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Seagrass biodiversity of the Fiji and Samoa islands, South Pacific

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Abstract Five seagrass species and one subspecies distributed in two families (Hydrocharitaceae and Cymodoceaceae) are reported from the Fiji Islands and the Samoan Archipelago. The Fijian seagrass flora comprises *Halophila decipiens*, *H. ovalis*, *H. ovalis* subspecies *bullosa*, *Halodule pinifolia*, *Halodule uninervis*, and *Syringodium isoetifolium*. *Halophila ovalis*, *H. ovalis* ssp. *bullosa*, and *S. isoetifolium* are the only taxa recorded from Samoa. Records of *Thalassia hemprichii*, *Cymodocea serrulata*, *Halophila minor*, and *Halophila ovata* credited to Fiji and Samoa are either erroneous or remain to be verified. All the species reported herein have an Indo-Pacific distribution, except *H. ovalis* ssp. *bullosa* endemic to Fiji, Tonga, and Samoa. *Halophila decipiens* is confirmed for the first time from Fiji with all specimens collected subtidally from 10–25m depth.

Keywords seagrasses; biodiversity; Indo-Pacific flora; distribution; Fiji; Samoa; *Halophila decipiens*; *Halophila ovalis* ssp. *bullosa*

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INTRODUCTION

Fifty-nine seagrass species are recognised worldwide. Twenty-four of these occur in the Indo-Pacific, considered to be part of the centre of origin for seagrass diversity, and 13 are found in the Pacific Islands (Coles et al. 2003a). Seagrasses from the Indo-west Pacific have been reported by den Hartog (1970), Tsuda et al. (1977), McMillan (1980), Mukai (1993), Pollard et al. (1993), Coles & Kuo (1995), and Short et al. (2001), with the most recent summations provided by Coles et al. (2003a) and Waycott et al. (2004). Seagrass diversity is highest in Papua New Guinea, which hosts all 13 species for the Pacific, and the diversity declines further away from this area, with two species reported from French Polynesia (Payri et al. 2000).

The seagrass floras of Fiji and Samoa remain poorly studied and understood. Setchell (1924) described the variety *bullosa* for a *Halophila ovalis* Hook.f. he collected from Tutuila Island, American Samoa. den Hartog (1970) recognised Setchell's variety as a subspecies of *H. ovalis*. Mukai (1993) added *Syringodium isoetifolium* (Asch.) Dandy to the Samoan flora. The recent work by Green and colleagues (Green et al. 2003) credited Samoa with four species, which incorrectly included *Cymodocea serrulata* (R. Br.) Asch. & Magnus. *Halophila minor* (Zoll.) Hartog was also recognised by Green et al. (2003), although populations of this species have yet to be found. The Fijian seagrass flora was documented by Parham (1972) with five taxa recognised: *Halophila ovalis* Hook.f. var. *ovalis*, *H. ovalis* Hook.f. var. *bullosa* Setch., *Halodule pinifolia* (Miki) Hartog, *H. uninervis* (Forssk.) Asch., and *S. isoetifolium*. *Ruppia maritima* L. var. *pacifica* H. St. John & Fosberg, was recorded by Greenwood (1943) as growing in brackish environments, but most records are from fresh water (Parham 1972). Three other seagrass species were added to the Fijian flora including *Thalassia hemprichii* (Ehrenb.) Asch. by Littler & Littler (2003), *H. minor* and *H. ovata* Gaudich. by Green et al. (2003). Despite our many surveys, we have been unable to find any populations of these species.

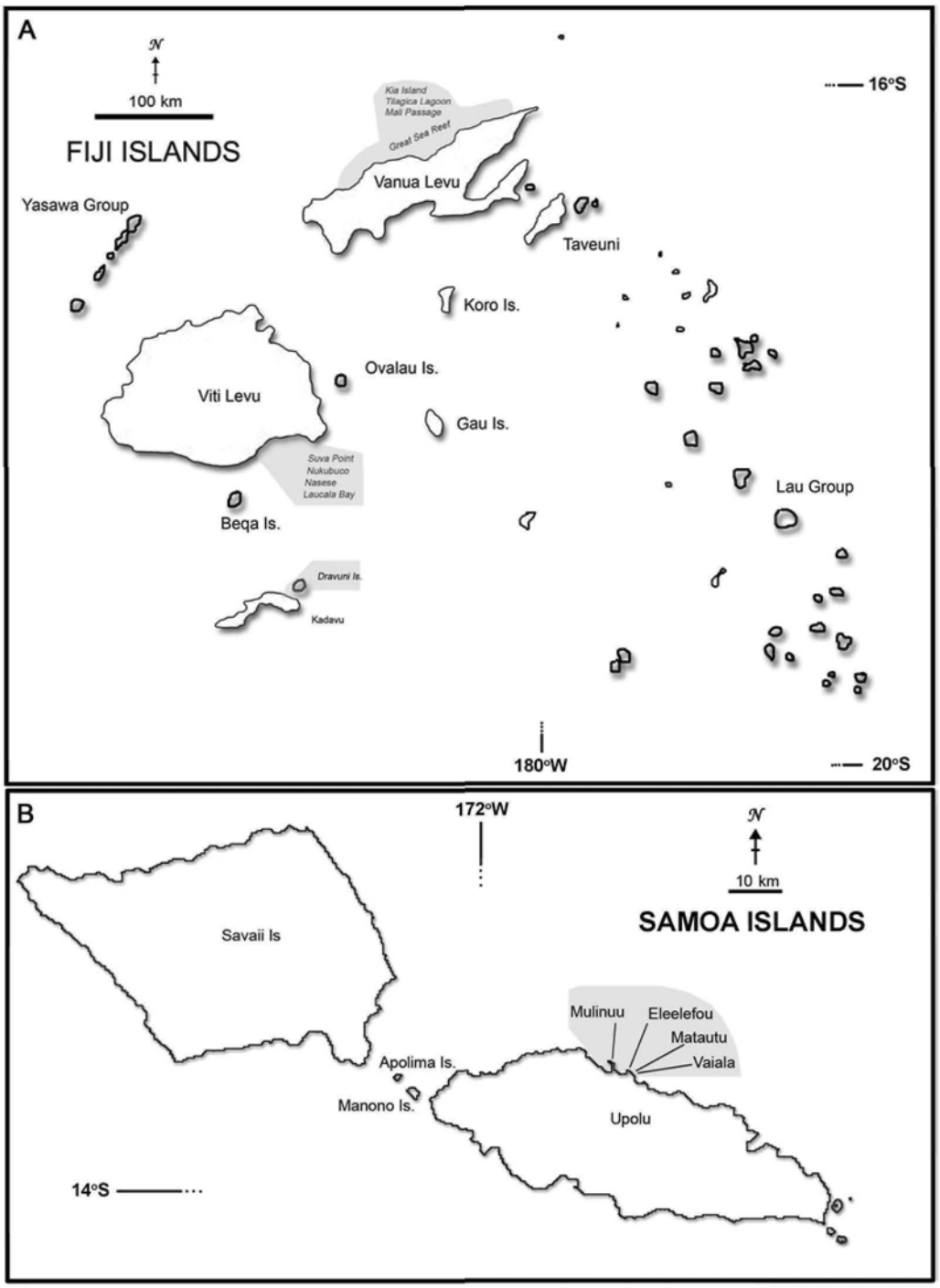

Fig. 1 Localities of recent seagrass collections (grey areas) in: **A**, Fiji and **B**, Samoa.

Recent floristic surveys carried out by the authors have provided new seagrass material for study including the confirmation of *Halophila decipiens* Ostenf. from the Fiji Islands.

MATERIALS AND METHODS

Seagrass specimens were collected by wading, snorkelling or scuba-diving to 25m depth. Our collections were made throughout Fiji and Samoa from 1997–2004 (see Fig. 1). Some of the collections were part of other projects, including the first author's MSc and PhD research (1998–2002, see Skelton & South 2001, unpubl. data), and the World Wide Fund for Nature's Great Sea Reef surveys in 2004 (Skelton & South unpubl. data). Some historical collections were examined; especially those made before 1997, and are included in this report. Representative plants were collected and preserved in a 4% formalin/seawater solution. Finer details of plants were observed under Olympus CX31 and Nikon SMZ645 stereo-microscopes. Voucher specimens were deposited at the South Pacific Regional Herbarium (Phycological Herbarium) in Suva, Fiji Islands (SUVA-A) (Table 1). The abbreviations of taxonomic authorities follow the International Plant Names Index (http://www.us.ipni.org/index.html [accessed 3 April 2006]), or Brummitt & Powell (1992).

Digital images were taken with Canon M95 or Nikon Coolpix 995 cameras, and were processed using Adobe® Photoshop 7 software.

RESULTS

The classification follows recent authors including Spalding et al. (2003) and Waycott et al. (2004). Five species and one subspecies were confirmed for Fiji and the Samoa Islands, distributed in two orders and three families.

Anthophyta

Monocotyledoneae

Helobiae

Cymodoceaceae

A recently erected family with members previously included in the larger Potamogetonaceae. Five genera are known, although only four are exclusively found in the marine environment. *Halodule* and

Table 1 Summary of collections housed in the South Pacific Regional Herbarium (Phycological Herbarium) (SUVA-A) and cited in the text.

SUVA-A	Species name	Locality	Collector	Date
891	*Halodule uninervis*	Suva Point, Fiji	McClatchey/N'Yeurt	10 May 1995
5574	*Halodule uninervis*	Nukubuco, Suva, Fiji	Malimali/Tuatai	7 Apr 2000
890	*Halodule uninervis*	Suva Point, Fiji	McClatchey/ N'Yeurt	10 May 1995
5552	*Halodule pinifolia*	Nukubuco, Suva, Fiji	Malimali/Tuatai	7 Apr 2000
892	*Halodule pinifolia*	Nasese, Suva, Fiji	McClatchey/N'Yeurt	10 May 1995
7118	*H. ovalis* ssp. *bullosa*	Mulinuu, Apia, Samoa	Skelton	17 Aug 2000
7109	*H. ovalis* ssp. *bullosa*	Mulinuu, Apia, Samoa	Skelton	17 Aug 2000
7112	*Halophila ovalis*	Eleelefou, Apia, Samoa	Skelton	20 Aug 2000
5554	*H. ovalis* ssp. *bullosa*	Nukubuco, Suva, Fiji	Malimali/Tuatai	7 Apr 2000
5363	*Halophila ovalis*	Mulinuu, Apia, Samoa	Skelton/Afiti	18 Sep 1998
7348	*Halophila ovalis*	Vaiala, Apia, Samoa	Skelton	6 Jul 2002
5365	*Halophila ovalis*	Mulinuu, Apia, Samoa	Skelton	17 Sep 1998
332	*Halophila ovalis*	Nukubuco, Suva, Fiji	Carlson	14 Jan 1973
455	*Halophila ovalis*	Laucala Bay, Suva, Fiji	South	8 Jul 1990
331	*Halophila ovalis*	Dravuni Is. Fiji	South	10 Apr 1991
330	*Halophila ovalis*	Nukubuco, Suva, Fiji	Carlson	26 Feb 1973
6996	*Halophila ovalis*	Vaiala, Apia, Samoa	Skelton/South	26 Aug 2000
5364	*Halophila ovalis*	Mulinuu, Apia, Samoa	Skelton	17 Sep 1998
7122	*S. isoetifolium*	Mulinuu, Apia, Samoa	Skelton	17 Aug 2000
7617	*S. isoetifolium*	Mulinuu, Apia, Samoa	Skelton/South	29 Aug 2000
329	*S. isoetifolium*	Laucala Bay, Suva, Fiji	Carlson	26 Feb 1973
5553	*S. isoetifolium*	Nukubuco, Suva, Fiji	Malimali/Tuatai	7 Apr 2000
578	*S. isoetifolium*	Nasese, Suva, Fiji	South	8 Apr 1993
7690	*Halophila decipiens*	Great Sea Reef, Fiji	Sykes et al.	10 Dec 2004
7691	*Halodule pinifolia*	Great Sea Reef, Fiji	Skelton	9 Dec 2004
7692	*Halodule uninervis*	Great Sea Reef, Fiji	Skelton	13 Dec 2004

Syringodium are found in Fiji, with only the latter genus extending towards Samoa.

Halodule Endl.

Halodule contains six species; four are distributed in the Atlantic Ocean, with two found in the Pacific (Green & Short 2003). Fiji and Tonga appear to be the easternmost limit of this genus in the Pacific Islands.

***Halodule pinifolia* (Miki) Hartog** Fig. 2

Halodule pinifolia (Miki) Hartog 1964: 309; den Hartog 1970: 158, fig. 44; Parham 1972: 350; Littler & Littler 2003: 288.
Diplanthera pinifolia Miki 1932: 787.

Voucher specimens

South Pacific Regional Herbarium, Suva. SUVA-A 892, Nasese reef flat, Suva, 10 May 1995, collected by W. McClatchey and A. N'Yeurt; SUVA-A 5552, Nukubuco reef flat, Suva, 7 April 2000, collected by S. Malimali and T. Tuatai; SUVA-A 7691, Kia Island, Great Sea Reef, Fiji, 9 December 2004, collected by P. Skelton.

Remarks

Halodule pinifolia forms homogenous patches in usually intertidal places, or occasionally intermixed with other seagrass species including the closely related *H. uninervis*. The Fijian populations are easily distinguishable in the field by their much narrower blade size compared with that of *H. uninervis* (1 mm versus 4 mm). Waycott et al. (2004) suggested that *H. pinifolia* and *H. uninervis* are conspecific, recognising that the plasticity of blade size is attributed to local conditions. Here we retained them as separate entities, as we did not find sufficient evidence from Fijian material to support this merger. Future studies, both ecological and molecular, would clarify the position of Fijian plants.

Distribution

Indo-west Pacific, reaching Vietnam to the west and Tonga to the east (den Hartog 1970: 158); absent from the Samoa Islands. First collected in Fiji by Setchell & Parks in 1926 (*fide* Parham, 1972: 350).

Fig. 2 *Halodule pinifolia*. Pressed herbarium specimen showing the narrower leaf blades, compared with *H. uninervis* (Fig. 3) (SUVA-A 7691).

***Halodule uninervis* (Forssk.) Asch.** Fig. 3

Halodule uninervis (Forssk.) Asch. in Boissier 1882: 24; Parham 1972: 350; Littler & Littler 2003: 288.
Zostera uninervis Forsskål 1775: 157.

Synonyms

Diplanthera madagascariensis Steud.; *Halodule australis* Miq.; *Halodule tridentata* F.V.M.; *Cymodocea australis* Trimen.; *Diplanthera uninervis* Asch.

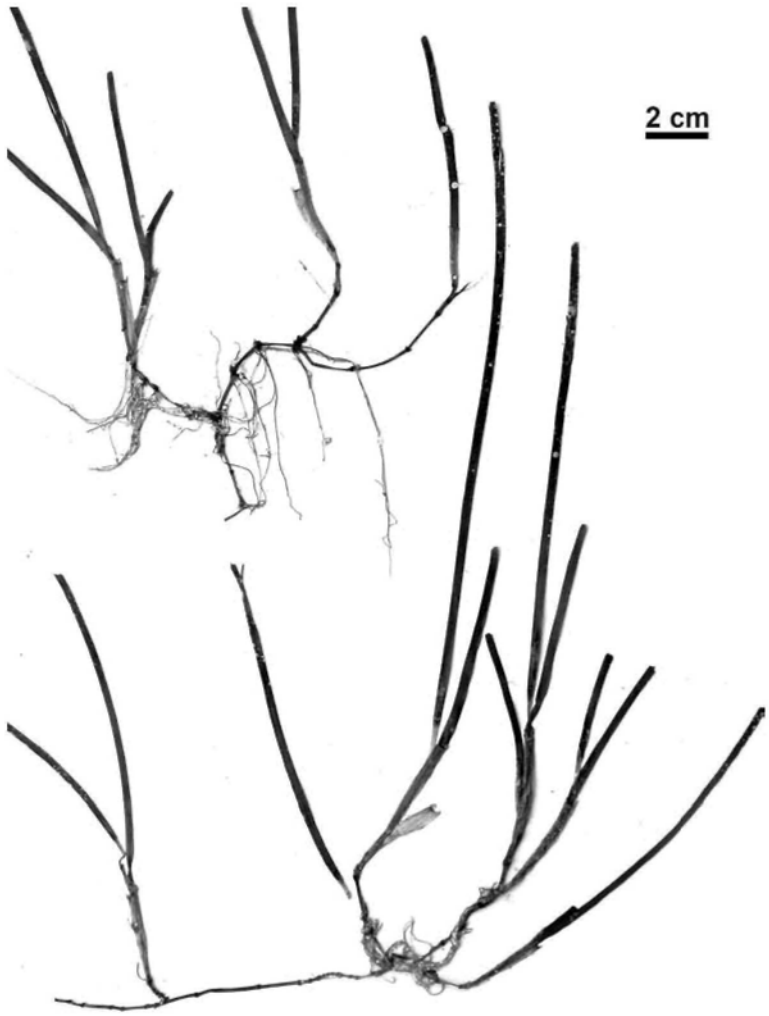

Fig. 3 *Halodule uninervis*. Pressed herbarium specimen showing the broader leaf blades compared with the narrower leaves of *H. pinifolia* (Fig. 2) (SUVA-A 7692).

Voucher specimens

South Pacific Regional Herbarium, Suva. SUVA-A 891, Suva Point, 10 May 1995, collected by W. McClatchey and A. N'Yeurt; SUVA-A 5774, Nukubuco reef flat, Suva, 7 April 2000, collected by S. Malimali and T. Tuatai; SUVA-A 7692, Tilagica Lagoon, Great Sea Reef, Fiji, 13 December 2004, collected by P. Skelton.

Remarks

Halodule uninervis often forms dense meadows at some sites, or is patchy and intermixed with other seagrass species (*viz. H. uninervis*, *S. isoetifolium*, or *Halophila* spp.). In the field, *H. uninervis* is easily distinguished from *H. pinifolia* by its generally broader leaf-blade. See comments under *H. pinifolia*.

Distribution

Indo-Pacific, from South Africa to Tonga (den Hartog 1970); absent from the Samoa Islands.

Syringodium Kütz.

Two species are recognised for this genus: *S. filiforme* Kütz. in Hohen. confined to the Caribbean region, and *S. isoetifolium* (Asch.) Dandy distributed in the Indo-Pacific region, including Fiji and Samoa.

Syringodium isoetifolium (Asch.) Dandy Fig. 4

Syringodium isoetifolium (Asch.) Dandy in Dandy & Tandy 1939: 116; Parham 1972: 350; Littler & Littler 2003: 288.

Fig. 4 *Syringodium isoetifolium*. Pressed herbarium specimen (SUVA-A 7122).

Vouchers specimens

South Pacific Regional Herbarium, Suva. SUVA-A 329, Laucala Bay, Suva, 26 February 1973, collected by B. Carlson; SUVA-A 578, Nasese reef flat, Suva, 8 April 1993, collected by G.R. South; SUVA-A 5553, Nukubuco reef flats, Suva, 7 April 2000, collected by S. Malimali and T. Tuatai; SUVA-A 7122, Mulinuu reef flat, Apia, 17 August 2000, collected by P. Skelton; SUVA-A 7617, Mulinuu reef flat, Apia, 29 August 2000, collected by P. Skelton and G.R. South.

Remarks

This species is usually found in the shallow subtidal areas (1–15 m depth) in Fiji and Samoa, and some populations are occasionally exposed during extreme low tide on the reef flats in Samoa.

Distribution

Syringodium isoetifolium has a widespread distribution, from the Indian Ocean to Samoa (Green et al. 2003; this study). Its presence in American Samoa remains to be confirmed, as recent collections failed to find any plants (Coles et al. 2003b; Skelton 2003).

Hydrocharitaceae

A family consisting of three genera, of which only *Halophila* is found from Fiji and Samoa.

Halophila Thouars

Provisionally, 14 species are recognised in this widely distributed genus, of which two species and one

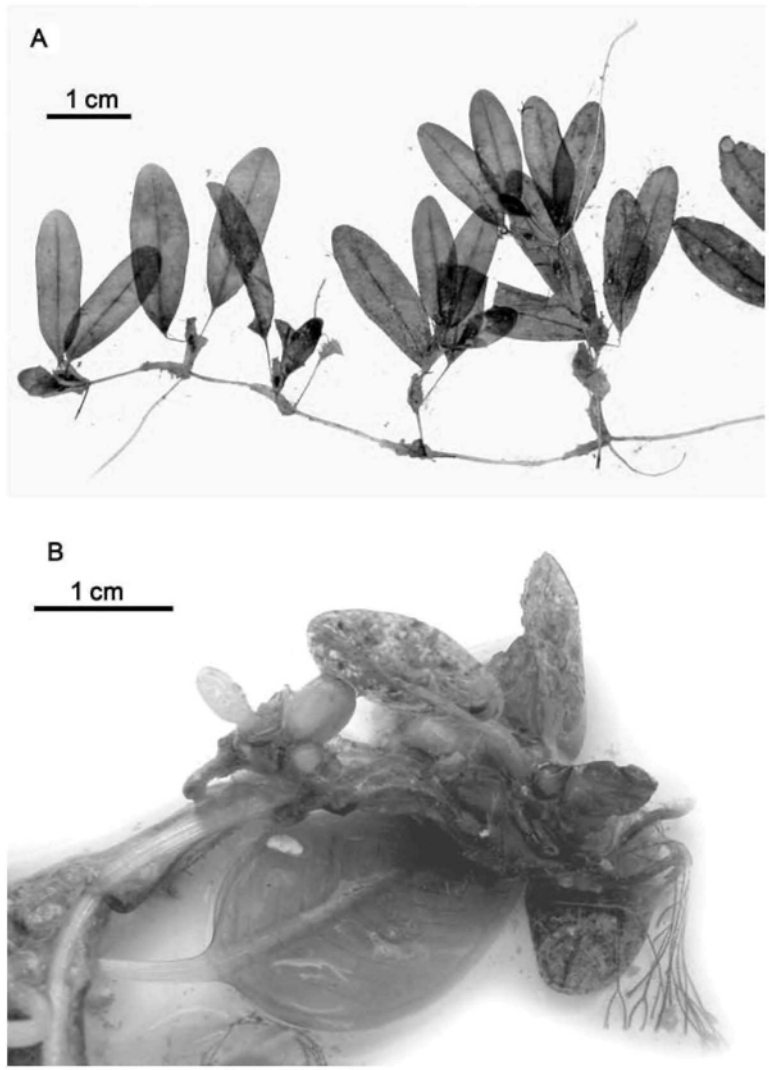

Fig. 5 **A**, *Halophila decipiens*. Pressed herbarium specimens showing the translucent leaf blades (SUVA-A 7690). **B**, Wet preserved material showing the conspicuous fruits.

subspecies are confirmed for Fiji and one species and one subspecies for Samoa. Recent molecular studies have suggested that several morphologically distinct taxa (*H. hawaiiana* Doty & Stone, *H. johnsonii* Eiseman, *H. ovata* Gaudich., and *H. minor* (Zoll.) Hartog) are conspecific with *H. ovalis* (R. Br.) Hook.f. (Waycott et al. 2002). A number of subspecies are recognised (see den Hartog 1970; Waycott et al. 2004), of which one occurs in Fiji and Samoa. The genus is easily recognised by its oval to elliptical leaves.

***Halophila decipiens* Ostenf.** Fig. 5A,B

Halophila decipiens Ostenfeld 1902: 260; den Hartog 1970: 254.

Voucher specimens

South Pacific Regional Herbarium, Suva. SUVA-A 7690, Mali Passage, Great Sea Reef, 10 December 2004, collected by H. Sykes, L. Sivo, M. Fiu, and P. Skelton.

Remarks

This is the first confirmed record of this species from the Fiji Islands. The specimens were collected from 10–25 m depth. The species grows in fine muddy/sandy substratum along the reef channels at the Great Sea Reef. The plants formed sparse patches and grow to 40 mm tall. The rhizome is delicate to 1 mm in diameter, with two scales from each node. The plant is attached via a single root that descends

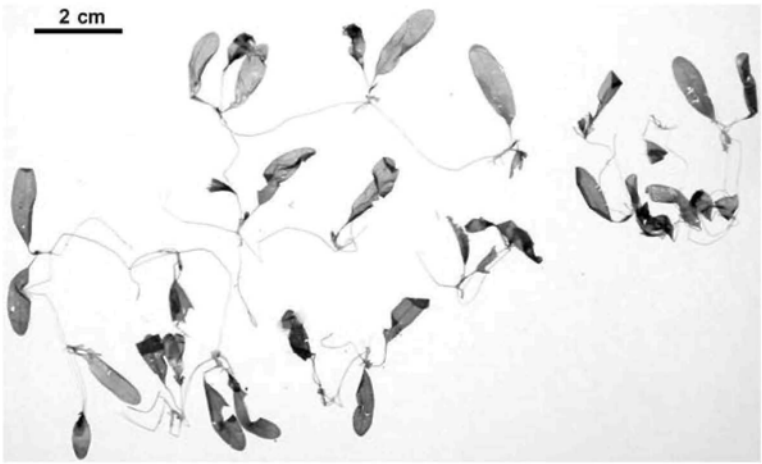

Fig. 6 *Halophila ovalis*. Pressed herbarium specimen, showing a somewhat delicate and light green form that is reminiscent of some *Halophila decipiens* (SUVA-A 5363).

opposite the uprights at every node. The internodes are 20–40 mm long. The leaf blade is ellipsoidal, 10–25 mm long, 4–10 mm wide, with a rounded apex. No bullation of the leaf blade was noted, but fine dentations along the leaf margin were observed. The midrib is distinct with two parallel veins running intra-marginally, all continuous from the stalk and fusing just below the tip. The midrib issues 6–9 paired veins that ascend slightly towards the intramarginal veins. Fine hairs are observed on both sides of the leaf blade. The materials collected were fertile (Fig. 5B), with conspicuous fruits abundant throughout the plant.

Distribution

The distribution of this species is taken from den Hartog (1970: 255–257) and includes Florida, West Indies, Central America (Panama, Costa Rica), South America (Venezuela, Colombia), Asia, and Australia. It has been reported from a few Pacific Islands including Hawaii, French Polynesia, New Caledonia (den Hartog 1970; McDermid et al. 2002). Although Littler & Littler (2003) illustrated this species from Fiji, their illustration is referable to *H. ovalis* subspecies *bullosa*, as evident by the bullations on the leaves. The presence of bullations on leaves of *H. decipiens* has not been reported in the literature.

***Halophila ovalis* (R. Br.) Hook.f.** Fig. 6

Halophila ovalis (R. Br.) Hook.f. 1858: 45.
Caulinia ovalis R. Brown 1810: 339

Synonyms

Halophila johnsonii Eiseman; *Halophila hawaiiana* Doty & Stone; *Halophila ovata* Gaudich.; *Halophila minor* (Zoll.) Hartog.

Voucher specimens

South Pacific Regional Herbarium, Suva. SUVA-A 7112, Eleele Fou pit, Apia, 20 August 2000, collected by P. Skelton; SUVA-A 5363, Palolo Deep Reserve "blue-hole", Apia, 18 September 1998, collected by P. Skelton and T. Afiti; SUVA-A 5365, Borrow-pit near Palolo Deep Reserve, Apia, 17 September 1998, collected by P. Skelton; SUVA-A 7348, Vaiala reef flat, Apia, 6 July 2002, collected by P. Skelton; SUVA-A 455, Laucala Bay, Suva, 8 July 1990, collected by G.R. South.

Remarks

The synonymy adopted here follows Waycott et al. (2004), who consider *H. ovalis* to be a complex of these closely related entities. This is the most common seagrass species in Samoa (P. Skelton unpubl. data). In some places it forms a dense meadow but is frequently encountered in small patches. It is also a highly plastic species especially in relation to blade size, shape, colour, and texture. *Halophila ovalis* and its subspecies *bullosa* are distinguished from *H. decipiens* by the lack of marginal serrations and hairs on either side of the leaf blade.

Distribution

The distribution has been revised in Green & Short (2003: p. 267, map 12) to incorporate the various entities now synonymised under *H. ovalis sensu lato*. It is widely distributed in the Indo-west Pacific region, the Caribbean, and the Indian Ocean.

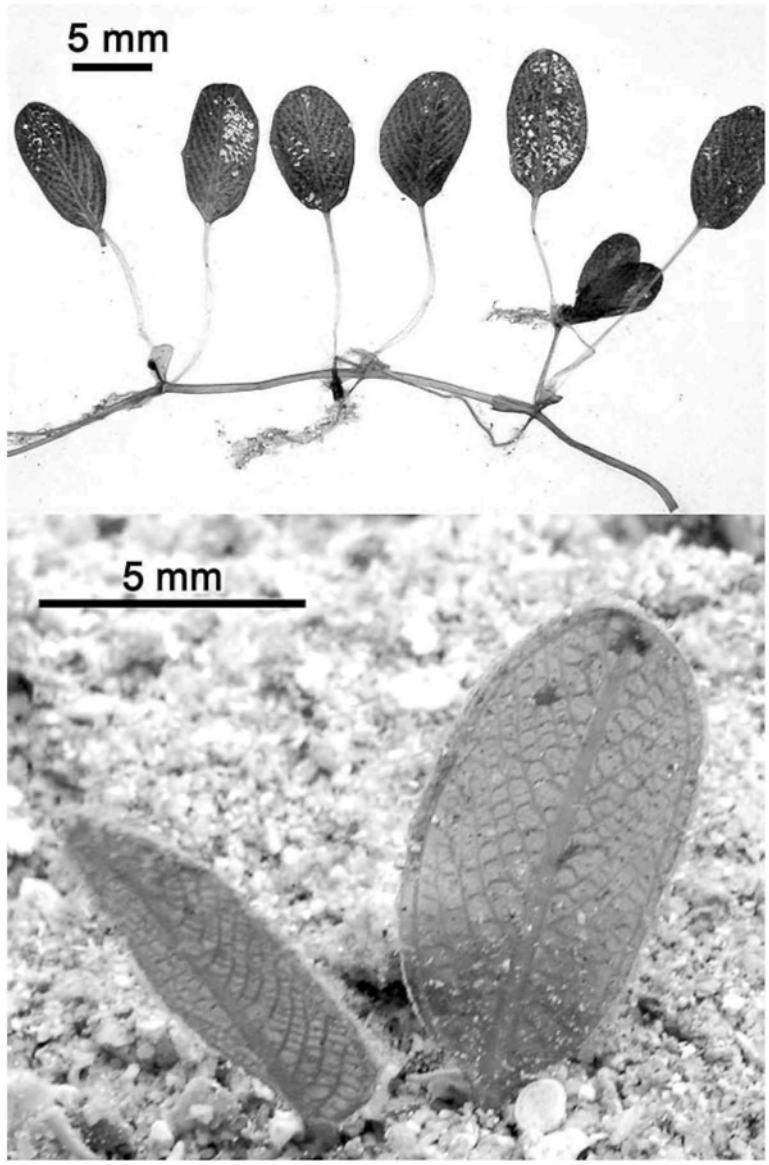

Fig. 7 **A**, *Halophila ovalis* subspecies *bullosa*. Pressed herbarium specimen, with the blades turning dark after pressing (SUVA-A 330). **B**, Field habit of a plant showing the bullation on the leaves.

Halophila ovalis subspecies ***bullosa*** (Setch.) Hartog Fig. 7A,B

Halophila ovalis subspecies *bullosa* (Setch.) Hartog 1970: 251.
Halophila ovalis var. *bullosa* Setchell 1924: 114–115.

Voucher specimens

South Pacific Regional Herbarium, Suva. SUVA-A 7109, 7118 Mulinuu reef flat, Apia, 17 August 2000, collected by P. Skelton; SUVA-A 331 Dravuni Island, Kadavu, 10 April 1991, collected by G.R. South; SUVA-A 330, Nukubuco reef flat, Suva, 26 February 1973, collected by B. Carlson; SUVA-A 5554, Nukubuco reef flat, Suva, 7 April 2000, collected by S. Malimali and T. Tuatai.

Remarks

This commonly encountered subspecies can often be found growing in habitats similar to those of *H. ovalis*. It grows from the intertidal to the shallow subtidal to 15 m depth and tolerates a wide variety of substrata from fine muddy sand to coarse sand, mixed sandy-rubble or large boulders with sandy patches.

This taxon is readily identified by the bullations (blister or pucker-like) on the leaf blades compared with the smooth leaves of *H. ovalis*.

DISCUSSION

The Fijian seagrass flora currently comprises five species and one subspecies, whereas two species and one subspecies occur in the Samoan flora. The seagrasses are distributed in three genera in Fiji (*Halophila*—2 spp. and a subspecies; *Halodule*—2 spp.; *Syringodium*—1 sp.), and two in Samoa (*Halophila*—1 sp. and subspecies; and *Syringodium*—1 sp.). The occurrence of *Thalassia* in Fiji has yet to be confirmed. Most of the species found in Fiji and Samoa have an Indo-west Pacific distribution, with the exception of *Halophila ovalis* ssp. *bullosa* apparently endemic to Fiji, Tonga, and Samoa (McMillan & Bridges 1982). The subspecies *bullosa* was recognised as unique by Setchell (1924), who described it as a new variety of *H. ovalis*. den Hartog (1970) recognised it at the subspecies level. Sachet & Fosberg (1973) proposed the inclusion of this species with *H. minor* (Zoll.) Hartog. McMillan & Bridges (1982) carried out culture experiments on plants from Fiji and Samoa, and observed that environmental manipulations can induce bullated or smooth-leaved plants. They recommended that this subspecies should be separated from *H. ovalis* and either be recognised as a distinct endemic taxon or placed under the polymorphic *H. minor*. We have retained this taxon as a subspecies of *H. ovalis* pending further studies.

Halophila decipiens is a pan tropical species that has only been confirmed from a few localities in the Pacific, including Hawaii (McDermid et al. 2002), French Polynesia (den Hartog 1970), New Caledonia (Garrigue pers. comm.), and now Fiji. Its disjunct distribution has led some to conjecture that it could be an alien species (den Hartog 1970; Phillips & Meñez 1988; Mukai 1993). However, the locality where this species was collected, considered a low impact area from shipping, makes it unlikely to be a new introduction, at least in the last 50 years. Surveys of major shipping ports and harbours are needed to determine its presence. This species could be confused with another deep-water species *H. capricorni* Larkum (1995), widely distributed on the Great Barrier Reef. *Halophila capricorni* is distinguished by its larger and stouter plants, and the presence of minute hairs only on one side of the leaf blade. Mukai (1993) speculated that French Polynesia and Hawaiian seagrasses may have arrived from the eastern Pacific along the Equatorial Current before the closing of the Panama Canal. This was because of the vast distances and current patterns between these two island groups (French Polynesia and Hawaii) and Malesia (centre of origin of Pacific Islands seagrass species) (Coles et al. 2003a). Green & Short (2003—appendix 3, map 6) plotted the distribution of *H. decipiens* showing a wide pan-tropical to subtropical spread, second only to that of *H. ovalis*. The discovery of the Fijian population narrows the distance between Malesia and the two eastern island groups (Hawaii and French Polynesia), strengthening the connection between these areas.

The sharp decline in species number in Samoa further supports the hypothesis of decreasing diversity relevant to increasing distance from the Indo-west Pacific centre of origin. Whether this is the maximum seagrass diversity from Fiji and Samoa remains to be seen, as we continue to investigate unexplored sites and deeper subtidal zones.

ACKNOWLEDGMENTS

This paper benefited from our participation in several scientific expeditions, including the Great Sea Reef Biodiversity Surveys, and the survey of the benthic marine algae of the Apia District and Vicinity of Samoa. We gratefully acknowledge the support of the Samoa Government (Department of Environment & Conservation and the Division of Fisheries), and the WWF-South Pacific Programme. Financial support for our participation was provided by the International Ocean Institute (Australia), Oceania Research and Development Associates, Inc., the TOTAL Foundation, and the University of the South Pacific. We thank Dr Rob Coles and two anonymous reviewers for their insightful comments and helpful suggestions.

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