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A revision of mangrove plants of the Solomon Islands, Vanuatu, Fiji, Tonga and Samoa

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A Report for the MESCAL Project, IUCN Oceania Office, Suva

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EXECUTIVE SUMMARY

1) This report documents and reviews the results of plant diversity surveys of mangrove vegetation conducted during 2012 by Dr Norm Duke in collaboration with five MESCAL country teams in Solomon Islands, Vanuatu, Fiji, Tonga and Samoa. Work in each country involved team training, support and consultation, as well as the compilation and preliminary review of data gathered.

2) Data presented in this report includes species keys and checklists for each country, noting a number of significant new discoveries for most. Success was measured not only by these new findings, but also by the enthusiasm, skills and confidence shown by each country work team.

3) The data provide essential pre-requisite information for subsequent vegetation surveys on biomass, carbon accumulation, and the condition of mangrove tidal wetlands of each country.

4) The number of mangrove species observed in all countries totalled 34 species, with 6 of these being hybrids. No single country had all species.

5) Mangrove species in the islands vary with: Samoa having 5; Tonga having 10; Fiji having 11; Vanuatu having 21; and Solomon Islands having 31. These numbers have something to do with the proximity to Papua New Guinea and SE Asia (as the world region with maximal mangrove diversity), but it has more to do with island size where smaller islands have less species.

6) It was notable that hybrids only occurred where both parental species grew in nearby locations. The hybrid intermediate forms are considered recognisable species in the list because they are a notable and distinctive in the field, and they maintain the same morphological characters consistently wherever they occur.

7) The species are from 18 genera, representing 14 different plant families. This is very high diversity in such a small plant habitat group. The most well-represented family is the Rhizophoraceae with 13 species and hybrids, while the second is the Acanthaceae family with 5, and the Lythraceae with 4. The next items list the number of species additional to those recorded in the 2010 World Mangrove Atlas.

8) There are 8 additional species observed for Solomon Islands, including: *Acanthus ebracteatus* subsp. *ebracteatus*; *Acrostichum aureum*; *Acrostichum speciosum*; *Avicennia rumphiana*; *Barringtonia racemosa*; *Bruguiera hainesii*; *Dolichandrone spathacea*; *Pemphis acidula*. At least two additional mangrove species require confirmation as they may also occur in the Solomon Islands, including: *Cynometra iripa*; *Rhizophora annamalayana*.

9) There are 3 additional species observed for Vanuatu, including: *Acrostichum speciosum*; *Dolichandrone spathacea*; *Rhizophora selala*. At least 3 additional mangrove species require confirmation as they may also occur in Vanuatu including: *Acanthus ilicifolius*; *Pemphis acidula*; *Rhizophora tomlinsonii*.

10) There are 2 additional species observed for Fiji, including: *Barringtonia racemosa*; *Rhizophora stylosa*. The latter record was clearly an error in the World Mangrove Atlas because the species is well known in the islands. At least two additional mangrove species require confirmation as they may also occur in Fiji, including: *Acrostichum speciosum*; *Pemphis acidula*.

11) Two additional species observed for Tonga, including: *Acrostichum speciosum*; *Rhizophora selala.*

12) One additional species observed for Samoa, including: *Acrostichum speciosum.* At least one additional mangrove species requires confirmation as it may also occur in Samoa, included *Pemphis acidula*.

TABLE OF CONTENTS

1 INTRODUCTION

This is a brief account and update on the mangrove plant species found in the five MESCAL project countries, Solomon Islands, Vanuatu, Fiji, Tonga and Samoa. This brief revision is based on field surveys conducted in March-May 2012 in association with the respective country teams.

2 METHODOLOGY

2.1 Preparations made before field surveys

For each country team, the immediate task was to prepare a briefing document (as specified below) before the first visit (see Table 1 for scheduling dates). The briefing document was used for preparation in achieving the overall MESCAL project goals. The briefing document was used by the MESCAL support team to supplement and support local collaboration and support, for the successful completion of planned objectives for each country.

Table 1. Schedule of field surveys and training with Dr Duke and team for each country in 2012.

Country:	Fiji
Travel:	5th March 2012
On-ground:	6 - 9 March 2012
Travel:	10th March 2012
Specialist Team:	Dr Norm Duke
Country:	Samoa
Travel:	31st March or 1st April 2012
On-ground:	2 - 4 April 2012
Travel:	5th April 2012
Specialist Team:	Dr Norm Duke
Country:	Solomon Islands
Travel:	9th April 2012
On-ground:	10 - 17 April 2012
Travel:	18th April 2012
Specialist Team:	Dr Norm Duke, Apanie Wood
Country:	Tonga
Travel:	22nd April 2012
On-ground:	23 -26 April 2012
Travel:	27th April 2012
Specialist Team:	Dr Norm Duke
Country:	Vanuatu
Travel:	6th May 2012
On-ground:	7 - 11 May 2012
Travel:	12th May 2012
Specialist Team:	Dr Norm Duke, Apanie Wood

This first task was to identify and itemise the resources available, any printed knowledge of mangroves (including: reports, magazine and newspaper articles), individuals who have specialist knowledge of mangrove plants, and the local capacity available to undertake mapping and/or floristic surveys in each country.

As further information, Dr Duke presented his most current knowledge, for all mangrove species believed to occur in each country, compared with records from other countries across the south west Pacific. Individual country team collaboration with this project was essential to validate and improve upon prior

knowledge of local mangrove biodiversity. The prior list of species were most helpful. There were no equivalent lists and data on saltmarsh plant species – these plants were also present in mangrove habitat.

2.2 Briefing document before conducting field surveys

Before conduct of biodiversity surveys of mangrove and saltmarsh plants, each team were asked to prepare and assemble the following information:

1. Identify and locate copies of all current lists/books of mangrove and saltmarsh plants described and/or recorded for each country, and for respective country demonstratiion sites.
2. Identify and locate individuals (noting availability) with expertise in identifying mangrove and saltmarsh plants in each country.
3. Identify and describe prior botanical surveys of mangrove biodiversity and distribution, who conducted such work, and when this work was undertaken.
4. Identify all printed knowledge of localised benefits of mangrove habitat, and individual plants in each country.
5. Identify and locate botanical reference collections and individual herbaria of preserved mangrove plants in each country.

2.3 Links with the integrated overall work program

The overall field program had a number of key components – the first two (including the biodiversity surveys) were considered highest priority:

1) mapping ground truth methods – required GPS; camera; 50-100m tape measure; 1.2m tape measure; data sheets.
2) species identification of mangrove and saltmarsh plants required a useful and relevant mangrove identification book. Copies of the mangrove guide book, 'Australia's Mangrove's (Duke 2006), was given to each team. Where local information was available this definitely was used. A plant press was requested for collection of reference voucher specimens for country herbarium, as needed. Specific other equipment included: GPS; camera; data sheets.
3) 'long plot' transect surveys for above ground carbon biomass estimates of different forest types – required all of the above equipment.
4) the shoreline video assessment method for monitoring habitat condition, and estimating carbon biomass along coastlines – required: a HD video camera; a laser range finder; a 4m boat with outboard motor (or equivalent); plus all other equipment listed above.

3 RESULTS

3.1 Overall Findings

The total number of mangroves in all countries totals 34 species, with 6 of these being hybrids. No single country had all species. It was notable that hybrids only occured where both parental species grew in nearby locations. The hybrid intermediate forms were considered as distinct species in the list because they were individually notable in the field, and they maintained morphological characters consistently wherever they occurred. The total species were from 18 genera representing 14 different plant families. This is considered very high diversity in such a small plant habitat group. The most well-represented family was the Rhizophoraceae with 13 species and hybrids, while the second was the Acanthaceae with 5, and the Lythraceae with 4. For specific details, see Tables 1 and 2.

Table 1. Numbers of specialist plant species, genera and plant families in mangroves of the Solomon Islands, Vanuatu, Fiji, Tonga and Samoa.

MESCAL Country	Family Confirmed TOTAL	Genera Confirmed TOTAL	Species Confirmed TOTAL	Records New to World Atlas 2011	Suspected additional records to confirm	Likely TOTAL
Solomon Islands	14	18	29	8+	2+	31
Vanuatu	8	10	18	3+	3+	21
Fiji	7	7	9	2+	2	11
Tonga	7	8	10	2	0	10
Samoa	3	4	4	1+	1	5

The numbers of confirmed mangrove species was increased in all countries from those listed in the World Mangrove Atlas (2010). And, in the Solomon Islands, Vanuatu, Fiji and Samoa, there was a reasonable expectation that additional species might be found. The respective number of these most likely additional species for each country are listed in Table 1, and specific species are listed in Table 2. The keys for each country (listed below) include all additional plants expected. The expectations are based on regional distribution patterns of each species, and their ability to disperse. There has been uncertainty also in some cases regarding the definition of mangrove species, as compared with mangrove associates. The definition has been covered in detail in various published texts – summarized by Duke (2006). In brief, a mangrove is determined mostly by its normal presence within the tidal zone between mean sea level and the highwater mark – and, it's usual absence from supra-tidal, upland locations.

Table 2. Mangrove plant species in the south west Pacific, MESCAL countries. Observations following 2012 surveys by Dr NC Duke with MESCAL country teams. Note, those additional to the World Mangrove Atlas (2010) listed with brackets (<X>), those confirmed are underlined (X), and those likely present (-?).

Plant Family Name	Mangrove species of the MESCAL countries	Solomon Islands	Vanuatu	Fiji	Tonga	Samoa
Acanthaceae	*Acanthus ebracteatus*	<X>				
Acanthaceae	*Acanthus ilicifolius*	X	-?			
Pteridaceae	*Acrostichum aureum*	<X>				
Pteridaceae	*Acrostichum speciosum*	<X>	<X>	-?	<X>	<X>
Myrsinaceae	*Aegiceras corniculatum*	X				
Acanthaceae	*Avicennia alba*	X				
Acanthaceae	*Avicennia marina*	X	X			
Acanthaceae	*Avicennia rumphiana*	<X>				
Lecythidaceae	*Barringtonia racemosa*	<X>		<X>		
Rhizophoraceae	*Bruguiera cylindrica*	X				
Rhizophoraceae	*Bruguiera gymnorhiza*	X	X	X	X	X
Rhizophoraceae	*Bruguiera* X *hainesii*	<X>				
Rhizophoraceae	*Bruguiera parviflora*	X	X			
Rhizophoraceae	*Ceriops tagal*	X	X			
Fabaceae	*Cynometra iripa*	-?				
Bignoniaceae	*Dolichandrone spathacea*	<X>	<X>			
Euphorbiaceae	*Excoecaria agallocha*	X	X	X	X	
Malvaceae	*Heritiera littoralis*	X	X	X	X	
Combretaceae	*Lumnitzera littorea*	X	X	X	X	
Arecaceae	*Nypa fruticans*	X				
Lythraceae	*Pemphis acidula*	<X>	-?	-?	X	-?
Rhizophoraceae	*Rhizophora* X *annamalayan*	-?				
Rhizophoraceae	*Rhizophora apiculata*	X	X			
Rhizophoraceae	*Rhizophora samoensis*		X	X	X	X
Rhizophoraceae	*Rhizophora mucronata*	X				
Rhizophoraceae	*Rhizophora* X *selala*		<X>	X	<X>	
Rhizophoraceae	*Rhizophora stylosa*	X	X	<X>	X	
Rhizophoraceae	*Rhizophora* X *lamarckii*	X	X			
Rhizophoraceae	*Rhizophora* X *tomlinsonii*		-?			
Rubiaceae	*Scyphiphora hydrophylacea*	X				
Lythraceae	*Sonneratia alba*	X	X			
Lythraceae	*Sonneratia caseolaris*	X	X			
Lythraceae	*Sonneratia* X *gulngai*	X	X			
Meliaceae	*Xylocarpus granatum*	X	X	X	X	X
TOTAL FAMILIES (14)	TOTAL SPECIES (34)	29+	18+	9+	10	4+

Further specific observations are listed in the following sections for the respective countries.

3.2 Country Surveys

3.2.1 Mangrove Biodiversity of the Solomon Islands

The list of mangroves of the Solomon Islands were updated from earlier accounts by Ellison (1995, 1999) and Pillai & Sirikolo (2001) for the World Mangrove Atlas by Spalding et al. (2010). There were notable

changes made from the World Mangrove Atlas list but this is still incomplete. The recent field survey has amended the record in large part, but there remains uncertainty about the exact list of mangrove species present in the Solomon Islands. This uncertainty is reflected in the current listings where some species are noted as requiring confirmation. Notably, there are about 8 additional species from the World Atlas account. The reason for so many missing species is directly related to the poor published record of mangrove habitats for this country, not with standing the obvious local expert knowledge. This is a key reason for the proposed publication of these results as soon as possible – as soon as surveys associated with the current project are completed.

Table 3. Mangrove plant species in the Solomon Islands. Observations following 2012 surveys by Dr NC Duke with the MESCAL country team. Note, those additional to the World Mangrove Atlas (2010) listed with brackets (<X>), those confirmed are underlined (X), and those likely present (-?).

Mangrove species	**Solomon Islands**
Acanthus ebracteatus	<X>
Acanthus ilicifolius	X
Acrostichum aureum	<X>
Acrostichum speciosum	<X>
Aegiceras corniculatum	X
Avicennia alba	X
Avicennia marina	X
Avicennia rumphiana	<X>
Barringtonia racemosa	<X>
Bruguiera cylindrica	X
Bruguiera gymnorhiza	X
Bruguiera hainesii	<X>
Bruguiera parviflora	X
Ceriops tagal	X
Cynometra iripa	-?
Dolichandrone spathacea	<X>
Excoecaria agallocha	X
Heritiera littoralis	X
Lumnitzera littorea	X
Nypa fruticans	X
Pemphis acidula	<X>
Rhizophora X *annamalayana*	-?
Rhizophora apiculata	X
Rhizophora mucronata	X
Rhizophora stylosa	X
Rhizophora X *lamarckii*	X
Scyphiphora hydrophylacea	X
Sonneratia alba	X
Sonneratia caseolaris	X
Sonneratia X *gulngai*	X
Xylocarpus granatum	X
TOTAL SPECIES :::	29+

In summary, of the confirmed records, there are 29 species (with a possibility of at least 2 more), from 18 genera and 14 plant families. As an aid to on-going field investigations, the following key, lists characters also for the likely additional ones.

Key to mangrove species of the Solomon Islands

1. Palm or ground fern **2**
1*. Tree or shrub **4**

2. Palm to 10 m ***Nypa fruticans***
2*. Ground fern to 1 m **3**

3. Growth form small, no stem, fronds to 1 m long, sterile pinnae tapering to a narrow acuminate point, 10-20 cm long, restricted generally to upper tidal elevations. ***Acrostichum speciosum***
3*. Growth form large, indistinct stem, fronds 1-3 m long, pinnae rounded or truncate, abruptly acuminate, 20-40 cm long, restricted to upper tidal elevations of runoff channels. ***Acrostichum aureum***

4. Sap milky white, exuding from broken leaf ***Excoecaria agallocha***
4*. No exuding sap from broken leaf **5**

5. Stem base buttresses, pneumatophores or simple. **6**
5*. Stem base with stilt or prop roots on saplings and trees. **27**

6. Compound leaves **7**
6*. Simple leaves **9**

7. Leaves opposite; large white flowers (200 mm long); long bean-like seed pod. ***Dolichandrone spathacea***
7*. Leaves alternate; small flowers (4-5 mm long); rounded seed pod **8**

8. Tree; large spherical seed pod (to 25 cm wide), smooth shiny surface. ***Xylocarpus granatum***.
8*. Shrub, small tree; small bivalve seed pod (to 2 cm wide); wrinkled surface. ***Cynometra iripa***

9. Alternate leaves along stems. **10**
9*. Opposite leaves along stems. **13**

10. Large leaves (> 6 cm long); large seed pods. **11**
10*. Small leaves (< 6 cm long); small vase-like fruiting pods; leaves not pubescent. **12**

11. Leaves pubescent under; small green-purple flowers amongst the leaves; seed pod keeled. ***Heritiera littoralis***
11*. Leaves not pubescent under; large fluffy white flowers hang down on racemes; seed pod 4-cornered. ***Barringtonia racemosa***

12. Rounded leaf apices; curved horn-like fruiting pods. ***Aegiceras corniculatum***
12*. Emarginate leaf apices; small vase-like fruiting pods. ***Lumnitzera littorea***

13. Low shrub, sometimes undercanopy; often spiny leaves. **14**
13*. Trees or shrubs, often canopy forming; leaves always entire. **15**

14. Corolla white mostly (one subspecies deep purple); bracteoles absent; open flower 2-2.5 cm long; mature fruit capsule less than 2 cm long; seed approximately 5-7 mm wide; inflorescence variable; plant typically delicate, sometimes spiny. ***Acanthus ebracteatus***

14*. Corolla partly light blue or violet, rarely all white; 2 bracteoles, to 1 cm long; open flower 3.5-4 cm long; mature fruit capsule 2.5-3 cm long; seed approximately 10 mm wide; inflorescence usually longer than 10 cm; plant typically robust with spiny to very spiny leaves. ***Acanthus ilicifolius***

15. Shrub; leaves variably pubescent, mostly small (< 5 cm long); flowers white. **16**
15*. Tree; leaves always glabrous on upper surface, large (> 5 cm long); flowers orange. **17**

16. Leaves fully pubescent dull, small (< 3.5 cm long); petals 6, white; mature fruit calyx smooth mostly. ***Pemphis acidula***
16*. Leaves fully glabrous shiny, larger (> 3.5 cm long); petals 4 mostly, white; mature fruit calyx with 8 ribs. ***Scyphiphora hydrophylacea***

17. Leaves pubescent under. **18**
17*. Leaves not pubescent under. **20**

18. Leaf apex usually rounded; flower small, < 7 mm long, corolla diameter 4-12 mm, calyx < 4 mm long; inflorescence capitate; radicle hairy along most, if not entire length; pericarp densely tomentose. ***Avicennia rumphiana***
18*. Leaf apex usually pointed; flower small 3-8 mm long, corolla diameter 3-7 mm, calyx 3-6 mm long; inflorescence spicate or capitate; radicle glabrous except for short hairy collar about distal tip; pericarp puberulent. **19**

19. Inflorescence usually spicate; propagule very elongate with pointed distal end; style barely extended from ovary, minute; stigma positioned below lower edge of anthers; ovary glabrous on upper surface near style, pubescent below. ***Avicennia alba***
19*. Inflorescence capitate; propagule ovoid with rounded distal end; style erect, short; stigma positioned between upper and lower edge of anthers; ovary pubescent below style***.*** ***Avicennia marina***

20. Leaf apices rounded or broadly obtuse; around 5-6 calyx lobes. **21**
20*. Leaf apices acute; 8 or more calyx lobes. **24**

21. Always 5 calyx lobes; viviparous elongate propagules. ***Ceriops tagal***
21*. Usually 6 calyx lobes, maybe 7 or 8; globose berry (apple) with numerous small seeds. **22**

22. Petals white if present; stamens white; calyx smooth and shiny, cup-shaped with mature fruit; fruit diameter < 4 cm, less than or equal to hypanthium ***Sonneratia alba***
22*. Petals red, stamens red or white; calyx leathery, fruit calyx flat-expanded or cup-shaped with mature fruit **23**

23. Tree often forms canopy; leaves ovate; fruit calyx flat-expanded; fruit globose and full. ***Sonneratia caseolaris***
23*. Often emergent tree above canopy; leaves broadly ovate; fruit calyx cup-shaped; fruit globose, often indented about persistent style. ***Sonneratia* X *gulngai***

24. Flowers small, less than 3 mm wide; petal spine exceeds lobes; calyces with 8 lobes. **25**
24*. Flowers large, greater than 3 mm wide; petal spine shorter than lobes or absent; calyces with 10-14 lobes. **26**

25. Fruit calyx ribbed, lobes adpressed (1/4-1/5 length of calyx) ***Bruguiera parviflora***
25*. Fruit calyx smooth, lobes reflexed (1/2 length of calyx) ***Bruguiera cylindrica***

26. Flowers multiple (2-3 buds per inflorescence) mostly; calyces with 11 lobes. ***Bruguiera hainesii***
26*. Flowers solitary (1 flower bud per inflorescence) always; calyces with 14 lobes.

Bruguiera gymnorhiza

27. Mature flower buds and fruit below leaves on leafy shoot, bracts corky brown, petals with no marginal hairs, style less than 2 mm long, stamens 10-12 ***Rhizophora apiculata***
27*. Mature flower buds and fruit within leaves in leafy shoot, bracts smooth green, petals with marginal hairs, style greater than 2 mm long, stamens mostly 8-11. **28**

28. Mature flower buds less than 15 mm long, petal margins very hairy, petals fully enclosing stamens, stamens around 8, calyx lobes less than 1 mm thick, mature fruits and hypocotyls seasonally present '*stylosa-mucronata'* complex**29**
28*. Mature flower buds greater than 15 mm long, petal margins minutely hairy, petals not enclosing stamens, stamens 9-11, calyx lobes greater than 1 mm thick; mature fruits and hypocotyls absent …*Rhizophora* hybrids… **30**

29. Style length less than 2.1 mm; mature buds smooth and irregularly ovate, remaining pale green, calyx lobes yellow; bracts minute, margins often indistinct; dichotomous inflorescence branches 0-1 (-2), some with one or two pedicels and one sessile flower attached to the one peduncle; stamens (7-) 8.
Rhizophora mucronata
29*. Style length 2.1-6 mm; mature buds smooth, regular and slightly ovate, usually pale yellow in colour, bracts quite distinct with dark crenulate margins; dichotomous inflorescence branches (0-)2-4(-6); stamens (6-)8 . . . ***Rhizophora stylosa***

30. Style length 1.4-2.0 mm. ***Rhizophora* X *annamalayana***
30*. Style length 2.1-6.0 mm. ***Rhizophora* X *lamarckii***

Notes:

1) The hybrids of *Rhizophora* occur quite predictably where-ever the two parent species exist. So, the hybrid species between *R. mucronata* and *R. apiculata*, *Rhizophora* X *annamalayana*, previously not recorded in this country, is expected in many places. And, the diagnostic characters are listed in the key.

2) The occurrence of *Cynometra iripa* is uncertain and its occurrence needs to be reconfirmed.

3) The *Xylocarpus* present in Solomon Islands has been referred to various species. You have *X. granatum*, and/or *X. rumphii*. The last one is an associate species while *X. granatum* is a mangrove. They look very similar. You can tell them apart using the following characters:

1. Leaflets usually 4, more or less elliptic, the apex rounded or at most narrowed to a blunt point; inflorescence less than 8 cm long; root systems above ground as buttresses or pneumatophores; bark scaly or fissured; fruit mature around 8-25 cm in diameter. *Xylocarpus granatum*
1*. Leaflets usually 4, 6 or 8, more or less ovate and narrowed to a distinctly pointed apex; root systems not conspicuous above ground, buttresses absent; bark longitudinally fissured; fruit mature around 7-8 cm in diameter. Mangrove associate – grows above tidal influence. *Xylocarpus rumphii*

3.2.2 Mangrove Biodiversity of Vanuatu

The list of mangroves of Vanuatu were updated from earlier accounts by Ellison (1995, 1999) for the Mangrove World Atlas by Spalding et al. (2010). There have been some notable changes from the World Atlas account, but these are still considered incomplete in this revision. The recent field survey has

amended the record in large part, but there remains uncertainty about the exact list of mangrove species present in the islands of Vanuatu. This uncertainty is reflected in the current listings where some species are noted as requiring confirmation. Notably there are about 3 additional species from the World Atlas account. The reason for these missing species is directly related to the poor published record of mangrove habitats in this country, not with standing any local expert knowledge. This is a key reason for the proposed publication of these results as soon as possible – as soon as surveys associated with the current project are completed.

Table 5. Mangrove plant species in the islands of Vanuatu. Observations following 2012 surveys by Dr NC Duke with the MESCAL country team. Note, those additional to the World Mangrove Atlas (2010) listed with brackets (<X>), those confirmed are underlined (X), and those likely present (-?).

Mangrove species	**Vanuatu**
Acanthus ilicifolius	-?
Acrostichum speciosum	<X>
Avicennia marina	X
Bruguiera gymnorhiza	X
Bruguiera parviflora	X
Ceriops tagal	X
Dolichandrone spathacea	<X>
Excoecaria agallocha	X
Heritiera littoralis	X
Lumnitzera littorea	X
Pemphis acidula	-?
Rhizophora apiculata	X
Rhizophora samoensis	X
Rhizophora X *selala*	<X>
Rhizophora stylosa	X
Rhizophora X *lamarckii*	X
Rhizophora X *tomlinsonii*	-?
Sonneratia alba	X
Sonneratia caseolaris	X
Sonneratia X *gulngai*	X
Xylocarpus granatum	X
TOTAL SPECIES :::	18+

In summary, of the confirmed current records, there are 18 species (with a possibility of at least 3 more), from 10 genera and 8 plant families. As an aid for on-going field investigations, the following key, lists characters also for the likely additional ones.

Key to mangrove species of the Vanuatu islands

1.	Ground fern, trunkless	***Acrostichum speciosum***
1*.	Tree or shrub	**2**
2.	Sap milky white, exuding from broken leaf	***Excoecaria agallocha***
2*.	No exuding sap from broken leaf	**3**
3.	Stem base buttresses, pneumatophores or simple.	**4**
3*.	Stem base with stilt or prop roots on saplings and trees.	**16**

4. Compound leaves **5**
4*. Simple leaves **6**

5. Leaves alternate; small yellow-green flowers (5 mm long); spherical seed pod. ***Xylocarpus granatum***
5*. Leaves opposite; large white flowers (200 mm long); long bean-like seed pod. ***Dolichandrone spathacea***

6. Alternate leaves along stems. **7**
6*. Opposite leaves along stems. **8**

7. Large leaves (> 6 cm long), pubescent under; large keeled seed pods. ***Heritiera littoralis***
7*. Small leaves (< 6 cm long), not pubescent under; small vase-like fruiting pods. ***Lumnitzera littorea***

8. Low shrub, sometimes undercanopy; often spiny leaves. ***Acanthus ilicifolius***
8*. Trees or shrubs, often canopy forming; leaves always entire. **9**

9. Shrub; leaves fully pubescent, small (< 3.5 cm long). ***Pemphis acidula***
9*. Tree; leaves glabrous sometimes pubescent under, large (> 3.5 cm long). **10**

10. Leaves pubescent under. ***Avicennia marina***
10*. Leaves not pubescent under. **11**

11. Leaf apices rounded or broadly obtuse; around 5-6 calyx lobes. **12**
11*. Leaf apices acute; 8 or more calyx lobes. **15**

12. Always 5 calyx lobes; viviparous elongate propagules. ***Ceriops tagal***
12*. Usually 6 calyx lobes, maybe 7 or 8; globose berry (apple) with numerous small seeds. **13**

13. Petals white if present; stamens white; calyx smooth and shiny, cup-shaped with mature fruit; fruit diameter < 4 cm, less than or equal to hypanthium ***Sonneratia alba***
13*. Petals red, stamens red or white; calyx leathery, fruit calyx flat-expanded or cup-shaped with mature fruit 14

14. Tree often forms canopy; leaves ovate; fruit calyx flat-expanded; fruit globose and full. ***Sonneratia caseolaris***
14*. Often emergent tree above canopy; leaves broadly ovate; fruit calyx cup-shaped; fruit globose, often indented about persistent style. ***Sonneratia* X *gulngai***

15. Calyces with around 14 lobes; leaves large (to 24 cm long). ***Bruguiera gymnorhiza***
15*. Calyces with 8 lobes; leaves small (to 13 cm long). ***Bruguiera parviflora***

16. Leaf mucronate tip spike, erect, mature flower buds rounded, inflorescences always bifurcate (2-branching) at first juncture **17**
16*. Leaf mucronate tip not erect, mature flower buds often angled, inflorescences both bifurcate and trifurcate (3 branching) at first juncture **19**

17. Mature flower buds and fruit below leaves in leafy shoot, bracts corky brown, petals with no marginal hairs, styles < 2 mm, stamens 10-12 ***Rhizophora apiculata***

17*. Mature flower buds and fruit within leaves in leafy shoot, bracts smooth green, petals with marginal hairs, stamens mostly 8 (rarely 6-9 **18**

18. Mature flower buds <15 mm L, petal margins very hairy, petals fully enclosing stamens, calyx lobes <1 mm thick, mature fruits and hypocotyls seasonally present ***Rhizophora stylosa***
18*. Mature flower buds >15 mm L, petal margins minutely hairy, petals not enclosing stamens, calyx lobes >1 mm thick, mature fruits and hypocotyls not present ***Rhizophora* X *lamarckii***

19. Leaf apex acute, leaf mucronate tip folded with length equal to width, mature fruits and hypocotyls never present **20**
19*. Leaf apex blunt, leaf mucronate tip a broad fold with length much less than the width, mature flower buds, mature fruits and hypocotyls regularly present ***Rhizophora samoensis***

20. Leaf apex broadly acute, mature flower buds smooth, stamens 8, style >2 mm long, minutely bifurcate, petal margins wooly, calyx lobes < 1 mm thick ***Rhizophora* X *selala***

20*. Leaf apex sharply acute, mature flower buds with slight ribs at base of lobe sutures, stamens 11-18, style <2 mm long, deeply bifurcate, petal margins minutely hairy, calyx lobes > 1 mm thick
Rhizophora* X *tomlinsonii

Notes:

1) *Pemphis acidula* is unconfirmed for Vanuatu, but it is likely to be located there.

2) The *Acrostichum* present in Vanuatu has often been referred to *A. aureum* but by checking the diagnostic characters (see below), it appears to be *A. speciosum*. This compares with the known distribution of these species across the southern Pacific Ocean.

1. Growth form small, no stem, fronds to 1 m long, sterile pinnae tapering to a narrow acuminate point, 10-20 cm long, restricted generally to upper tidal elevations. *Acrostichum speciosum*

1*. Growth form large, indistinct stem, fronds 1-3 m long, pinnae rounded or truncate, abruptly acuminate, 20-40 cm long, restricted to upper tidal elevations of runoff channels.
Acrostichum aureum

3) The *Xylocarpus* present in Vanuatu has been referred to various species. You have *X. granatum*, and/or *X. rumphii*. The last one is an associate species while *X. granatum* is a mangrove. They look very similar. You can tell them apart using the following characters:

1. Leaflets usually 4, more or less elliptic, the apex rounded or at most narrowed to a blunt point; inflorescence less than 8 cm long; root systems above ground as buttresses or pneumatophores; bark scaly or fissured; fruit mature around 8-25 cm in diameter. *Xylocarpus granatum*

1*. Leaflets usually 4, 6 or 8, more or less ovate and narrowed to a distinctly pointed apex; root systems not conspicuous above ground, buttresses absent; bark longitudinally fissured; fruit mature around 7-8 cm in diameter. Mangrove associate – grows above tidal influence. *Xylocarpus rumphii*

4) The *Rhizophora* present in Vanuatu is incomplete – and, this key has more listed than has been recorded. But, at least 6 species (as described in the key) are expected to occur there because of the known hybrid combinations for the confirmed species present.

5) The *Acanthus* present in Vanuatu is most likely to be *A. ilicifolius*. It is worth checking though for *A. ebracteatus* using the following diagnostic characters:

1.Open flower 2-2.5 cm long; corolla white mostly, sometimes deep purple; bracteoles absent; mature fruit less than 2 cm long; seed approximately 5-7 mm wide; inflorescence variable; plant typically delicate. *Acanthus ebracteatus*

1*. Open flower 3.5-4 cm long; corolla in part light blue or violet, rarely white; bracteoles persistent, in fruit to 1 cm long; mature fruit 2.5-3 cm long; seed approximately 10 mm wide; inflorescence usually longer than 10 cm; plant typically robust with spiny to very spiny leaves. *Acanthus ilicifolius*

3.2.3 Mangrove Biodiversity of Fiji

The list of mangroves of Fiji were updated from earlier accounts by Ellison (1995, 1999) for the Mangrove World Atlas by Spalding et al. (2010). There have been some notable changes from the World Atlas account, but these still are considered incomplete in this revision. The recent field survey has amended the record in large part, but there remains uncertainty about the exact list of mangrove species present in the islands of Fiji. This uncertainty is reflected in the current listings where some species are noted as requiring confirmation. Notably, there are at least 2 additional species from the World Atlas account. The reason for these missing species is directly related to the inadequate published record of mangrove habitats for this country, not with standing the obvious local expert knowledge. This is a key reason for the proposed publication of these results as soon as possible – as soon as surveys associated with the current project are completed.

Table 6. Mangrove plant species in the islands of Fiji. Observations following the 2012 surveys by Dr NC Duke with the MESCAL country team. Note, those additional to the World Mangrove Atlas (2010) listed with brackets (<X>), those confirmed are underlined (X), and those likely present (-?).

Mangrove species	**FIJI**
Acrostichum speciosum	-?
Barringtonia racemosa	<X>
Bruguiera gymnorhiza	X
Excoecaria agallocha	X
Heritiera littoralis	X
Lumnitzera littorea	X
Pemphis acidula	-?
Rhizophora samoensis	X
Rhizophora X *selala*	X
Rhizophora stylosa	<X>
Xylocarpus granatum	X
TOTAL SPECIES :::	9+

In summary, of the confirmed current records, there are 9 species (with a possibility of at least 2 more), from 7 genera and 7 plant families. As an aid for on-going field investigations, the following key, lists characters also for the likely additional ones.

Key to the mangrove species of Fiji

1.	Ground fern, trunkless	***Acrostichum speciosum***
1*.	Tree or shrub	**2**
2.	Sap milky white, exuding from broken leaf	***Excoecaria agallocha***
2*.	No exuding sap from broken leaf	**3**
3.	Compound leaves	***Xylocarpus granatum***
3*.	Simple leaves	**4**
4.	Alternate leaves along stems.	**5**
4*.	Opposite leaves along stems.	**7**
5.	Large leaves (> 6 cm long); large seed pods.	**6**
5*.	Small leaves (< 6 cm long); small vase-like fruiting pods.	***Lumnitzera littorea***
6.	Leaves pubescent under; small green-purple flowers amongst the leaves; seed pod keeled.	***Heritiera littoralis***
6*.	Leaves not pubescent under; large fluffy white flowers hang down on racemes; seed pod 4-cornered.	***Barringtonia racemosa***
7.	Shrub; leaves pubescent, small (< 3.5 cm long).	***Pemphis acidula***
7*.	Tree; leaves glabrous, large (> 3.5 cm long).	**8**
8.	Buttress roots, knees; calyx with around 14 lobes.	***Bruguiera gymnorhiza***
8*.	Stilt roots, looping, aerial; calyx with 4 lobes.	**9**

9. Leaf mucronate tip prominent, narrow spike, mature flower buds rounded, inflorescences always bifurcate (2-branching) at first juncture. ***Rhizophora stylosa***

9*. Leaf mucronate tip not erect, mature flower buds often angular, inflorescences bifurcate (2 branching) and trifurcate (3 branching) at first juncture **10**

10. Leaf apex broadly acute; leaf mucronate tip folded under leaf, length equal to width; mature fruits and hypocotyls never present ***Rhizophora* X *selala***

10*. Leaf apex blunt; leaf tip a broad thickened lip folded under leaf, width much greater less than the length; mature fruits and hypocotyls normally present ***Rhizophora samoensis***

Notes:

1) *Pemphis acidula* is unconfirmed for Fiji, but it is likely to be located there.

2) The *Acrostichum* present in Fiji has often been referred to *A. aureum* but by checking the diagnostic characters (see below), it appears to be *A. speciosum*. This compares with the known distribution of these species across the southern Pacific Ocean.

1. Growth form small, no stem, fronds to 1 m long, sterile pinnae tapering to a narrow acuminate point, 10-20 cm long, restricted generally to upper tidal elevations. *Acrostichum speciosum*

1*. Growth form large, indistinct stem, fronds 1-3 m long, pinnae rounded or truncate, abruptly acuminate, 20-40 cm long, restricted to upper tidal elevations of runoff channels.

Acrostichum aureum

3) The *Xylocarpus* present in Fiji has been referred to various species. You have *X. granatum*, and/or *X. rumphii*. The last one is an associate species while *X. granatum* is a mangrove. They look very similar. You can tell them apart using the following characters:

1. Leaflets usually 4, more or less elliptic, the apex rounded or at most narrowed to a blunt point; inflorescence less than 8 cm long; root systems above ground as buttresses or pneumatophores; bark scaly or fissured; fruit mature around 8-25 cm in diameter. *Xylocarpus granatum*
1*. Leaflets usually 4, 6 or 8, more or less ovate and narrowed to a distinctly pointed apex; root systems not conspicuous above ground, buttresses absent; bark longitudinally fissured; fruit mature around 7-8 cm in diameter. Mangrove associate – grows above tidal influence. *Xylocarpus rumphii*

3.2.4 Mangrove Biodiversity of Tonga

The list of mangroves of Tonga were updated from earlier accounts by Ellison (1995, 1999) for the Mangrove World Atlas by Spalding et al. (2010). There have been some changes from the World Atlas account. The recent field survey has amended the record in part. Notably there are 2 additional species from the World Atlas account. The reason for these missing species is directly related to the inadequate published record of mangrove habitats for this country, not with standing any local expert knowledge. This is a key reason for the proposed publication of these results as soon as possible – as soon as surveys associated with the current project are completed.

Table 7. Mangrove plant species in the islands of Tonga. Observations following the 2012 surveys by Dr NC Duke with the MESCAL country team. Note, those additional to the World Mangrove Atlas (2010) listed with brackets (<X>), those confirmed are underlined (X), and those likely present (-?).

Mangrove species	**Tonga**
Acrostichum speciosum	<X>
Bruguiera gymnorhiza	X
Excoecaria agallocha	X
Heritiera littoralis	X
Lumnitzera littorea	X
Pemphis acidula	X
Rhizophora samoensis	X
Rhizophora X *selala*	<X>
Rhizophora stylosa	X
Xylocarpus granatum	X
TOTAL SPECIES :::	10

In summary, of the confirmed current records, there are 10 species, from 8 genera and 7 plant families. As an aid for on-going field investigations, the following key, lists the diagnostic characters.

Key to mangrove species of the Tongan islands

1. Ground fern, trunkless ***Acrostichum speciosum***
1*. Tree or shrub **2**

2. Sap milky white, exuding from broken leaf ***Excoecaria agallocha***
2*. No exuding sap from broken leaf **3**

3. Compound leaves ***Xylocarpus granatum***
3*. Simple leaves **4**

4. Alternate leaves along stems. **5**
4*. Opposite leaves along stems. **6**

5. Large leaves (> 6 cm long), pubescent under; large keeled seed pods. ***Heritiera littoralis***
5*. Small leaves (< 6 cm long), not pubescent under; small vase-like fruiting pods. ***Lumnitzera littorea***

6. Shrub; leaves pubescent, small (< 3.5 cm long). ***Pemphis acidula***
6*. Tree; leaves glabrous, large (> 3.5 cm long). **7**

7. Buttress roots, knees; calyx with around 14 lobes. ***Bruguiera gymnorhiza***
7*. Stilt roots, looping, aerial; calyx with 4 lobes. **8**

8. Leaf mucronate tip prominent, narrow spike, mature flower buds rounded, inflorescences always bifurcate (2-branching) at first juncture. ***Rhizophora stylosa***
8*. Leaf mucronate tip not erect, mature flower buds often angular, inflorescences bifurcate (2 branching) and trifurcate (3 branching) at first juncture **9**

9. Leaf apex broadly acute; leaf mucronate tip folded under leaf, length equal to width; mature fruits and hypocotyls never present .....***Rhizophora* X *selala***
9*. Leaf apex blunt; leaf tip a broad thickened lip folded under leaf, width much greater less than the length; mature fruits and hypocotyls normally present ..... ***Rhizophora samoensis***

Notes:

1) It is worth checking *Xylocarpus* present. The *Xylocarpus* in Tonga has been referred to other species. I am sure you have *X. granatum*, and/or *X. rumphii*. The last one is an associate species while *X. granatum* is a mangrove. They look very similar. You can tell them apart using the following characters:

1. Leaflets usually 4, more or less elliptic, the apex rounded or at most narrowed to a blunt point; inflorescence less than 8 cm long; root systems above ground as buttresses or pneumatophores; bark scaly or fissured; fruit mature around 8-25 cm in diameter. *Xylocarpus granatum*

1*. Leaflets usually 4, 6 or 8, more or less ovate and narrowed to a distinctly pointed apex; root systems not conspicuous above ground, buttresses absent; bark longitudinally fissured; fruit mature around 7-8 cm in diameter. Mangrove associate – grows above tidal influence. *Xylocarpus rumphii*

3.2.5 Mangrove Biodiversity of Samoa

The list of mangroves of Samoa were updated from earlier accounts by Ellison (1995, 1999) for the Mangrove World Atlas by Spalding et al. (2010). There have been some changes from the World Atlas account, but these are still considered incomplete in this revision. The recent field survey has amended the record, but there remains uncertainty about the exact list of mangrove species present in the islands of Samoa. This uncertainty is reflected in the current listings where one species is noted as requiring confirmation. Notably there is at least one additional species from the World Atlas account. The reason for the missing species is directly related to the inadequate published record of mangrove habitats for this country, not with standing the local expert knowledge. This is a key reason for the proposed publication of these results as soon as possible – as soon as surveys associated with the current project are completed.

Table 8. Mangrove plant species in the islands of Samoa. Observations following the 2012 surveys by Dr NC Duke with the MESCAL country team. Note, those additional to the World Mangrove Atlas (2010) listed with brackets (<X>), those confirmed are underlined (X), and those likely present (-?).

Mangrove species	**Samoa**
Acrostichum speciosum	<X>
Bruguiera gymnorhiza	X
Pemphis acidula	-?
Rhizophora samoensis	X
Xylocarpus granatum	X
TOTAL SPECIES :::	4+

In summary, of the confirmed current records, there are 4 species (with a possibility of at least 1 more), from 4 genera and 3 plant families. As an aid for on-going field investigations, the following key, lists characters also for the likely additional one.

Key to mangrove species of the Samoan islands

1.	Ground fern, trunkless	***Acrostichum speciosum***
1*.	Tree or shrub	**2**
2.	Compound leaves	***Xylocarpus granatum***
2*.	Simple leaves	**3**
3.	Shrub; leaves pubescent, less than 3.5 cm long.	***Pemphis acidula***
3*.	Tree; leaves glabrous, greater than 3.5 cm long.	**4**
4.	Stilt roots, looping, aerial; calyx with 4 lobes.	***Rhizophora samoensis***
4*.	Buttress roots, knees; calyx with around 14 lobes.	***Bruguiera gymnorhiza***

Notes:

1) *Pemphis acidula* is unconfirmed for Samoa, but it is likely to be located there.

2) The *Acrostichum* present in Samoa has often been referred to *A. aureum* but by checking the diagnostic characters (see below), it appears to be *A. speciosum*. This compares with the known distribution of these species across the southern Pacific Ocean.

1. Growth form small, no stem, fronds to 1 m long, sterile pinnae tapering to a narrow acuminate point, 10-20 cm long, restricted generally to upper tidal elevations. *Acrostichum speciosum*
1*. Growth form large, indistinct stem, fronds 1-3 m long, pinnae rounded or truncate, abruptly acuminate, 20-40 cm long, restricted to upper tidal elevations of runoff channels. *Acrostichum aureum*

3) The *Xylocarpus* present in Samoa has been referred to various species. You have *X. granatum*, and/or *X. rumphii*. The last one is an associate species while *X. granatum* is a mangrove. They look very similar. You can tell them apart using the following characters:

1. Leaflets usually 4, more or less elliptic, the apex rounded or at most narrowed to a blunt point; inflorescence less than 8 cm long; root systems above ground as buttresses or pneumatophores; bark scaly or fissured; fruit mature around 8-25 cm in diameter. *Xylocarpus granatum*
1*. Leaflets usually 4, 6 or 8, more or less ovate and narrowed to a distinctly pointed apex; root systems not conspicuous above ground, buttresses absent; bark longitudinally fissured; fruit mature around 7-8 cm in diameter. Mangrove associate – grows above tidal influence. *Xylocarpus rumphii*

4 DISCUSSION

4.1 Mangrove biodiversity update

The biodiversity surveys conducted for this MESCAL project have provided extremely valuable new observations that refine and improve our knowledge of mangrove plant distributions throughout the region. There were no countries that did not have some additions. Sometimes the species were known by the local observers, but international knowledge and awareness was lacking. A successful outcome of this project has been to further link local and international knowledge about mangroves.

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