

On the reinstatement of *R. samoensis* and *R. brevistyla* in East Pacific red mangroves (*Rhizophora*, *Rhizophoraceae*)

Xavier Cornejo¹, Carmita Bonifaz¹

¹Herbario GUAY, Departamento de Botánica, Facultad de Ciencias Naturales, Universidad de Guayaquil, Av. Raúl Gómez Lince s.n. y Av. Juan Tanca Marengo (campus Mapasingue), Guayaquil, Ecuador. Orcid: 0000-0002-4081-4047

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Abstract

On the basis of previously presented molecular studies, *Rhizophora samoensis* (Hochr.) Salvoza and *R. brevistyla* Salvoza (*Rhizophoraceae*) are here reinstated as valid names for the Eastern Pacific red mangroves. The identical meaning of vernacular names of *R. samoensis* from Samoa and coastal Ecuador is here reported for first time. The lectotype of the basionym *Rhizophora mangle* var. *samoensis* is designated.

Keywords: Lectotype; mangal; Pacific Ocean, transoceanic; vernacular names.

Resumen

Con base en estudios moleculares previamente presentados, se reestablece *Rhizophora samoensis* (Hochr.) Salvoza y *R. brevistyla* Salvoza como nombres válidos de mangles rojos para el Pacífico Este. Se reporta por primera vez el idéntico significado de los nombres vernáculos de *R. samoensis* en Samoa y costa de Ecuador. Se designa el lectotipo del basónimo *Rhizophora mangle* var. *samoensis*.

Palabras claves: Lectotipo; manglar; nombres vernáculos; océano Pacífico; transoceánico.

Introduction

Rhizophora L. (*Rhizophoraceae*) is the emblematic and most conspicuous Pantropical genus of mangroves; it is characterized by aerial prop roots, decussate branches and evergreen simple leaves, a pair of deciduous narrowly-lanceolate stipules in a conical-terminal arrangement, cymose-axillary inflorescences, berry-like fruits that develop piercing-pendulous outer embryos termed hypocotyls, propagules or radicles (Salvoza, 1936; Hou, 1960; Tomlinson, 1986; Duke, 2010; Cornejo, 2014; Cerón-Souza et al., 2010; Prance, 2018). The genus comprises six species and hybrids commonly known as red mangroves which for thousands of years have provided many goods and services to countless human groups that have settled and flourished along seacoasts mostly in tropical and also in subtropical belts between latitudes of around 32°N and 38°S (Stothert, 2011; Lo et al., 2014; Prance, 2018).

Currently, the species of *Rhizophora* are grouped into two biogeographically disjunct and isolated realms, whose genetic divergence using cpDNA has been estimated to have occurred approximately 10.6 MA (5.4 to 16.3 MA), when the Tethys Sea closed

(Takayama et al. 2021). Each of those *Rhizophora* realms are floristically dissimilar and having a particular composition, namely the Indo-West Pacific (IWP) and Atlantic-East Pacific (AEP) (Salvoza, 1936; Tomlinson, 1986; Duke, 2010; Takayama et al., 2021), the AEP group is the focus of this paper. Two species and a hybrid are formally recognized to occur broadly along both coasts of the American continents: *R. mangle* L. (1753, the nomenclatural generic type), *R. racemosa* G. Mey (1818) and *R. x harrisonii* Leech. (1918; Cerón-Souza et al., 2010; Cornejo, 2013; Prance, 2018).

Rhizophora has been monographed by Salvoza (1936), Hou (1960) and Prance (2018); however, recent molecular studies (Takayama et al., 2013, 2021; Francisco et al., 2018; Mori et al., 2021) are challenging the traditional taxonomy and nomenclature on this genus for AEP, that since Linnaeus' time has been mostly based on morphology. The genetic studies (op. cit.) suggest that the strong similarity in nuclear and chloroplast markers and the identical haplotype and alleles does not allow genetic differentiation between the Polynesian *R. samoensis* (Hochr.) Salvoza lineage, the only species of *Rhizophora* in Samoa (Whistler, 1992; Fig. 1: A, B) and most of the eastern Pacific populations (Fig. 2: A, B), the latter traditionally

* Correspondencia del autor:

E-mail: xcornejoguay@gmail.com



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identified as *R. mangle*, coupled to the absence of clear-cut morphological characters, indicates that both names of indistinguishable transpacific populations refer to a single genetic taxonomic entity (Duke, 2002; Takayama et al., 2013, 2021; Mori et al., 2021). Furthermore, due to the apparently absence of sharp morphological characters to separate the populations of *R. mangle* from the Pacific and Atlantic coasts and following the principle of priority, Art. 11 of ICBN (Turland et al., 2018), *R. samoensis* has been synonymized and treated in a very broad sense as *R. mangle* (Linnaeus, 1753; Guppy, 1906; Hou, 1960; Prance, 2018), the older name for a species genetically distinct and originally described from the West Indies.

Conversely, recent studies based on molecular markers have revealed a diphyly and different genetic structure of *R. mangle* and *R. racemosa* on the oceanic basins of either side of the American continent, which plays the role of a barrier to gene flow within the genus, and that *R. racemosa* from the Atlantic basin is more genetically similar to *R. mangle* from the same basin than to *R. racemosa* trees from the Pacific coast (Mori et al., 2021; Cerón-Souza com. pers.). The distinct genealogical lineages present two conspicuous allopatric patterns of distribution, each of those belonging and restricted to highly distinctive separate biogeographic units that started to differentiate from each other at least 3.1 to 3.5 MYA ago; they have been isolated since the closure of the Isthmus of Panama, an event occurred ca. 2.8 MYA, and are independently and parallel-evolving (Takayama, 2013; O’Dea et al., 2016; Cerón-Souza, unpublished). Consequently, the molecular results exhibit a case of “taxonomic inconsistency” and notorious limitation of “current morphology-based species designations” that is impractical for a precise definition of biological lineages, yielding a lack of accuracy for conservation and management purposes on East Pacific red mangroves (Mori et al., 2021). It is worthy mentioning that in the East Pacific, the endemic flora and fauna of the Galapagos Islands are a well-known case of allopatric evolution and speciation in isolated environments that in terms of periods of time is comparable to that of the *Rhizophora* in the same Pacific basin. The major islands of the Galapagos emerged between 4 to 0.07 MYA (Geist et al., 2014), allowed during this relatively short time span or even posteriorly to less than 50.000 YBP, the subsequent evolutionary formation of the conspicuous endemic taxa, e.g. the woody genus *Scalesia* (Darwin’s giant daisies, Asteraceae), which comprises 15 species (1.4 MYA to 24.000 YBP), the pink iguana *Conolophus marthae* (1.5 MYA), the Galapagos’ marine iguana *Amblyrhynchus cristatus* (less than 50.000 YBP), etc... (MacLeod et al., 2015; Hedrick, 2019; Fernández-Mazuecos et al., 2020), all of those within similar dates as or even younger than the red mangroves divergence on the same Pacific basin. Furthermore, must be considered that the fossil evidence suggests that during Eocene the Extra-Andean cordilleras in Northwestern South America (e.g. Chongón-Colonche)

were shallowly submerged as a reef within an open marine environment (Moreira, 2019), and that those initially emerged as isolated islands as a consequence of a collision of coastal Ecuador against the western Andean margin most likely during or posteriorly to the latest Oligocene-Miocene (ca. 28.1 to 20.4 MY) (Jaillard et al., 1995), having a similar path of evolution that involved the colonization by prehistoric mangroves (Cornejo & Lombardi, 2021) in proto Northwestern South America, at least 10 MY before the emergence and formation of present Galapagos islands and the closure of isthmus of Panama (op. cit.).

Currently, the proven natural lineages correlate with well-defined biogeographical patterns and provide valuable insights for delimiting species (Fujita et al., 2012). Therefore, the Red Mangroves species deserve to have their own names, and a re-evaluation and reshaping of the nomenclature of East Pacific *Rhizophora* is presented here. The accurate nomenclatural perspective of mangrove diversity allows the East Pacific taxa to be regarded as separate conservation and management units, as previously suggested (Takayama et al., 2013).

Whether a genetical-biogeographic or a morphological base is chosen for the recognition of biological entities, this is an open viewpoint that is not in conflict with ICN for species and names (Turland et al., 2018). Consequently, although there is a marked tendency of different length of (dry) sepals between *R. mangle* s.s. (11-15 mm long) versus *R. samoensis* (7-11 mm long), and different length of pistils and leaf shape between *R. racemosa* s.s. (pistils up to 7 mm long and blades mostly oblanceolate to oblanceolate-elliptic or narrowly elliptic) versus *R. brevistyla* Salvoza (pistils 3-5 mm long and blades usually lanceolate or ovate to elliptic-oblong or broadly elliptic to obovate) (Gregory; 1958; Cornejo, 2014), the recognition of separate taxa of *Rhizophora* for East Pacific is mostly based on unequivocal genetical and biogeographical evidence rather than sharply phenotypical-morphological differentiation. Therefore, as *R. mangle*, *R. racemosa* and *R. x harrisonii* are the earliest red mangroves in AEP, discovered and typified from the West Indies and Guianas, respectively (Linnaeus, 1753; Hou, 1960; Prance, 2018), those names remain attached to the Atlantic basin taxa, and consequently, changes in the nomenclature are needed for the East Pacific red mangroves. Reviewing the nomenclatural history of the East Pacific *Rhizophora*, which fortunately is well-documented, Salvoza (1936) formally recognized *R. samoensis* at specific rank and established *R. brevistyla* as a new species, both regarded as the American Pacific counterpart for the Atlantic *R. mangle* and *R. racemosa*; those are the unique names for red mangroves in the East Pacific region that must be followed according to ICN (Turland et al., 2018). Salvoza’s nomenclatural proposal was accepted in Flora of Panama (Gregory, 1958), but due to the apparently slight morphological differences ended up relegated to the synonymy of the Atlantic *R. mangle*

and *R. x harrisonii* (Hou, 1960, as *R. harrisonii*), respectively; and this nomenclatural conclusion on East Pacific taxa has been broadly accepted to the present day (Cornejo, 2013, 2014; Prance, 2018). In the latter, the synonymization of *R. brevistyla* as *R. x harrisonii* was effected without any other option because Hou (op. cit.) thought that *R. harrisonii* was the only species in the genus with multiflorous inflorescences on the west coasts of the Americas, regarding *R. racemosa* as restricted to the Atlantic basin. *Rhizophora brevistyla* has been cited as a hybrid for EAP (Duke, 2017; Saenger et al., 2019), however, that name it is not regarded as valid because the hybrid status has not been formally presented following Art. 41.1, and 41.5 of ICBN (Turland et al., 2018).

Conversely, supported by the recently discovered genetic lineages on the East Pacific, the names proposed by Salvoza are here reinstated, and the populations of red mangroves traditionally identified as *R. mangle s.l.* and *R. racemosa s.l.* on the Pacific coasts of America are here recognized as *R. samoensis* and *R. brevistyla*, respectively, two genetically porous species that have experienced ancient and steady hybridization and introgression (Cerón-Souza, 2010); however, the latter species need further explanations. According to Hou (1960:629), the contracted or rather loose architecture of inflorescences is the first character to separate *R. racemosa* from *R. x harrisonii*; however, molecular results (Mori et al., 2021, fig. 4, 5; Cerón-Souza et al., unpublished) demonstrate that in the East Pacific *Rhizophora*, the individuals that have inflorescences that could be rather contracted (typical of *R. racemosa*) or somewhat elongate, slender and loose (what though to be *R. x harrisonii*), do not have a genetic differentiation among them and that the apparently morphological differences neither suggest a hybrid origin. The molecular evidence (Mori et al., 2021 fig. 4, 5; Cerón-Souza et al., unpublished) reveals that both names are a same genetic entity that can express phenotypic plasticity exhibiting contracted or slender and loose inflorescences without taxonomic value. This unexpected new information demonstrates that the traditionally used morphological character cannot separate the species and the hybrid, respectively. Consequently, opposite to Hou (1960) and Prance (2018), the Pacific *R. brevistyla* cannot be synonymized under the Atlantic *R. x harrisonii* because: i) is an allopatric different genetic lineage that has been independently originated and separately maintained on the other side of the American continent (Mori et al., 2021), ii) the rather contracted vs. loose structure of inflorescences do not correlate to a hybrid, but to a genetically consistent single species; and, iii) *R. brevistyla* has no natural dispersal capacity for reaching even the Galapagos islands that are located 500 to 650 M west off the coast of continental Ecuador, therefore, the notorious shorter capacity of dispersal, whether caused by a lower tolerance to sea salinity and/or to high Equatorial solar irradiance intensity in open sea or due to any other limiting factor, must

be regarded as a distinctive physiological-ecological difference if compared *R. brevistyla* against to the also Equatorial but trans-Atlantic populations of *R. x harrisonii s.s.* or *R. racemosa s.s.*, that have a conspicuously greater dispersal range -in a higher sea surface salinity- exhibiting an average disjunction of ca. 2,500 to 3,500 M (Breteler 1969, 1977; Tomlinson, 1986; Lo et al., 2014; Jones and Cessi, 2017; Craig et al., 2017). Therefore, the populations identified as *R. racemosa s.l.* and *R. x harrisonii s.l.* in East Pacific both are here recognized as one species under the name of *R. brevistyla*. A nomenclatural hybrid between *R. samoensis* and *R. brevistyla* is expected to be formally recognized pending further additional molecular studies.

Regarding to the morphology, the isotype of *Rhizophora mangle* var. *samoensis* Hochr., the basionym of *Rhizophora samoensis* that is held on G Herbarium, exhibit an inflorescence with 6 flowers (Fig. 1: A), that trait has been confirmed by recent field exploration in mangroves of Samoa (photos sent to senior author by Yero Kuethe), where *R. samoensis* produce inflorescences with 6 to 7 flowers (Fig. 1: B), and matches the description for this species (Salvoza, 1936). On the eastern Pacific, the populations of *R. samoensis* (currently known as *R. mangle*) often have inflorescences with 2 to 4 flowers, and sometimes 5 to 7 flowers (Fig. 2: A, B). Molecular studies (Takayama et al., 2013, 2021; Mori et al., 2021), have demonstrated that the 2 to 7 flowers per inflorescence in the transpacific populations of *R. samoensis* is the result of phenotypical plasticity within a same genetic entity. As the main character of *R. samoensis* (as *R. mangle* from E Pacific) has been stated and believed to be 2 to 4 flowers per inflorescence (e.g., Hou, 1960; Cornejo, 2014; Prance, 2018), the circumscription of this species must be broadened including the number of flowers per inflorescence that present the overlooked G isotype, therefore, an updated key to the species is provided.

Taxonomy

1. ***Rhizophora samoensis*** (Hochr.) Salvoza, Nat. Appl. Sci. Bull. Philipp. 5(3): 220, fig. 6. 1936. (Fig. 1: A, B; 2: A, B).

Basionym: *Rhizophora mangle* var. *samoensis* Hochr., Candollea 2: 447. 1925. TYPE: SAMOA. île d'Upolu, Apia, mangrove, 26 Mar 1905 (fl), B. P. G. Hochreutiner 3423 (Lectotype, designated here: G-00446757 [image!]; isotype: G [image!]).

Two mounted type specimens of *Rhizophora mangle* var. *samoensis* are hold in G herbarium, both with the same collector, number of collections, locality, and date, that with the printed label and barcode is here selected as lectotype.

Usually identified as: *Rhizophora mangle* L. *sensu lato*.

Habitat and distribution: In the east Pacific from Baja California to northwestern Peru, also in the Galapagos and trans-Pacific disjunct to the Indo West Pacific in Western Polynesia: Tonga

and Samoa; South Melanesia: New Caledonia, Vanuatu, and Fiji (Salvoza, 1936; Gregory, 1958; Duke, 2010).

For a full description and additional comments see Cornejo 2014:234 (as *R. mangle*).

2. *Rhizophora brevistyla* Salvoza, Nat. Appl. Sci. Bull. Philipp. 5(3): 211, fig. 2. 1936. (Fig. 2: C, D).

TYPE: PANAMA. Panama, along the Pacific coast, Bella Vista, 10 Sep 1929 (fl), F. M. Salvoza 1007 (Holotype: A-55199 [image!]; isotypes: L-9919 (fragm.), S-04-1961 [image!]).

Usually identified as: *Rhizophora racemosa* G. Mey., *sensu lato*; *R. harrisonii* Leechm., *sensu lato*; *R. x harrisonii* Leechm., *sensu lato*.

Habitat and distribution: In the east Pacific from El Salvador to northwestern Peru (Salvoza, 1936; Gregory, 1958).

For a full description and additional comments see Cornejo 2014:238 (as *R. racemosa*).

Key To The East Pacific Species Of *Rhizophora*

- 1a. Inflorescences pauciflorous, 1-2-branched, geminate, cymose or true cymes with

2 to 7 flowers; ovules always cream; fully developed hypocotyls 13-30 cm long.....

Rhizophora samoensis

- 1b. Inflorescences multiflorous, 3-5(-6?)-branched, cymose, with 8-64 (or more?) flowers; ovules sometimes pink or reddish to crimson-red; fully developed hypocotyls 20-52 cm long.....*Rhizophora brevistyla*

Meaning of vernacular names of *Rhizophora samoensis* in samoa and coastal ecuador

It is interesting to note the identical meaning of vernacular names in different languages and similar perspectives of *R. samoensis* regarding other species of mangroves from Samoa and coastal Ecuador (Acosta-Solis, 1961:79; Dinaf-Clirsen,1991; Cornejo, 2014; Whistler, 2000; Iakopo, 2006). *Rhizophora samoensis* in Samoan is known as "Togo tane" that means male mangrove (Whistler, 2000; Iakopo, 2006), whereas in coastal Ecuador the same species is known among several other Spanish vernacular names as "mangle macho" and "mangle caballero", both also meaning male mangrove (Acosta-Solis, 1961:79;

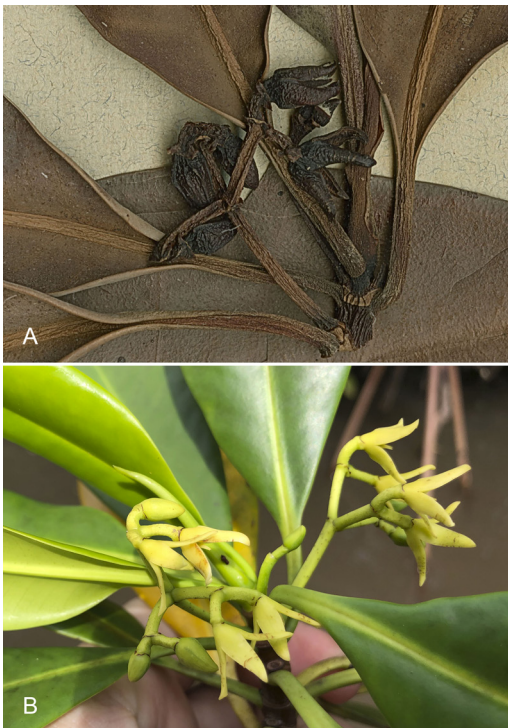


Fig. 1. *Rhizophora samoensis*, terminal leafy branches and inflorescences holding 6 to 7 flowers, from Upolu island, Samoa. A. Close up from G Isotype. B. Fresh material.— A Courtesy of G Herbarium. B. Courtesy of YERO KUETHE.

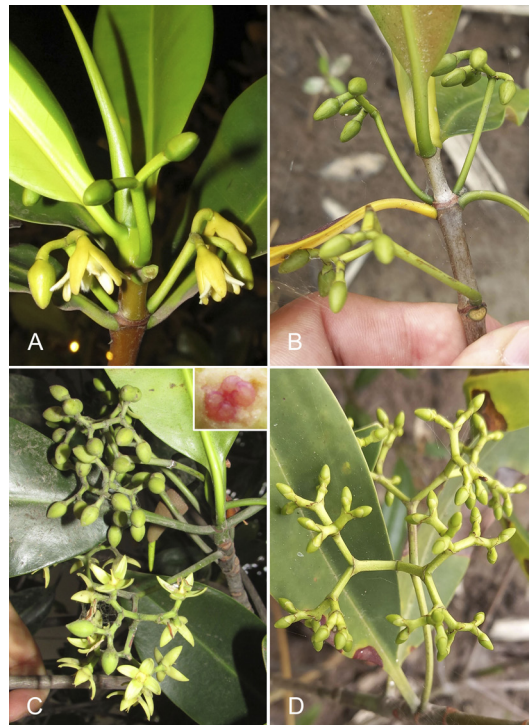


Fig. 2. *Rhizophora samoensis*, terminal leafy branches and inflorescences holding 2 to 6 flowers, from Ecuador. A. From San Cristobal, Galápagos islands. B. From Nuevo Porvenir, province of Guayas, continental Ecuador. C. From University of Guayaquil, province of Guayas. D. From Nuevo Porvenir, province of Guayas. A-D Photos by XAVIER CORNEJO.

Dinaf-Clirsen, 1991; Cornejo, 2014). In the latter region the "macho" word when applied to plants strictly means male (obs. pers.), and because of the taller height that *R. samoensis* can achieve, it is used to differentiate it from shorter species of mangroves, regarded and named as female mangroves, that is *Hilairanthus germinans* (L.) Cornejo (syn. *Avicennia germinans*, Acanthaceae) in coastal Ecuador as well as *Bruguiera gymnorhiza* the Samoan "Togo fafine" that translated is female mangrove in Samoa (Acosta-Solís, 1961:79; Whistler, 2000; Iakopo, 2006:15). The same meaning of vernacular names of the remarkable trans-Oceanic disjunct populations of *R. samoensis* on eastern and western Pacific exhibits a case of random coincidence or perhaps the evidence of some transoceanic connection (Gilmore, 1930; Heyerdahl, 1952; MacDougall, 2003; Warren, 2016; Ioannidis et al., 2020) that suggests that "mangle macho" may have been a translation to Spanish inherited from a lost pre-Hispanic autochthonous language (Galeote, 1997; Herrero-López, 2016), that was the putative ancestral origin of the mentioned vernacular names of *R. samoensis* in coastal Ecuador (Figure 1 y 2).

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