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RESEARCH NOTE

First report of the Japanese species *Grateloupia lanceolata* (Halymeniaceae, Rhodophyta) from California, USA

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SUMMARY

The Japanese red alga *Grateloupia lanceolata* (Okamura) Kawaguchi was discovered in southern California at Santa Catalina Island in spring 2003 and April 2008 and in central California at the mouth of the Elkhorn Slough in Moss Landing in May, June and July of 2008. The morphology of thalli from both localities agrees with published figures. Sequences from the *rbc*L gene and the nuclear marker, internal transcribed spacer-1 from Californian *G. lanceolata* were identical to those from two specimens of *G. lanceolata* introduced to the Thau Lagoon, Mediterranean France and a specimen from Japan. It is likely that the import of oysters for mariculture played a role in its introduction into California.

Key words: California, *Grateloupia*, Halymeniaceae, internal transcribed spacer, introduced, non-native, *rbc*L, Rhodophyta.

The number of introductions to California of seaweeds native to Japan and Asia is growing. The brown alga *Sargassum muticum* (Yendo) Fensholt (Critchley 1983), red alga *Lomentaria hakodatensis* Yendo (Dawson & Neushul 1966; Abbott & Hollenberg 1976), and the green alga *Codium fragile* subsp. *fragile* (Suringar) Hariot (Silva 1979, as *C. fragile* subsp. *tomentosoides* (van Goor) P.C. Silva) have been part of the flora for decades. Since 1995, the brown algae *Undaria pinnatifida* (Harvey) Suringar (Silva *et al.* 2002) and *Sargassum horneri* (Turner) C. Agardh (Miller *et al.* 2007, as *S. filicinum* Harvey) (Miller *et al.* 2007), and the red algae *Gelidium vagum* Okamura (Hughey *et al.* 1996) and *Caulacanthus ustulatus* (Mertens ex Turner) Kützing (Gabrielson *et al.* 2004; Miller 2004) have been added to the list of exotic seaweeds established in California.

The latest discovery in this series of invasions is *Grateloupia lanceolata* (Okamura) Kawaguchi, a red alga that is native to Japan (Okamura 1934) as *Aeodes lanceolata*) and Korea (Lee 2008). In spring 2003, an unknown species of *Grateloupia* was observed by the first author growing in a broken seawater pipe at the University of Southern California's Wrigley Marine Science Center (WMSC) on Santa Catalina Island, Los Angeles County (33°26′42″N, 118°29′04″W). The first author also observed this entity growing on mooring lines in the nearby town of Two Harbors. On 7 April 2008, specimens for this study (Fig. 1, UC 1934302, Fig. 2, UC 1934304) were collected from the mouth of the seawater outfall pipe at the WMSC and from docks and mooring lines in Catalina Harbor (33°25′50″N, 118°30′21″W), where they were abundant growing with *Hydroclathrus clathratus* (C. Agardh) M. Howe and *Scytosiphon lomentaria* (Lyngbye) Link. Collections included cystocarpic, male, and tetrasporic thalli. At Santa Catalina Island, *G. lanceolata* is a large, foliose species that stands out among the native red algae, which are generally diminutive and highly dissected. *Grateloupia filicina* (Lamouroux) C. Agardh has been recorded from Santa Catalina Island but is easily distinguished from *G. lanceolata* by its slender, highly branched axes.

Thalli from the Moss Landing Boat Launching Facility and from the marina docks at the Moss Landing Marina, Moss Landing (36°48′46″N, 121°47′14″W) were collected in great abundance in May (UC 1934310), June (Fig. 3, UC 1934305, UC 1934309), and July (Fig. 4, UC 1934313) of 2008. At some parts of the dock, there were large clumps of 20 or more blades that covered most of the substrate and included cystocarpic, male, and tetrasporic thalli. Plants were

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Fig. 1. *Grateloupia lanceolata* male gametophyte from Catalina Harbor, Santa Catalina Island, California (UC1934302); voucher for DNA analysis.

Fig. 2. *Grateloupia lanceolata* tetrasporophyte from the Wrigley Marine Science Center, Santa Catalina Island, California (UC1934304).

Fig. 3. *Grateloupia lanceolata* male gametophyte from Moss Landing Boat Facility, Moss Landing, California (UC1934310); voucher for DNA analysis.

Fig. 4. *Grateloupia lanceolata* tetrasporophyte from Moss Landing Boat Facility, Moss Landing, California (UC1934312).

growing with *Lomentaria hakodatensis, Ulva lactuca* L. and the native species *Grateloupia californica* Kylin. The latter was merged with *Grateloupia doryphora* (Montagne) M. Howe by Abbott and Hollenberg (1976), but molecular and morphological studies determined that *G. doryphora* is probably restricted to Peru and perhaps Chile (Gavio & Fredericq 2002). *Grateloupia californica* was described by H. Kylin from La Jolla, California; this is the correct name for the California species (P.W. Gabrielson, unpubl. data, 2003).

At Moss Landing, the native species *Grateloupia californica* grows sympatrically with *G. lanceolata*. However, *G. californica* is smaller (3–5 cm wide and 15–20 cm high), generally unbranched but often with lateral proliferations, and greenish-brown. Thalli of *G.*

lanceolata are conspicuous (6–10 cm wide at Moss Landing and 5–7 cm wide at Santa Catalina Island, 30–45 cm high at both localities), sometimes branched near the base with three to six lanceolate blades that are tannish-brown, grading to dark red to black toward the base (Figs 1–4). Like other species of *Grateloupia*, specimens at both sites were lubricous.

The identity of *G. lanceolata* was confirmed with *rbc*L and internal transcribed spacer-1 (ITS-1) sequences. DNA was extracted from silica gel dried material and fresh material following the methods described by Hughey *et al.* (2001). Sequences (GenBank *rbc*L FJ013036- Moss Landing, *rbc*L FJ013037- Santa Catalina Island, ITS FJ013039- Moss Landing, ITS FJ013040- Santa Catalina Island) were identical to two non-native specimens from Thau Lagoon (*rbc*L AY775396 & AY775398, ITS AF412010 & AF412011) and one native specimen from Kobe, Hyogo, Japan (*rbc*L AY775385, ITS not analyzed). In comparison, *rbc*L sequences of *G. californica* (*rbc*L FJ013038) differ by 84 nucleotides for this 1266 base pair (bp) segment and by 28 nucleotides for the 123 bp ITS-1 region (ITS AF412007).

Grateloupia lanceolata was reported from Thau Lagoon, Mediterranean France (Verlaque 2001) and its identity was later confirmed using morphological and molecular methods (Verlaque *et al.* 2005). This species was probably introduced to France in the 1970s with the Japanese oyster (Verlaque *et al.* 2005). The use of cultivated oysters (*Crassostrea gigas*) from Japan for mariculture in California has been implicated in many accidental introductions (Miller 2004). Tomales Bay, where *Caulacanthus ustulatus* and *Geldium vagum* were first reported in California, is the site of several oyster farms; the Tomales Bay Oyster Farm in Marshall has operated since 1909. A faunal survey at Elkhorn Slough, far from international shipping, yielded 56 exotic species, many of which probably arrived with cultured Atlantic and Asian oysters (Wasson *et al.* 2001). According to Carlton (1979) and Caffrey *et al.* (2002), oysters were repeatedly outplanted in the Monterey area for a period of about 70 years, until the middle 1970s. It is likely that the Moss Landing population originated decades ago from hitchhiking spores or sporelings on non-native oysters.

Santa Catalina Island, however, is remote from oyster cultivation sites. Nevertheless, genetic studies using non-native oysters from Quilicene, Puget Sound, Washington, have been conducted at the Wrigley Marine Science Center for years, and these oysters have been raised in nets in Catalina Harbor. It would be valuable to know if *Grateloupia lanceolata* occurs in the vicinity of oyster farms in Puget Sound. Other possible vectors, which may be responsible for the introduction of *G. lanceolata* at both sites, include initial introduction by international shipping via ballast water (Flagella *et al.* 2007), by hull fouling of coastal shipping vessels (Hay 1990), or by floating plastic debris (Barnes 2002).

The successful introduction of *Grateloupia lanceolata* to three very different environments (the Mediterranean, southern California and central California) suggests that this species is a 'weed', with ample reproduction, tenacious recruitment and broad physiological tolerances as an adult (Nyberg & Wallentinus 2005). Although it was conspicuous at Santa Catalina Island, it has been heretofore undetected amid other foliose red algae at Moss Landing and may be cryptic at other central and northern California sites, as well as in Oregon and Washington. This is a species to watch for on the eastern Pacific coast – especially where oysters have been cultivated.

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