

Reassessment of Seagrass Species in the Marshall Islands¹

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Abstract—Recent collections of specimens of *Halophila gaudichaudii* J. Kuo, previously identified as *Halophila minor* (Zollinger) den Hartog, from Kwajalein Atoll in September 2016 and the archiving of the specimens at BISH validate the previous observation of this seagrass genus in the Marshall Islands. Previously, no voucher specimen was available for examination. Molecular analyses of the Kwajalein *Halophila* specimens may demonstrate conspecificity with *Halophila nipponica* J. Kuo with *H. gaudichaudii* relegated as a synonym. Herbarium specimens of *Cymodocea rotundata* Ehrenberg and Hemprich ex Ascherson from Majuro Atoll were found at BISH and may represent the only specimens from the Marshall Islands archived in a herbarium. *Cymodocea rotundata*, however, has been documented in past literature and archived via digital photos in its natural habitat in Majuro. The previous validation of *Thalassia hemprichii* (Ehrenberg) Ascherson with specimens, and the recent validation of *Halophila gaudichaudii* and *Cymodocea rotundata* with specimens reaffirm the low coral atolls and islands of the Marshall Islands as the eastern limit for the three species in the Pacific Ocean.

Introduction

In a review of the seagrasses in Micronesia, Tsuda et al. (1977) reported nine species of seagrasses in Micronesia with new records of *Thalassodendron ciliatum* (Forsskål) den Hartog from Palau, and *Syringodium isoetifolium* (Ascherson) Dandy and *Cymodocea serrulata* (R. Brown) Ascherson & Magnus from Palau and Yap. The eastern range of *Syringodium isoetifolium* was extended from Yap to Chuuk when specimens (GUAM) were collected off Moen Island (now Weno) in the Chuuk Lagoon in December 1977 by Jeanine Olsen Stojkovich (University of Guam) and reported by Kock & Tsuda (1978). In December 1977, specimens of *Halodule pinifolia* (Miki) den Hartog were collected by Joyce Vann Basilius (Peace Corps volunteer) in Palau and were reported as a new species record for Micronesia by McMillan (1980), thus increasing the number of seagrass species in Micronesia to 10 species. The finding of *Cymodocea rotundata* Ehrenberg & Hemprich ex Ascherson by McDermid & Edward (1999) in Pohnpei and adjacent Ant Atoll filled the previously disjunct distribution of this species between Chuuk (151° E) and Kosrae (163° E) in the Caroline Islands.

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Only a single seagrass species, *Thalassia hemprichii* (Ehrenberg) Ascherson, was initially documented with preserved specimens from the Marshall Islands, the easternmost atolls and coral islands in Micronesia. Specimens of *T. hemprichii* had been collected, preserved, and deposited in Herbaria (BISH, GUAM, NY, US) from three atolls (Ujelang, Ailinglaplap, Jaluit), and reported by Fosberg (1955, 1961, 1976), den Hartog (1970), and Tsuda et al. (1977).

The second Marshallese species, *Halophila minor* (Zollinger) den Hartog, was reported in the lagoon of Kwajalein Atoll by Titgen et al. (1988) in an unpublished marine environmental assessment of the U.S. Army's leased lands. Specimens identified by Susanne C. Wilkins (University of Guam) as *H. minor* were observed during January and February 1988, adjacent to the lagoon shores opposite the runway on Kwajalein Islet, and between Fuel Pier and Yokohama Pier at Roi-Namur Islet. The report of *H. minor* at Kwajalein Atoll by Titgen et al. (1988) represented the first communication of a second species of seagrass, other than *Thalassia hemprichii*, in the Marshall Islands. According to S.C. Wilkins (personal communication, 5 August 2012) who was a member of the field party, specimens of the seagrass were collected, but unfortunately were not retained as vouchers. The identification of the Kwajalein specimens as *H. minor* was not surprising, since *H. minor* was reported from Palau and Yap in the western Caroline Islands and Guam and Saipan in the southern Mariana Islands (Tsuda et al. 1977).

In a taxonomic treatment of the *Halophila* species in Japan, based on a comprehensive review of the literature and the examination of specimens including types from various geographic localities, Kuo et al. (2006a) concluded that eight distinct species, including four new species of *Halophila*, occurred in Japanese waters. *Halophila gaudichaudii* J. Kuo was described as a new species to replace the illegitimate name *Halophila ovata* Gaudichaud (Sachet & Fosberg 1973), which in turn was considered conspecific with *H. minor*. Kuo et al. (2006a) also described *Halophila nipponica* J. Kuo, *Halophila mikii* J. Kuo and *Halophila okinawensis* J. Kuo as new species and also recognized *H. minor* as one of the eight distinct species.

In a reassessment of the Japanese *Halophila*, based on the combination of morphological examination and nuclear ribosomal ITS1, 5.8S rDNA, and ITS2 sequence analyses, Uchimura et al. (2008) demonstrated conspecificity of *H. minor* and *Halophila ovalis* (R. Brown) Hooker f. These two species were the only species of *Halophila* reported previously in Micronesia. Genetic analysis of Waycott et al. (2002) earlier found clear evidence of *H. minor* as a distinct species. Xu et al. (2010) reported four distinct alleles in *H. minor*; the alleles were absent in *H. ovalis*. Uchimura et al. (2008) also reported the conspecificity of *H. gaudichaudii*, *H. nipponica* and *H. okinawensis* which were recently described as new species in Kuo et al. (2006a), and recommended that the first species, *H. nipponica*, reported in the study was the name to be used. *H. gaudichaudii*, and *H. okinawensis*, as well as *Halophila japonica* Uchimura & Faye in Uchimura et al. (2006) published two months after Kuo et al. (2006a), would also be synonymous with *H. nipponica*.

Thaman & Vander Velde (2003) included the third species of seagrass, *Cymodocea rotundata*, in their listing of vascular plants from Majuro Atoll and documented the species observed in 1999, 2000 and 2001, with records of digital photos (DPMJ0098 and DPMJ0099) of the species in its natural habitat. The digital photos from Majuro (DPMJ) were archived in both the Geography Department and the South Pacific Regional Herbarium of the University of the South Pacific (Fiji) and at the Marshall Islands Library (Majuro). Regrettably, no voucher specimens were cited.

In a popular booklet targeting school children, Merlin et al. (2004) reported three species of seagrasses in the Marshall Islands: *Thalassia hemprichii* from Ujelang, Ailinglaplap, and Jaluit Atolls, *C. rotundata* from Majuro Atoll and nearby Arno Atoll, and *H. minor* from Kwajalein Atoll. Mark Merlin (personal communication, 24 May 2012) informed the first author that he did not possess any voucher specimens of *Cymodocea* nor *Halophila* from the Marshall Islands. Short et al. (2007) credited the Marshall Islands with only two species of seagrasses, i.e., *T. hemprichii* and *C. rotundata*, based on the peer-reviewed published literature.

This study documents *Halophila gaudichaudii* (Kuo et al. 2006a) or *Halophila nipponica* (Uchimura et al. 2008, includes *H. gaudichaudii* as synonym) from Kwajalein Atoll with voucher specimens, and considers *H. minor*, as only reported in Tsuda et al. (1977), as a misapplied species name for Micronesian *H. gaudichaudii*. It also reports on herbarium specimens of *Cymodocea rotundata* collected in 1988 from Majuro Atoll discovered in Herbarium Pacificum (BISH) of the Bishop Museum.

Materials and Methods

Documentation of *H. gaudichaudii* in the Marshall Islands was based on recently collected specimens by the second author from three southern islets of Kwajalein Atoll in the Marshall Islands on 12 and 17 September 2016. Specimens were collected by hand while SCUBA diving. Each collection location was georeferenced using a global positioning system (GPS) device at the surface directly above the collection point and photos were taken at depth to document each sample and its surrounding environment. At the end of the field day, each sample was rinsed with ambient seawater and arranged on waxed paper for transport back to Honolulu.

During the morphological examination, the distance between the intramarginal vein and the margin of the *Halophila* leaf blade was measured with an ocular micrometer via an Olympus compound microscope. The herbarium specimens of *Cymodocea rotundata* were serendipitously found in BISH and examined with a dissecting microscope. The two herbarium specimens of *C. rotundata* from the Marshall Islands were collected in 1988 from Majuro Atoll by an unknown collector and by Derral R. Herbst (a research associate of the Bishop Museum), respectively. All specimens were databased and archived in Herbarium Pacificum (BISH).

Results

Halophila gaudichaudii J. Kuo

Figures 1 & 2

Remarks: The Kwajalein Atoll specimens were morphologically more similar to *H. gaudichaudii* as described by Kuo et al. (2006a) than *H. nipponica* which includes *H. gaudichaudii* as a synonym (Uchimura et al. 2008). The length and width of the leaf blades were similar to *H. gaudichaudii*. Shimada et al. (2012) has, however, shown morphological variations in *H. nipponica*. The distance between the intramarginal vein and the leaf blade margin has been cited as a key character (Uchimura et al. 2006) in differentiating *Halophila* species. Our measurements of 0.32–0.58 mm show the Kwajalein *Halophila* specimens to be more applicable to *H. gaudichaudii*. Identical measurements conducted on herbarium specimens, initially identified as *H. minor* and later identified as *H. gaudichaudii* by John Kuo in November 2007 from Guam (BISH 507023 and 749549) and Saipan (BISH 112332 and BISH 417301) in the Mariana Islands, showed similar measurements of 0.32–0.40 mm with the Kwajalein specimens.

It seems prudent at this time to utilize the name *H. gaudichaudii* until molecular analyses are conducted on the Kwajalein specimens. All specimens examined clearly lacked the surface hairs and fine serrated margins present on the leaf blades of *Halophila decipiens* Ostenfeld which was a species considered prior to the examination of the *Halophila* specimens from Kwajalein Atoll.

Description: Rhizomes of the Kwajalein specimens of *Halophila gaudichaudii* were fine and fragile, 160–320 µm in diameter. The leaf blades were mainly obovate, 7–14 mm long and 4–6 mm wide, with entire margins and rounded apices. Cross veins were not obvious on most of the drying and dried leaf blades; however, cross veins when observed numbered less than 8 pairs. The intramarginal vein was continuous along the inner edge and measured 0.32–0.58 mm from the margin of the leaf blade.

Habit: All three collection sites were in small, lagoon facing boat harbors, at shallow depths (3–8 m deep), and with steady water flow. Visibility at depth was greater than 25 m. Benthic cover was unconsolidated sediment, mostly sand (sediment with a visual grain size) with occasional scattered rocks. *Halophila gaudichaudii* was found growing on the surface of the sand, often with rhizomes fully exposed.

Specimens examined: BISH 766518 (Fig. 1), coll. N. Sukhraj, harbor, 7.6 m deep, Illeginni Islet, Kwajalein Atoll, Marshall Islands (9.087867 N lat., 167.474105 E long.), 12 September 2016; BISH 766519, coll. N. Sukhraj, harbor, 3 m deep, Ennylebegan Islet, Kwajalein Atoll, Marshall Islands (8.798734 N lat., 167.61925 E long.), 17 September 2016; BISH 766520, coll. N. Sukhraj, 4.6 m deep, Kwajalein Islet, Kwajalein Atoll, Marshall Islands (8.723858 N lat., 167.720877 E long.), 17 September 2016.

Pacific islands distribution: Mariana Islands (Gaudichaud 1827 as *H. ovata*), Guam (den Hartog 1970 as *H. ovata*, Stone 1971 as *H. minor*, Tsuda et al. 1977 as *H. minor*); Saipan (den Hartog 1970 as *H. ovata*, Tsuda et al. 1977 as *H. minor*); Palau (Tuyama 1940 as *H. ovata*, Ohba et al. 2007 as *H. minor*); Yap (Tsuda et al. 1977 as *H. minor*). *Halophila gaudichaudii* or *H. minor* has not been reported from any of the Polynesian or Melanesian islands, except from New Caledonia (den Hartog 1970 as *H. ovata*).

Cymodocea rotundata Ehrenberg and Hemprich ex Ascherson

Figure 3

Remarks: *Cymodocea rotundata* is clearly distinguished from *Thalassia hemprichii* by its smooth rhizome, narrow linear leaves and semi-circular seeds (see den Hartog 1970, Phillips & Meñez 1988).

Description: Rhizomes of the Majuro Atoll specimens of *C. rotundata* were 1.5 mm in diameter with rhizoids descending (up to 9 cm long) opposite the upright leaf-sheath with mainly 3–4 linear, occasionally sickle-shaped, leaves per leaf-sheath. Leaves were 3 mm wide and up to 17 cm long, with 9–12 parallel veins. Approximately 50% of the leaf tips of the herbarium specimens were intact, i.e., not bitten by herbivorous fish or damaged via physical means. The intact leaf tips are mainly rounded, and at times possess slightly notched apices. The fruits are semi-circular in shape, 10 mm long and 5 mm wide, with teeth on the ridges varying in number and length.

Specimens examined: BISH 556968, unknown collector, Majuro Atoll, Marshall Islands, July 1988; BISH 753217 (with fruits), coll. D. R. Herbst (9195), Majuro Atoll, Marshall Islands, 25 September 1988.

Pacific islands distribution: Palau & Kayangel Atoll (Hosokawa 1943, den Hartog 1970, Tsuda et al. 1977, Ohba et al. 2007); Yap, Woleai Atoll, Ifaluk Atoll (den Hartog 1970, Tsuda et al. 1977); Chuuk (Tsuda et al. 1977); Pohnpei (McDermid & Edward 1999); Kosrae (Hosokawa, 1943). *Cymodocea rotundata* has not been collected from the Mariana Islands (Tsuda et al. 1977), Hawaii (Doty and Stone 1966; McDermid et al. 2002), nor from any of the other central Pacific islands south of the equator in the Pacific Ocean (Mukai 1993, Coles & Kuo 1995, Payri et al. 2000, N'Yeurt & Payri 2004, Skelton and South 2006). The species, however, is present in the species-rich western Pacific, i.e., Ryukyu Islands (Miki 1932; Tsuda & Kamura 1990, Kuo et al. 2006b), Papua New Guinea (Johnstone 1979) and New Caledonia (den Hartog 1970).

Discussion

Three seagrass species, *Thalassia hemprichii*, *Cymodocea rotundata*, and *Halophila gaudichaudii* [= *H. nipponica*], are now validated from the Marshall Islands. The eastward attenuation of seagrass species is still evident across (west to east) the vast Caroline Islands of Micronesia (Lobban & Tsuda 2003) with 10 species in Palau, seven species in Yap, five species in Chuuk, three or four species (Coles & Kuo 1995 include *Cymodocea serrulata*) in Pohnpei, and now three species in the Marshall Islands. The low coral atolls and islands of the Marshall Islands serve as the eastern limit for the three species in the Pacific Ocean.

The presence of *H. gaudichaudii* in the Marshall Islands is surprising since it has been reported only from Guam and Saipan in the Mariana Islands, and may possibly occur at Yap and Palau in the Caroline Islands. The published records from Palau are based on Tuyama (1940) as *H. ovata* and Ohba et al. (2007) as *H. minor*. Herbarium specimens of *H. minor* from Palau are deposited at the Palau International Coral Reef Center and in the personal Herbarium of Karla J. McDermid, University of Hawaii-Hilo (K. J. McDermid, personal communication, 2 June 2012).

The presence of *T. hemprichii* and *C. rotundata* in the Marshall Islands was not surprising. Kock & Tsuda (1978) observed the assemblages of five of the seven seagrass species in Yap lagoon and found *T. hemprichii*, *C. rotundata* and *Enhalus acoroides* (Linnaeus f.) Royle more abundant than *Syringodium isoetifolium* (circular patches, <2 m diameter) and the diminutive non-competitive *Halophila ovalis*. *Enhalus acoroides*, which can tolerate lower salinity, formed monotypic stands near dense mangroves, inshore channels and inner harbors in coastal waters of Yap. These three dominant seagrass species were the same species distributed throughout the Caroline Islands, i.e., from Palau to Kosrae.

McDermid & Edward (1999) found *C. rotundata* the dominant seagrass in the shallow near-shore waters (5–45 m from shore) of Pohnpei; *T. hemprichii* was dominant 45–50 m offshore. In Yap, *C. rotundata* was tolerant of high mid-day water temperature and low salinity during heavy rain (Bridges & McMillan 1986). Seedlings of *C. rotundata* were found in various stages of development in Yap lagoon (McMillan et al. 1982), which suggested that germination occurred all year round. A species with a tolerance of high water temperature during the mid-day, exposure in the intertidal zone, low salinity during heavy rains and germination capabilities all year-round makes *C. rotundata* a hardy colonizing species.

This study demonstrates that a *Halophila* with morphological characters similar to *H. gaudichaudii* (Kuo et al. 2006a) is present at Kwajalein Atoll. There is also a good possibility that the specimens identified as *H. gaudichaudii* from Kwajalein Atoll, when subjected to molecular analyses, will demonstrate conspecificity with *H. nipponica* as per Uchimura et al. (2008).

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Figure 1. Herbarium specimens of *Halophila gaudichaudii* J. Kuo from Illeginni Islet, Kwajalein Atoll, Marshall Islands, BISH 766518. Scale = 2 cm. Photo by Nicholas Walvoord and Barbara H. Kennedy, Natural Sciences, Bishop Museum.

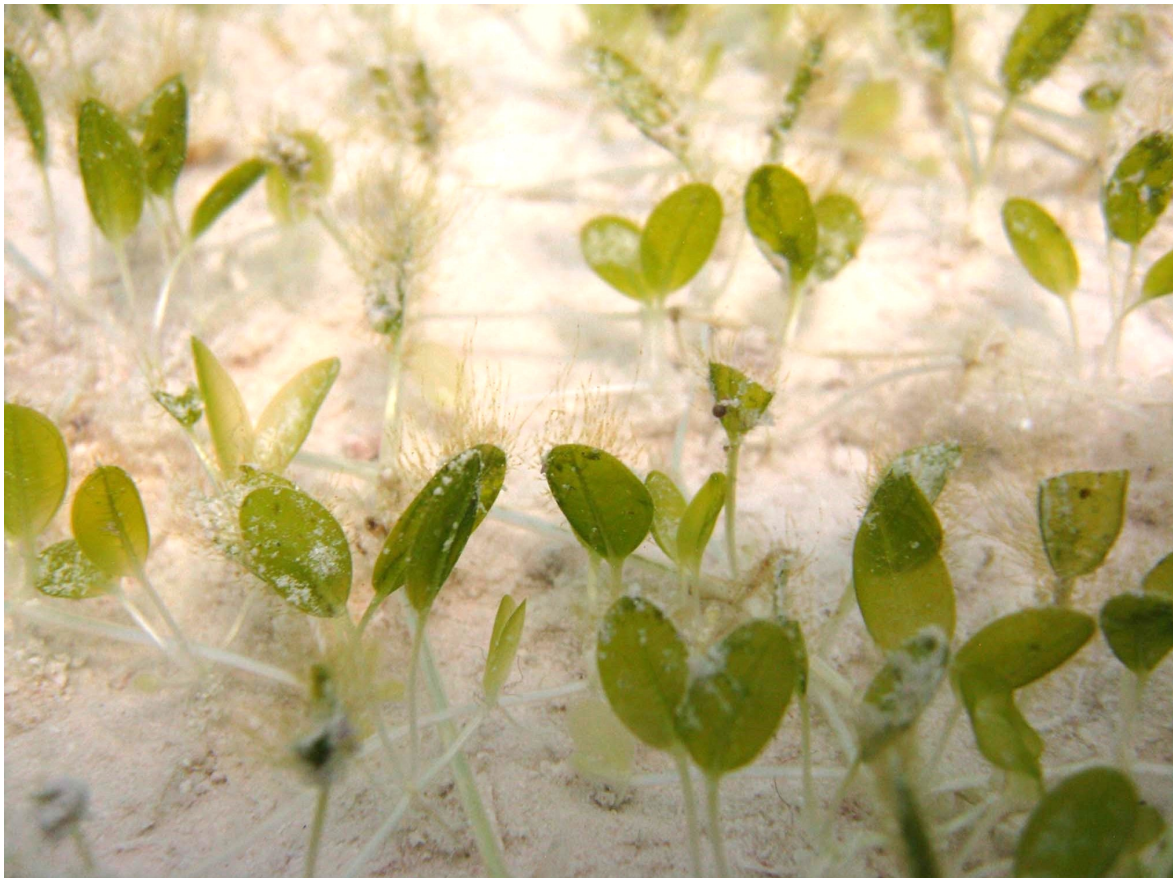


Figure 2. In-situ photo of *Halophila gaudichaudii* J. Kuo in harbor, 7.6 m deep, Illeginni Islet, Kwajalein Atoll, Marshall Islands. Photo by Steve Kolinski, Pacific Islands Regional Office, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 12 Sept. 2016.



Figure 3. Herbarium specimen of *Cymodocea rotundata* Ehrenberg and Hemprich ex Ascherson with fruits (arrow) from Majuro Islet, Majuro Atoll, Marshall Islands, BISH 753217. Scale = 2 cm. Photo by Nicholas Walvoord, Natural Sciences, Bishop Museum.

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