

The spread of the European adventive *Caulacanthus okamurae* Yamada (*Caulacanthaceae*, *Rhodophyta*) to Ireland

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Caulacanthus okamurae Yamada (as ‘*Okamurai*’) was first described (Yamada 1933: 278, no fig.) from “Hokkaido down to Formosa [Taiwan]” based on *Endocladia complanata sensu* Okamura (Okamura 1908: 129, pl. XXVII: figs 12-20; pl. XXVIII: figs. 13-17, as “*Endocladia complanata* Harv.”). Okamura (1908) described and illustrated this species in beautiful detail, and it was very clear to Yamada that it was an undescribed species unrelated to *Endocladia*. A lectotype (SAP, no number given) was selected by West & Calumpong (1990: 182) of material collected by K. Okamura on 11 June 1899 from “Prov. Mikawa” [today comprising the eastern portion of Aichi Prefecture, Chūbu region of Honshū, Japan]. The species was later reported from China (e.g., Tseng 1984: 112, pl. 59: fig. 1), Korea (e.g., Lee & Kang 1986), and Taiwan (e.g., Lewis & Norris 1987). In the eastern Pacific, the species was reported by R.E. Norris & Wynne (1969, as *Caulacanthus ustulatus*) from Washington, USA, by Miller (2012) from California, and by J.N. Norris, Aguilar-Rosas & Pedroche (2017) from the Gulf of California, México. It is not clear if the eastern Pacific populations are the result of an introduction or introductions or represent overlooked native populations.

Rio & Cabioch (1988) reported “*Caulacanthus ustulatus*” from Carantec in Brittany, west of Roscoff, where it was first found in 1986 near some oyster beds (Rueness & Rueness 2000). Subsequently, the species was reported to have spread widely in Brittany (from Saint-Brieuc to Le Croisic) by 2006 and was also reported from Le Havre in Normandy (Le Duff, Breton & Ar Gall 2008). Rueness (1997) cultured material from Asia and Roscoff (France), and Rueness & Rueness (2000) published the first clear indication on molecular grounds that the *Caulacanthus* populations from NW France represented an introduction from the Pacific but without naming the species. Stegenga & al. (2006) reported plants from the Netherlands. Mineur & al. (2006) reported *Caulacanthus* from Plymouth in SW Britain where it was first found in 2000 or 2004 (Brodie & al. 2016: 1024; Bunker & al. 2017: 107), and the species, now referred to as *Caulacanthus okamurae* (see Brodie & al. 2016: 1010, 1024), is now mostly found in Devon and Cornwall in SW England and in Pembrokeshire, W Wales (Bunker & al. 2017: 107, map), but an outlier population has also been reported from Kent (Tittley 2016). Bárbara & al. (2019: 2, fig. 2 A-K) gave a comprehensive account of plants from NW Spain (Galicia), and the means of visually separating the two taxa in Atlantic Spain where populations were well established by 2013 and where *Caulacanthus okamurae* is now found in a wide range of habitats.

Caulacanthus ustulatus (Turner) Kützinger was originally described by Turner (1808-1809) as *Fucus acicularis* [var.] β *ustulatus* Turner based on an unpublished name “*Fucus ustulatus* Mertens, MSS” for material from “*Gades*” [Cádiz, Spain]. The name is often cited as “*Caulacanthus ustulatus* (Mertens ex Turner) Kützinger” (e.g. Athanasiadis 2016: 455), but this is incorrect as Turner (1808-1809) did not employ Mertens’s exact manuscript name. Kützinger (1843: 395) included two species in his new genus *Caulacanthus* Kützinger: *C. ustulatus* from Europe and *C. fastigatus* Kützinger, seemingly from Brazil. The genus was lectotypified by J. Agardh (1851: 433; see Searles 1968: 46, pl. 10a) with *Caulacanthus ustulatus* (Turner) Kützinger and *C. fastigatus* Kützinger is regarded as a variety (Pilger 1920: 5) or as a synonym of *Caulacanthus ustulatus*. *Caulacanthus ustulatus* is a common intertidal native along the shores of Portugal, Galicia and the north coast of Spain, apparently reaching its northern limit around Biarritz (Bornet & Thuret 1876: 55, pl. XIX: figs 1-4), and in the western Mediterranean (see Athanasiadis 2016: 455). The species

is widely distributed in the Indian Ocean (Silva, Basson & Moe 1996), and the latter authors cite several heterotypic synonyms from South Africa, Indonesia and New Zealand. A full list of reports of the species worldwide is given by Zuccarello, West & Rueness (2002: 163).

West & Calumpong (1990: 182) described the life history of and entity referred to *Caulacanthus ustulatus* from the Philippines with tetrasporophytes and gametophytes being more or less isomorphic and the gametophytes being dioecious. Crosses with a strain of *Caulacanthus indicus* Weber Bosse from Queensland were successful although the progeny showed reduced fertility, and the authors proposed to relegate *C. indicus* to the synonymy of *Caulacanthus ustulatus*. A strain of *Caulacanthus okamurae* from Korea remained sterile in culture, and thus no crossing experiments were possible. The correct application of these names in SE Asia requires further study.

Rueness & Rueness (2000) appear to be the first authors to definitively state that the Brittany populations represented an introduction from the Pacific as their sequence data revealed two distinct groupings: a Pacific group containing the samples from China, Japan and Roscoff and a group containing the samples from southern Europe with “minor morphological differences” between the two groups. Zuccarello, West & Rueness (2002) carried out similar molecular analyses again finding two distinct lineages: a Pacific lineage containing samples from China, Korea, Australia, the Philippines and the Pacific coast of the USA, plus a “cryptic introduction” to Roscoff, and a separate lineage from Spain and Portugal, but were also reluctant to recognise that the first group (including the Roscoff population) represented *Caulacanthus okamurae* and the latter *Caulacanthus ustulatus* concluding that “... that *C. ustulatus* be used for all samples until further studies can be conducted.” Mineur & al. (2006, 2007) referred the Roscoff and Mediterranean specimens to *Caulacanthus okamurae*. By 2008, the name “*Feldmannophycus okamurae* (Yamada) Mineur, Maggs et Verlaque”, *nom. inval.* was being employed by Zenetos & al. (2008: 125, 128) for Mediterranean populations, citing “Verlaque et al. in press”, but validity was not achieved as the basionym was not cited fully and directly. Subsequent publications generally adopted the name *Caulacanthus okamurae* Yamada for NE Atlantic and W Mediterranean adventive populations and *Caulacanthus ustulatus* (Turner) Kützinger for the native European populations, but it is clear that further taxonomic revision of *Caulacanthus* worldwide is required together with an assessment of the genus *Feldmannophycus* (Maggs & Verlaque, pers. comm) in the Mediterranean.

On 17 September 2020 a well-established mid-intertidal population of *Caulacanthus okamurae* was found on a Lower Carboniferous rock platform at Curragh on the eastern side of Ardmore Bay (Fig. 1). This shore is, for seaweed at least, one of the most diverse on the south coast of Ireland (Guiry 1977), the rocks of which are mostly dominated by less-than-hospitable Devonian “Old Red” Sandstones, with outcrops of limestone providing some relief, particularly in west Co. Waterford at Whiting Bay, Ardmore Bay and Dungarvan Bay. *Caulacanthus okamurae* was most common growing epiphytically on *Osmundea pinnatifida* (Hudson) Stackhouse (Fig. 2) but also grew at the base of older fucoids such as *Fucus vesiculosus* L., *F. serratus* L. and *Ascophyllum nodosum* (L.) Le Jolis, often resembling *Vertebrata lanosa* (L.) T.A.Christensen. Plants on *Osmundea* could easily be mistaken for *Gelidium pulchellum* (Turner) Kützinger, which has many seasonal guises, but most commonly grows at the margins of large pools and on limpets, either in such pools or on rock on wave-exposed shores, but which is not found as an epiphyte. *Caulacanthus okamurae* forms “spiky” pom-poms, is more profusely branched and the branches are terete as opposed to flattened, and irregularly reflexed. Microscopical examination shows an asymmetrical apical cell in *C. okamurae* as opposed to a symmetrical apical cell in intact *G. pulchellum* branches. *Caulacanthus okamurae* is reported from mussels (*Mytilus* spp.) in Britain, France and Spain, but no mussels are present on the semi-wave-exposed Co. Waterford shore. Reproductive plants (tetrasporophytes or gametophytes) were not found. A voucher specimen has been lodged in GALW (16411).

The seaweed flora at Curragh currently also includes two other Asian invasive species, *Bonnemaisonia hamifera* Hariot and *Sargassum muticum* (Yendo) Fensholt, seasonally present, mostly in larger rock pools. The latter species is now found on most shores in Ireland, and it can be expected that *Caulacanthus okamurae* will spread in a similar manner. The manner in which the species arrived in Ireland can only be speculated upon, but the relative proximity of a population in Pembrokeshire in Wales suggests that it originated from there either in drift or by means of leisure boat or shellfish transfer or ropes or shell. *Undaria pinnatifida* (Harvey) Suringar was well established at a marina at Kilmore Quay in the neighbouring Co. Wexford in 2016, where it is likely to have been introduced by leisure craft or commercial vessels (Kraan 2017). After years of relatively low levels of seaweed introductions, perhaps protected by low economic activity in the last century, Ireland is clearly catching up rapidly.

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Figs 1, 2. *Chondracanthus okamurae* Yamada, Curragh, Co. Waterford, Ireland (17 September 2020). Mid-intertidal plants growing profusely as an epiphyte on *Osmundea pinnatifida*.