Holocene. These transformations were driven by multiple factors, including climate fluctuations, ocean currents, river dynamics, and other environmental processes (Martin et al., 1993; Luz et al., 2010). Paleolagoons were frequently transformed into lakes, and river courses were periodically diverted. All studied sediments fall within the Atlantic Forest biome; however, ombrophilous Atlantic Forest vegetation did not extend into coastal lagoon areas adjacent to the sea. Further inland, lake environments were dominated by seasonal semideciduous forest interspersed with open-plant communities, while pioneer species colonized the variable surroundings of these lagoons and lakes.

As shown by the analyzed records, vegetation formations during the late Pleistocene (e.g., the Búzios core and the Guandu sediment block) exhibit similar compositions, differing primarily in spatial extent and intensity. Most of the studied sequences begin around ~6,000 yr BP (e.g., cores from Lagoa de Cima, Lagoa Comprida, Poço das Antas, São Gonçalo-T14, and Sepetiba1). Local variations in vegetation - encompassing forests, restingas, mangroves, and herbaceous communities - were common and largely influenced by geological features and fluctuations in sea level. These dynamic changes are intrinsic to the region's history, highlighting the importance of continued study to better understand the past and anticipate future ecological trajectories.

Site	Conventional age (^{14}C yr BP)	Palynological data
Lagoa de Cima (RJ93/1 core)	3,220 ± 40	Prior to approximately 7,000 cal yr BP, the region appears to have been predominantly occupied by hygrophilous forest formations with subordinate grassland components. Beginning around 6,500 cal yr BP, palynological evidence reveals a progressive restructuring of the vegetation, characterized by a sustained decline in arboreal taxa and a concomitant expansion of grassland communities. By ca. 4,000 cal yr BP, the pollen assemblage became increasingly dominated by herbaceous and heliophilous taxa, indicative of a pronounced shift toward more open vegetation structures and the establishment of comparatively drier environmental conditions (Luz et al., 2011).
	6,880 ± 65	
	6,985 ± 50	
Lagoa do Campelo (Campelo 2001)	2,320 ± 80	At approximately 2,300 yr BP, a marked increase in palynomorph accumulation rates is observed, primarily attributable to the augmented representation of herbaceous taxa and hydrophilic pollen types. This shift likely reflects an intensification of local vegetational productivity coupled with enhanced moisture availability (Luz et al., 2006).
	2,790 ± 40	
Lagoa Salgada (T02)	2,540 ± 60	At Lagoa Salgada, the integration of palynological and isotopic datasets indicates the onset of a humid climatic regime around 3,000 yr BP, which supported a heterogeneous mosaic of open grasslands, restinga, and rainforest formations. By approximately 2,540 yr BP, however, isotopic evidence documents a transition toward drier climatic conditions, concomitant with the expansion of grassland communities. This arid interval was subsequently superseded by a renewed phase of increased moisture availability, facilitating the re-establishment and expansion of rainforest and restinga vegetation (Toledo, 2009; Barth et al., 2001).
Lagoa Comprida (LC1)	3,780 ± 30	In the Jurubatiba region, palynological records from sediment cores LC1 and Juruti1 document the persistence of characteristic restinga vegetation formations since approximately 6,312 calibrated years before present (cal yr BP). This vegetational assemblage remained established until roughly 1,943 cal yr BP, likely within a mosaic landscape composed of forested patches interspersed with open shrub thickets—an arrangement broadly analogous to the contemporary vegetation structure of the region (Luz et al., 2022; Misumi, 2020).
	5,000 ± 30	
	5,070 ± 30	
	5,120 ± 30	
	5,620 ± 30	
Lagoa Comprida (JURUT1)	5,710 ±40	
	5,890 ±30	
	4,700 ±30	
	6,000 ±30	
	6,090 ±40	
	6,350 ±30	
	6,140 ±40	

Poço das Antas (PA1)	1,880 ± 80 4,090 ± 40 6,080 ± 40	Between approximately 6,080 and 4,090 yr BP, the regional vegetation was dominated by Ombrophilous Forest formations, bordered by localized patches of grassland, peat, and secondary vegetation. During the ensuing interval, from 4,090 to 1,880 yr BP, palynological evidence reveals a pronounced increase in pollen types associated with grassland formations, secondary growth, and pioneer taxa, reflecting a concomitant decline in forest components. From roughly 1,880 yr BP onward, the pollen record indicates a gradual re-expansion of Ombrophilous Forest cover, particularly along hill slopes, suggesting a shift toward more humid climatic conditions or a reduction in disturbance intensity (Coelho et al., 2008).
Poço das Antas (PA2)	1,810 ± 40 3,520 ± 40	
Búzios (RJ 92-5/core)	100 + 50 3.960 + 40 4.830 + 80 4.910 ± 80 4.900 ± 100 7.090 ± 100	The sediment core recovered from Ferradura Lagoon, Armação dos Búzios, Rio de Janeiro—radiocarbon-dated (^{14}C) to approximately 8,060–7,700 cal yr BP at its basal section and extending to the present—indicates that the surrounding vegetation was primarily composed of restinga formations and semideciduous seasonal forest. Analysis of the core stratigraphy allowed the distinction of three depositional phases: an initial continental phase, followed by a lagoonal phase, and a more recent lagoon–lake phase. This well-defined sequence underscores the suitability of the Ferradura core for generating high-resolution paleoenvironmental reconstructions and enhancing our understanding of Late Holocene environmental dynamics in the region. (Freitas et al., 2012)
Maricá (T2/MAR/core)	3,990	A sediment core retrieved from Maricá Lagoon, Rio de Janeiro State - whose basal section is dated to approximately 3,990 years before present (yr BP) - was analyzed for its pollen content. Palynological evidence from this level indicates that restinga vegetation physiognomies predominated in the areas surrounding the lagoon at that time (Ishimine, 2025)
Lagoa de Itaipu (ITA/01)	7,180 ± 60 29,350 ± 590 31,100 ± 310 31,440 ± 530 38,490 + 940	Field vegetation has dominated the surroundings of Itaipu Lagoon since the Pleistocene, and throughout the period analyzed, there is no evidence for the widespread establishment of high-biodiversity rainforest formations. The lagoon itself was definitively formed around 7,000 yr BP (Bartholomeu, 2010).
Baía de Guanabara (T4)	1,760± 50	Around 6,500 calibrated years before present (cal yr BP), Dense Ombrophilous Forest constituted the dominant vegetation formation in the region, as recorded in sediment core T14, a condition that persisted until approximately 4,210 cal yr BP, corroborated by data from cores T8 and PV (Barreto et al., 2007; Barth et al., 2006). From circa 3,520 cal yr BP, a decline in the relative abundance of forest pollen taxa was documented, coinciding with a slight increase in pollen from hygrophilous plants, pteridophyte spores, and algae, predominantly of the genus Botryococcus (Barreto et al., 2007). In the uppermost 60 cm of cores retrieved from Guanabara Bay (T8, T13, and T14), a pronounced reduction of Dense Ombrophilous Forest elements was evident, accompanied by a substantial expansion of grassland taxa and the introduction of exotic species associated with anthropogenic activities. Additionally, mangrove vegetation displayed a continuous presence from approximately 1,760 cal yr BP onward (Barreto et al., 2007, 2015, 2017).
Baía de Guanabara (T8)	4,210 ± 40	
Baía de Guanabara (T13)	2,820 ± 40 3,520 ± 50	
Baía de Guanabara (T14)	550 ± 40 3,950 ± 40 5,700 ± 40	
Praia Vermelha (PV)	4,270 ± 60 4,520 ± 80	

Camorim Dam (C/core)	ca. 120 yrs.	Sediment core analysis from the Camorim Dam site, a reservoir that began operating in 1908, documents the persistence of secondary Atlantic Rainforest as the dominant plant community within Pedra Branca State Park (Barth et al., 2023).
Guandu (G/sedimentary column)	35,200 ± 340	Pleistocene Lowland Forest and Swamp Forest formations in the Guandu River basin are strongly influenced by hydrological dynamics, with dry lowland vegetation persisting in areas beyond the floodplain (Misumi et al., 2014).
	39,400 ± 480	
	> 40,890	
	> 42,500	
Guaratiba (L/sedimentary samples)	non	Samples from the geomorphological compartments representing crab, swamp, and algal facies of the Piracão River within the Guaratiba mangrove were analyzed. Three sediment cores were collected, although no radiocarbon (^{14}C) dating was performed. Mangrove vegetation was consistently recorded across all cores studied (Belem, 1985).
Sepetiba (D/core)	565 ± 20	Between approximately 6,300 and 4,650 yr BP, palynological records indicate the coexistence of taxa characteristic of Dense Ombrophilous Forest alongside species typical of *restinga* formations (Santos et al., 2000; Coelho et al., 2002). From 4,650 to 1,350 yr BP, an expansion of open vegetation types was documented, concomitant with a decline in forest-associated pollen taxa. Subsequently, between approximately 1,350 and 10 yr BP, forest vegetation indicators show a renewed increase. Within this interval, specifically between ca. 775 and 213 yr BP, the pollen record also exhibits a heightened frequency of taxa associated with savanna and open field ecosystems (Coelho et al., 2002).
	6,130 ± 40	
Sepetiba (E/core)	5,980 ± 40	
Paraty (S1/core)	2,087 ± 24 to 4,789 ± 27	Three sediment levels were analyzed. Mangrove vegetation was consistently recorded with market presence of *Rhizophora* and, in younger sections, of *Piper* and Fabaceae. Atlantic Forest vegetation formations were poorly represented. Highest pollen grain frequency was detected around 5,200 yr BP. (Freitas et al., 2025).
Paraty (S2/core)	1,304 ± 23 to 6,955 ± 27	Seven sediment levels were analyzed. Mangrove vegetation was consistently recorded with market presence of *Rhizophora* and, in addition, of *Piper*, Fabaceae and Poaceae. Atlantic Forest vegetation formations were poorly represented. Highest pollen grain frequency was detected around 5,200 yr BP. (Freitas et al., 2025).

Table 3. Palynological datasets were collected and analyzed across multiple mesoregions within the State of Rio de Janeiro

CRediT authorship contribution statement

Ortrud Monika Barth: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Visualization, Funding acquisition. Alex da Silva de Freitas: Conceptualization, Writing – original draft, Visualization. Cintia Ferreira Barreto: Writing – original draft, Visualization.

Declaration of competing interest

The authors declare no known financial or personal conflicts of interest that could have influenced the research presented in this paper.

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