# California

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# NOTEWORTHY COLLECTIONS

## CALIFORNIA

DASYA SESSILIS Yamada (DASYACEAE).—San Diego Co., attached to floating docks at 4000 Coronado Bay Rd., Coronado Cays, Coronado Bay, San Diego, 32°37′50.75″N, 117°08′00.75″W, thalli tetrasporic, 28 December 2008, *J. R. Hughey s. n.* (UC 1944736, UC 1944737); same location, thalli cystocarpic, 28 November 2009, *J. R. Hughey s. n.* (UC 1944757); Orange Co., attached to vertical faces of concrete pilings from 0 to 3 m and on floating docks, Huntington Harbor, Huntington Beach, 33°43′20.748″N, 118°03′21.8874″W, thalli tetrasporic, 23 August 2006, *A. Lyman s. n.* (UC 1944739); Los Angeles Co., attached to vertical sides of concrete pilings and wood on floating docks, Long Beach, 33°46′36.012″N, 118°12′37.8354″W, thalli tetrasporic, 26 February 1976, *R. Setzer s. n.* (AHFH 81053 in UC [UC 1846061]) as *D. pedicellata* var. *stanfordiana* (Farlow) Dawson); same location, 24 August 2006, *A. Lyman s. n.* (UC 1944738).

*Previous knowledge*. Native to Japan (Y. Yamada 1928, Scientific reports of the Tôhoku Imperial University 4:497–534), type locality: Asamushi, Futago-Jima, Oshima, Benten-Jiwa, Pacific. Also reported from Korea (Y. Lee and S. Kang 2001, A catalogue of the seaweeds in Korea, pp. 1–662) and the Philippines (P. C. Silva et al. 1987, Smithsonian Contributions to Marine Sciences 27:1–179). Introduced to France via oyster importation (M. Verlaque 2002, Phycologia 41:612–618), Spain via mussel cultivation (V. Peña and I. Bárbara 2006, Anales del Jardin Botánico de Madrid 63:13–26), and Portugal, by an unknown vector (R. Araujo et al. 2009, Botanica Marina 52:24–46). Fertile tetrasporophytes of the invasive *D. sessilis* were collected in abundance in France from June to December and in Spain year round. Sexual plants from France and Spain were reported from March to October.

*Significance*. First report of *D. sessilis* from the northeastern Pacific. Specimens from San Diego, Huntington Harbor, and Long Beach were in good morphological and anatomical agreement with illustrations of this species (Yamada, *loc. cit.*; Verlaque, *loc. cit.*; Peña and Bárbara, *loc. cit.*). The tetrasporophytic plants from San Diego were conspicuous, growing up to 15 cm high, forming bushy thalli with fuzzy axes and laterals. *Dasya sessilis* is distinguishable from the native species, *D. sinicola* var *californica* (Gardner) Dawson, by having wider axes (2+ mm vs. 0.5–1.4 mm). Identification was confirmed by analysis of part of the cytochrome oxidase subunit 2 and 5S RNA genes, and the *cox*2–*cox*3 intergenic spacer of the mitochondrial genome on a specimen from San Diego (GenBank GU473263). The resulting 198 bp (base pair) fragment was identical in sequence to the invasive Mediterranean specimen of *D. sessilis*, but differed from *D. baillouviana* by 12 bp. A sequence from a *Dasya* specimen from Coyote Point, San Francisco Bay (GenBank GU473264) differed from *D. sessilis* by 6 bp. Additional confirmation was obtained from the ribulose-1, 5-biphosphate carboxylase/oxygenase (*rbc*L) gene from the Huntington Beach and Long Beach specimens which was identical to *D. sessilis* from San Diego (GenBank GU473265–GU473267).

GRATELOUPIA LANCEOLATA (Okamura) Kawaguchi (HALYMENIACEAE).—San Diego Co., attached to floating docks at 4000 Coronado Bay Rd., Coronado Cays, Coronado Bay, San Diego, 32°37′50.75″N, 117°08′00.75″W, thalli tetrasporic and sterile, 28 December 2008, *J. R. Hughey s. n.* (UC 1944744); same location, 27 July 2009, *J. R. Hughey s. n.* (UC 1944743, UC 1944742); Ventura Co., on docks, Port Hueneme, 34°08′59.964″N, 119°12′36.0354″W, thallus tetrasporic, 26 July 2006, *A. Lyman s. n.* (UC 1944741); San Francisco Co., attached to floating docks at the San Francisco Marina, San Francisco, 37°47′14.37″N, 122°26′18.90″W, thalli tetrasporic, procarpic, and sterile, 15 September 2009, *K. A. Miller s. n.* (UC 1944746-UC 1944748).

*Previous knowledge*. Native to Japan (K. Okamura 1934, Icones of Japanese algae 7:42), type locality: Kii Province, Enoshima, Tateyama, Kazusa, Pacific. Reported from the Mediterranean, Thau Lagoon, France (M. Verlaque 2001, Oceanologica Acta 24:29–49) where it was likely introduced in the 1970s with the importation of the Japanese oyster (M. Verlaque et al. 2005, Phycologia 44:477–496). Specimens of *G. lanceolata* from France were collected from March to December, and reported to have established large, reproductive populations (Verlaque et al., *loc. cit.*). Recently, fertile material of *G. lanceolata* was discovered in southern California at Santa Catalina Island in the spring of 2003 and 2008, and in central California at the mouth of Elkhorn Slough in Moss Landing in May, June, and July of 2008 (K. A. Miller et al. 2009, Phycological Research 57:238–241). Miller et al. (*loc. cit.*) speculated that mariculture of oysters played a role in the introduction of *G. lanceolata*, which might be growing cryptically at other sites in California, Oregon, and Washington.

*Significance*. Discovery of *G. lanceolata* at three new localities in California. Thalli of *G. lanceolata* exhibited considerable morphological variation depending on age and collection locality. The mature specimens collected in San Diego in December were approximately 20 cm high and 3 cm wide, with uniformly dark red blades that forked once or twice above, and lacked epiphytes. Juvenile specimens from San Diego collected in July matched the description above, however mature thalli were pigmented brown to black with fully to partially eroded blades, and covered with diatoms and bryozoans. The fronds from Port Hueneme were dark red and expanded to 20 cm high and 5 cm wide, linear to lobate in shape with a few marginal proliferations, and covered with epiphytic bryozoans. Mature thalli collected from San Francisco were 100 cm high and 40 cm wide and uniformly dark red brown, bullate and with proliferous margins, and often found covered with non-native tunicates. *Grateloupia lanceolata* is distinguishable in harbors and bays from the native species in California, *G. californica* Kylin, by having thicker blades at maturity (600 μm-1 mm vs. 400–700 μm), a darker color (dark red vs. greenish-brown), and medullary filaments that run anticlinally and periclinally in

direction vs. predominantly periclinally in *G. californica*. Identification was confirmed using Internal Transcribed Spacer-1 (ITS-1) sequences. The ITS-1 sequence (GenBank GU339499) obtained from *G. lanceolata* from San Diego differed by one nucleotide from eight identical sequences of *G. lanceolata* from other localities: Port Hueneme (GenBank GU339500), San Francisco (GenBank GU339501–GU339503), Thau Lagoon, France (GenBank AF412010 and AF412011), Santa Catalina Island (GenBank FJ013039), and Moss Landing (GenBank FJ013040). Although oyster spat was implicated in past introductions of *G. lanceolata*, it is unknown at this time if mariculture, international shipping via ballast water, or hull fouling by coastal shipping vessels are the responsible vectors. These collections support the speculation of Miller et al. (*loc. cit.*) that *G. lanceolata* was introduced to harbors from southern to northern California, and is growing undetected among native Californian species.

GRATELOUPIA TURUTURU Yamada (HALYMENIACEAE).—Santa Barbara Co., attached to docks in the Santa Barbara boat harbor, 34°24′27.90″N, 119°41′32.40″W, thalli tetrasporic and cystocarpic/spermatangial, 1 August 2009, *J. R. Hughey s. n.* (UC 1944749, UC 1944750).

*Previous knowledge*. Native to Japan and Korea, type locality: Muroran, Hokkaido, Pacific (Verlaque et al., *loc. cit.*). *Grateloupia turuturu* was first reported outside of its native range in 1973 in Portsmouth, England (W. F. Farnham and L. M. Irvine 1973, British Phycological Journal 8:208–209). Since then, it has invaded the northwest Atlantic, France, The Netherlands, Portugal, Spain, the Canary Islands, the west coast of Africa from Mauritania to Namibia, Tasmania, New Zealand, Russia, and much of Asia (M. D. Guiry and G. M. Guiry, AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; [accessed 27 October 2009]). Earlier reports of this species in the Atlantic were incorrectly identified as *G. doryphora* (Montagne) M. A. Howe by Farnham and Irvine (*loc. cit.*) and M. Villalard-Bohnsack and M. H. Harlin (1997, Phycologia 36:324–328). B. Gavio and S. Fredericq (2002, European Journal of Phycology 17:349–359) were the first to show that *G. turuturu* was the correct name to apply to the species invading the Atlantic. *Grateloupia turuturu* spreads by spores contained in the ballast water of ship hulls (Villalard-Bohnsack and Harlin, *loc cit.*). Once the ballast water is discharged, the spores germinate and thrive in varied environments, including waters that are nutrient enriched and those that fluctuate in salinity and temperature. Based on the aggressiveness of this marine alga, as well as its presence in major shipping ports, *G. turuturu* was predicted to spread throughout North America and the rest of the world (C. Simon et al. 1999, Botanica Marina 42:437–440). *Grateloupia turuturu* is characterized as having simple blades that are pinkish to maroon in color, lubricous in texture, ruffled on the margins, and growing in clumps of 5–12 (Verlaque et al., *loc. cit.*).

*Significance*. First report of *G. turuturu* in the northeastern Pacific. Specimens from Santa Barbara representing both tetrasporangial and gametangial thalli were in good morphological and anatomical agreement with illustrations of this species (Gavio and Fredericq, *loc. cit.*; Verlaque et al., *loc. cit.*). Sporophytic thalli are linear in shape, while gametophytes are suborbicular in outline. In contrast to *G. californica* and *G. lanceolata* (refer to anatomical comparison above), *G. turuturu* has relatively thin blades (200 μm–350 μm), loosely interwoven, predominantly anticlinally arranged medullary filaments, and a phenology where growth and spore production take place in the fall. Identification was confirmed on two of the Santa Barbara specimens using ITS-1 (GenBank GQ499329 and GQ499330) and *rbc*L gene sequences (GenBank GQ499331 and GQ499332). DNA sequences from specimens from Santa Barbara were identical to previously published sequences of *G. turuturu* from Japan and Korea, and to introduced specimens from New Zealand, North America, Britain, and France.

In Santa Barbara, *G. turuturu* was found attached growing on the docks in a harbor with 1,133 slips that accommodates resident house and pleasure boats, and traveling sail boats and yachts. Since *G. turuturu* was growing in this rather small harbor, it is likely that this seaweed was introduced by traveling boaters, rather than by commercial shipping vessels. If this is the case, Santa Barbara is not likely the site of primary introduction. It is more probable that *G. turuturu* was first established in a larger shipping port, then secondarily introduced via sail boat by ballast water or by attachment to the hull, although an analysis of the latter mode of introduction by recreational yachts was found unlikely (F. Mineur, M. P. Johnson and C. A. Maggs 2008, Environmental Management 42:667–676). Thorough surveys in the nearby marinas of San Francisco, Newport, and San Diego may support this hypothesis. Based on how rapidly *G. turuturu* has spread globally and this report of its newly recognized presence in California, this species should be considered the most invasive red seaweed on the planet.

NEOSIPHONIA HARVEYI (J. W. Bailey) M.-S. Kim, H.-G. Choi, Guiry and G. W. Saunders (RHODOMELACEAE).—Humboldt Co., attached to the underside of floating wood docks and on the vertical sides of concrete pilings 0 to 6 m in depth, Humboldt Bay, 40°48′25.344″N, 124°09′59.8674″W, thallus tetrasporic, 8 August 2006, *A. Lyman s. n.* (UC 1944754).

*Previous knowledge*. Native to Japan; introduced to Norway, British Isles, Atlantic Europe, New Zealand, east coast of North America from Newfoundland to North Carolina (L. McIvor et al. 2001, Molecular Ecology 10:911–919) and Florida (D. S. Littler et al. 2008, Submersed plants of the Indian River Lagoon, 286 pp.); lectotype locality: Stonington, Connecticut, USA (C. A. Maggs and M. H. Hommersand 1993. Seaweeds of the British Isles. Volume 1. Rhodophyta. Part 3A. Ceramiales, 444 pp.). In California, McIvor et al. (*loc. cit.*) identified a specimen collected in 1994 from Monterey Bay as *Polysiphonia acuminata* Gardner. This specimen shared the same *rbc*L haplotype (i.e., haplotype F) as that from invasive specimens of *Neosiphonia harveyi* from New Zealand and North Carolina, and is closely related to a haplotype from Honshu, Japan.

*Significance*. Second report from northeast Pacific Ocean and California, approximately 650 km north of original range. This inconspicuous seaweed is easily overlooked or mistaken for native species. The thallus is distinguished from other taxa by the following characteristics: up to 5 cm tall, dark red, 4 pericentral cells, trichoblasts, and tetraspores that occur in spiral series. Identification of the Humboldt sample was confirmed

by analyzing a portion of the *rbc*L gene. The nucleotide *rbc*L sequence (GenBank GU339504) generated from the Humboldt specimen was identical to a specimen of *N. harveyi* from Akkeshi, Hokkaido, Japan (GenBank AF342901). Both the Humboldt and Akkeshi sequences contain a genetic marker (A → G at position 231) that McIvor et al. (*loc. cit.*) defined as diagnostic for haplogroup B. These data support a second, unrelated introduction of *N. harveyi* to California. Oyster culture is a likely vector for seaweed introductions (F. Mineur et al. 2007, Biological Conservation 137:237–247). The history of oyster farming in California has been reviewed by E. M. Barrett (1963, Fish Bulletin 123. The California Oyster Industry. UC San Diego: Scripps Institution of Oceanography Library. Website http://escholarship.org/uc/item/1870g57m). In 1896, adult eastern oysters, *Crassostrea virginica*, were imported from New York populations experimentally and raised in Humboldt Bay, but failed by 1912. They were again imported from the east coast from 1935 until the early 1940s. Since 1902, the Pacific oyster, *Crassostrea gigas*, was imported from various sites in Japan to oyster farms in Puget Sound, Washington. In 1928, the first experimental planting of Pacific oysters in California was made by the California Department of Fish and Game in Tomales Bay, with several other experimental plantings following in the early 1930s. According to P. S. Galtsoff (1930, Oyster industry of the Pacific coast of the U. S. Report U. S. Commissioner Fisheries, pp. 367–400), oysters from Akkeshi Bay were deemed the best adapted for transplanting to North America. However, the decision to exclude Pacific oysters from Humboldt Bay, the largest California bay available for oyster culture, delayed the state's development of the industry. Importation of the Pacific oyster from Japan to Humboldt Bay was initiated in 1953, and in 1957–58, Pacific oyster spat were imported from Willapa Bay, Washington to Humboldt Bay. Large scale production of Pacific oysters in Humboldt Bay began in 1955 and has continued to be an important industry. Although it is clear from our work that *Neosiphonia harveyi* in Humboldt Bay originated in Japan, the trajectory of the introduction is unknown. It may be primary (directly from Japan to California), secondary (from Japan to the east coast of the U.S. or to Washington, thence to California) or even tertiary, since oysters from San Francisco Bay were exported to Humboldt Bay (Barrett, *loc. cit.*).

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