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Field and morphological observations of *Gelidium longipes* (Gelidiales, Rhodophyta), a rare endemic red alga from northern New Zealand

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Abstract Field observations of the little known, New Zealand endemic red alga *Gelidium longipes* (Gelidiales, Rhodophyta) indicate that this species has a highly restricted distribution in northern New Zealand. Prior to this work *G. longipes* had not been collected for 50 years. This study located two closely situated and very small populations in the Bay of Islands; extensive fieldwork in comparable sites to the north and south of this region has not located any further sightings of this species. Material housed in the Agardh herbarium, Lund, is designated as the lectotype of this species and duplicate material is identified in New Zealand herbaria. This is the second species of New Zealand endemic *Gelidium* that has been found to have a very restricted distribution; *G. allanii* has been reported previously from isolated and restricted populations in northern Northland.

Keywords Gelidiales; *Gelidium longipes*; northern New Zealand

INTRODUCTION

The New Zealand endemic red alga *Gelidium longipes* J.Agardh (Gelidiales) was described from specimens collected in 1874–75 in the Bay of Islands, north-eastern New Zealand, by the Swedish explorer Berggren (Agardh 1876, p. 547). This species has remained poorly known with few collections present in herbaria. Adams (1994) described *G. longipes* as being "local" and distributed in the northern North Island and Kermadec Islands, although the geographic range of this species has been recorded by earlier authors from the Kermadec Islands (Gepp & Gepp 1911; Laing 1926) to Dunedin (Naylor 1954). Chapman (1969) commented on the similarity in habit of this species with *G. ceramoides* Levring as well as with "*G. subulifolium* (Harv.) V.J.Chapm.". Adams (1994) noted that "*G. longipes*, described from New Zealand plants, includes at least some of the entities recorded as *G. crinale*, a European species".

There has been considerable taxonomic and nomenclatural confusion within the genus *Gelidium* in New Zealand. The work presented here is part of a larger study of New Zealand members of the order Gelidiales. In this paper we report on field investigations of the distribution of *Gelidium longipes* as well as the examination of the morphology and anatomy of herbarium specimens and field material.

MATERIALS AND METHODS

Specimens housed in New Zealand herbaria, AK/AKU, CHR, and WELT, that had been identified as *G. longipes*, *G. crinale*, and *G. pseudointricatum* (Lindauer material from the northern North Island identified by Levring) were examined, as well as material of *G. longipes* held in the Agardh Herbarium, LD (Fig. 1) (Holmgren et al. 1990).

Over a period of 10 years, from c. 1991 to 2001, a number of collecting trips have been made throughout the New Zealand region, from the Three Kings Islands to Stewart Island, and including the Chatham Islands. Particular focus has been placed on sites in the Bay of Islands, the type locality of *G. longipes*, and along the coastline of the northern North Island. In particular, sites were visited from which *G. longipes* had been reported previously.

Field material was rinsed in seawater and sorted. For morphological examination samples were preserved in 3–5% formalin/seawater. Live material

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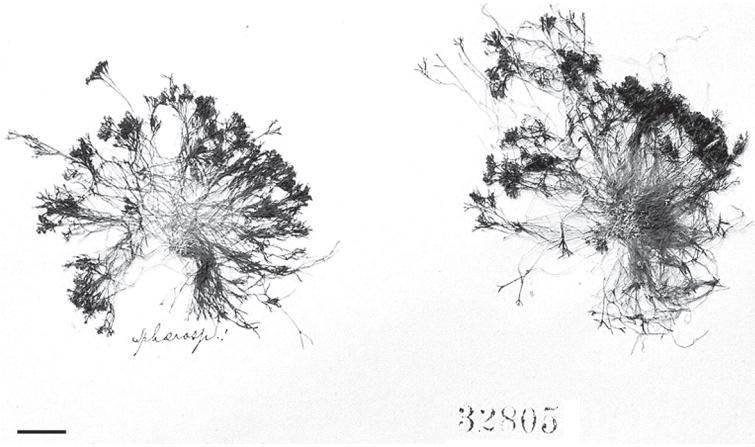

Fig. 1 Lectotype specimen of *Gelidium longipes* J.Agardh, LD 32805. Scale bar = 1 cm.

from the population at Waitata reef was retained for growth observations, cleaned in sterile seawater, and subsamples were transferred into 54-mm-diam. tissue-culture petri plates with sterile f/2 growth medium (Guillard & Ryther 1962), and maintained at 15°C with 15:9 L:D and 20 µmol photon m^{-2} s^{-1} and 20°C with variable photoperiod and 20 µmol photon m^{-2} s^{-1}. Voucher specimens were retained and lodged in the herbarium of the Museum of New Zealand Te Papa Tongarewa (WELT).

RESULTS

Herbarium material

In the Agardh herbarium (LD) there is a specimen sheet of *Gelidium longipes*, collected by Berggren in the Bay of Islands, on which 6 clumps are mounted (LD 32805) in addition to a packet containing a loose clump (LD 32806) (Fig. 1). In New Zealand herbaria there are four duplicate specimens collected by Berggren and identified by Agardh. All the Berggren material is in excellent condition and clearly displays the characters used by Agardh to distinguish this species: thalli form dense hemispherical clumps, and the axes are elongate and terete, becoming flattened and branching at the tips. Agardh commented on the pale colour in the lower part of the axes and the intense apical pigmentation. We are designating specimen LD 32805 as the Lectotype of *Gelidium longipes*.

Of the 63 specimens that were examined from New Zealand herbaria, 38 sheets from 17 collection dates were confirmed to be material of *G. longipes*, coming from 4 locations: Kermadec Is (29–31°S, 177–178°W) (6 sheets from a single collection), Bay of Islands (c. 35°S, 174°W) (several sites, 25 sheets and 14 collections), Scott's Point (34°32′S, 172°47′E) (6 sheets from 3 collections), and the Noises Is (36°32′S, 174°28′E) (a single herbarium sheet). The majority of the specimens were collected by V. W. Lindauer between 1938 and 1942, and no herbarium specimens of *G. longipes* were found that had been collected after 1942. Specimens incorrectly identified as *G. longipes* from the South Island included material as diverse as *Gelidium ceramoides* (strictly dichotomous, with a highly restricted distribution), *Capreolia implexa* (fine, prostrate), and *Gymnogongrus torulosus* (irregularly branched, wiry).

REPRESENTATIVE MATERIAL EXAMINED: Bay of Islands, *Berggren*, 1874–75, LD 32805 (Lectotype), LD 32806, AK 147035, WELT A1251, CHR 328893, CHR 329786; Russell, Stormy Bay, *Lindauer*, Feb 1937, AK-VWL 366; Russell, Waitata, *Lindauer*, May 1938, AK-VWL 1075; Russell, Long Beach, *Lindauer*, Mar 1936, AK 143868; Russell, Long Beach, *Nelson & Knight*, Aug 1992, WELT A25042; Kermadec Is, *Oliver*, Nov 1908, WELT A1618.

Field collections

In the course of our field observations, the northern North Island was the only region where we located *G. longipes*. We were able to confirm the existence of only two extant populations of this species, both in the Bay of Islands: one adjacent to Waitata reef near Long Beach, and the other smaller population in a neighbouring embayment, c. 200 m distant.

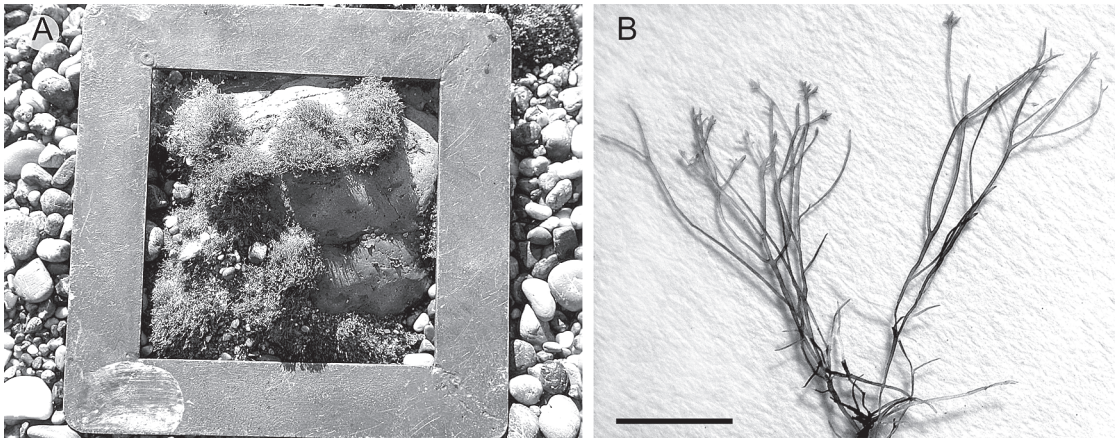

Fig. 2 **A**, Growth of *G. longipes* in the Bay of Islands. Inner side of quadrat frame = 10 cm; **B**, Herbarium specimen of *G. longipes* showing sparsely branched axes and club-shaped terminal ramuli. Scale bar = 5 mm.

Despite intensive searching in a number of locations in the Bay of Islands, and to the north and south of this area, no further populations were located.

Habitat observations

The Waitata reef population grows in dense clumps on rock in the lower intertidal zone (Fig. 2A). The clumps are present in an area that is scoured and/or buried by gravel. In these tightly packed clumps the lower sections of many axes are yellowish with little red pigmentation, apparently growing out of the light and buried by sediment. The bases of the axes are tightly bunched and intertwined. This growth habit is apparent in the specimens collected by Berggren.

The population present in the embayment neighbouring the Waitata reef is much less abundant. It is in an area that undergoes burial by coarse sand, and the axes are growing with other turfing species, such as *Corallina officinalis*, *Chondracanthus chapmanii*, and *Laurencia thyrsifera*.

Morphological observations

The thalli (2–5 cm) are dark red to red-brown, with slender erect terete axes that are only infrequently and irregularly branched in the lower portion (Fig. 2B). The holdfast system consists of tangled, slender terete stolons with rhizoids extending from the lower surface and attaching the clumps of thalli to rock. At the branch tips the axes taper sharply to the prominent apical cells (Fig. 3A,B). Some axes are unbranched although there are often clusters of short branches or slightly compressed club-shaped terminal ramuli (Fig. 2B). The majority of specimens examined were fertile with terminal spathulate tetrasporangial stichidia. In some specimens the axis has continued to grow beyond the stichidium and occasionally a second stichidium is present on the same branch. Cystocarps are globose and bilocular, occurring on short laterals near the branch apices or in an intercalary position on unbranched axes.

Growth in culture

At both 15° and 20°C, small fragments (approximately 1 mm long) survived for the 9 weeks they were maintained. After 11 days in culture at 20°C an apical cell developed from each cut surface and a stolon-like axis developed to 0.2 mm in length (Fig. 3A). After a further 4 weeks culture at 20°C, axes as long as 19 mm were observed to have grown from cut surfaces, while the original branch apices remained unchanged from the time the cultures were established (Fig. 3A). Elongation occurred from all cut surfaces, regardless of aspect or direction with respect to the intact organism. A single apical cell and branch system grew from each cut surface, with the development of external rhizoids at numerous points along the stolon (Fig. 3A,B). Similar growth and elongation was observed at both 15° and 20°C. It is likely that this type of vegetative regeneration could result in the growth bands observed in the field-collected axes. The bands have apparently

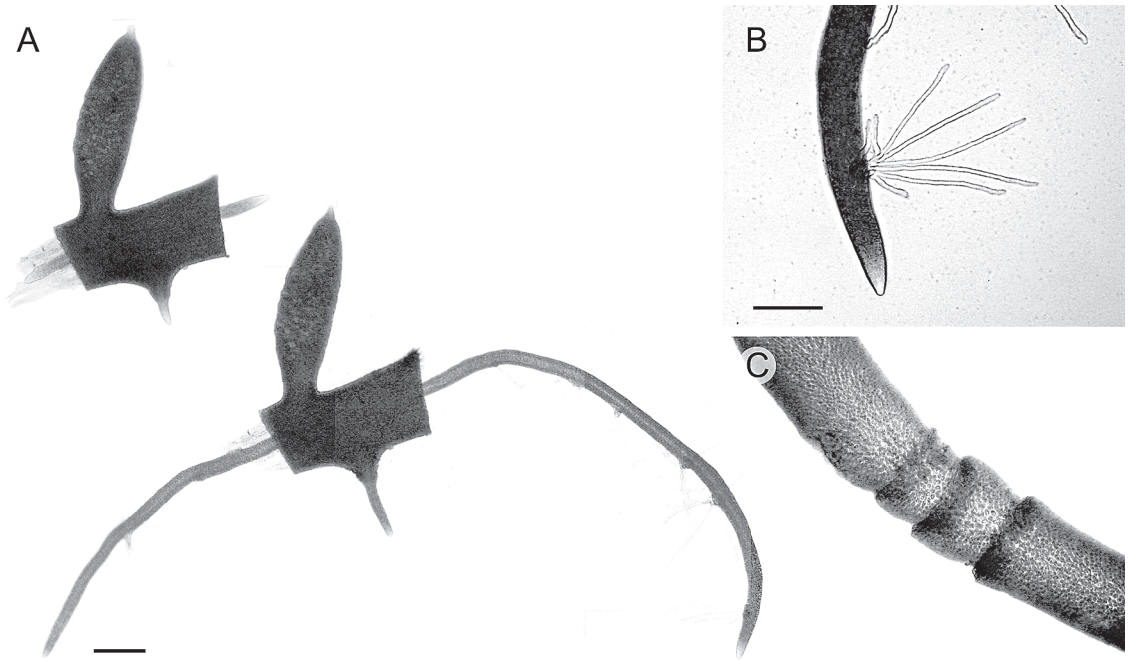

Fig. 3 **A**, Upper left, axis fragment maintained in culture for 11 days; main image (composite), axis fragment after 40 days showing extension of regenerating axes and developing rhizoid clumps; **B**, Rhizoids developing from lower surface of stolon; **C**, Field collected axis showing growth bands. Scale bars: A = 2 mm; B = 100 µm.

resulted in areas where axes have been damaged and there has been subsequent repair and initiation of new growth (Fig. 3C).

DISCUSSION

This study has located the New Zealand endemic red alga *Gelidium longipes* at two closely situated populations in north-eastern North Island, 50 years after the last known collections of this species. The other sites where *G. longipes* has been found prior to this study, Kermadec Is, Scott's Point, and the Noises Is, are remote and as yet we have been unable to sample these areas. We have, however, made thorough collections in northern Northland and have not located any additional populations. There is no evidence either from our field collections or from the examination of herbarium material which supports the suggestion of some earlier authors that this species may occur in other parts of the New Zealand region.

The morphology of *G. longipes* enables this species to be readily distinguished in the New Zealand context, as no other taxa share its growth habit or are found in the same habitat. Although Chapman (1969) linked *G. longipes* with *G. subulifolium* and *G. ceramoides*, the name *G. subulifolium*, as originally applied by Harvey (1855), refers to small, densely pinnate *Gelidium* growing on mussel shells. *Gelidium ceramoides* was described by Levring (1949) as growing to 15 cm in height, and is restricted to south-east Otago and Stewart Island. In a subsequent study of *Gelidium* species in northern New Zealand, the largest New Zealand species of *Gelidium*, *G. allanii*, was characterised (Nelson et al. 1994). This endemic species also has a very restricted distribution with few populations known from the Bay of Islands and the region north, primarily on the east coast but also with one population located in the Hokianga Harbour. In contrast to both *G. allanii* and *G. longipes*, the other northern endemic species of *Gelidium*, *G. caulacantheum*, is widespread and commonly found on intertidal shores

in a wide range of habitats. As currently understood *G. caulacantheum* is very variable morphologically (Dromgoole & Booth 1985; Adams 1994). Guiry & Womersley (1993) established *Capreolia implexa* on the basis of life history and morphological characters for specimens from Australia and New Zealand that had previously been placed in *G. pusillum*. The genus *Capreolia* is well supported by subsequent molecular sequence analyses that also indicate that *G. caulacantheum* is more closely related to *Capreolia implexa* than to other species of *Gelidium* (Freshwater et al. 1995).

Morphological variability has dogged all taxonomic studies of the genus *Gelidium*: Bornet referred to it as a "genre diabolique" (Dixon & Irvine 1977a). There have been many studies searching for reliable taxonomic characters in *Gelidium* (e.g., Stewart 1976; Rodrigues & Santelices 1987; Santelices 1990) but to date there has been little success. There are some morphological similarities between *G. longipes* and the specimens that are placed in the European species *G. crinale* (Turner) Gaillon, a taxon that has been reported to have a cosmopolitan distribution. Renfrew et al. (1989) considered that descriptions of *G. crinale* from treatments of Hawaiian, Pacific, and Atlantic North American floras demonstrated "the lack of diagnostic characters defining this species". Dixon & Irvine (1977b) combined a number of *Gelidium* species, recognising only two morphologically variable species in the British Isles: *G. pusillum* (which included *G. crinale*) and *G. latifolium*. This treatment has not been followed by Coppejans (1995) who recognised *G. crinale* as a distinct species in Belgium and northern France. Illustrations of *G. crinale* (Coppejans 1995) show similarities with the external morphology of *G. longipes*. Womersley & Guiry (1994) recognised *G. crinale* in the southern Australian flora, commenting on the similarity of Australian specimens with Turner's original description and illustrations. However, Freshwater & Rueness (1994) in a study of European *Gelidium* species commented that "the concept of *G. crinale* is poorly understood and consequently a sample definitively identified as this taxon could not be included in this study". They consider that Turner's description of *G. crinale* could apply to a "sparsely branched form of the highly polymorphic *G. pulchellum*".

The use of molecular sequence data is providing fresh insights into the phylogenetic relationships within the Gelidiales as well as an improved understanding of generic boundaries (Freshwater et al. 1995; Bailey & Freshwater 1997; Patwary et al. 1998). Although there are similarities in the morphology of *G. longipes* and *G. crinale*, we will continue to recognise *G. longipes*, based on New Zealand type material, until molecular sequence data enable us to more fully clarify the relationships of these taxa; a study is currently under way.

The development of clusters of rhizoids in *G. longipes* is similar to that reported in the Californian species *G. robustum*, where rhizoidal cell clusters were produced under low light and in long-day conditions, whereas branch initiation was found to be facilitated by higher light levels (D'Antonio & Gibor 1985). This led D'Antonio & Gibor (1985) to suggest that low light conditions enable effective settlement of germlings and this may be important in areas of high wave action. In the habitats where *G. longipes* is found wave action is only moderate, but the lower axes are buried by sand/gravel and, thus, experience very low light levels. The apparent repair zones found on *G. longipes*, as well as our observations of growth in culture, suggest that this species is capable of rapidly regenerating from cut surfaces as well as producing abundant rhizoids for anchoring to the substrate. Many of the herbarium specimens as well as field-collected samples examined were found to be fertile; both tetrasporangial and cystocarpic material have been seen. Given the clump-forming habit, the capacity to form stolons, and the frequent presence of fertile axes, the rarity of this species is somewhat puzzling. The size of the populations of *G. longipes* make this species vulnerable to any locally experienced changes to the conditions on the reefs in the Bay of Islands.

In recent years, increasing recognition of the movement of marine species around the world has led to researchers questioning records of infrequently located species, suggesting that these may be cryptogenic species (Carlton 1996). Freshwater et al. (1995) suggested that *G. allanii* might be a Japanese species introduced into New Zealand waters. The distribution of *G. allanii* makes this hypothesis most unlikely as it is found in areas that are not accessible to commercial vessels and are remote from areas normally visited by pleasure craft (Nelson et al. 1994). Although the two populations of *G. longipes* that we have located are in the Bay of Islands, an area which has received a great deal of shipping traffic over a period of more than 150 years, the specific sites at which *G. longipes* is growing are distant from wharves or mooring areas for pleasure or commercial craft. The collections from remote populations at the Kermadec Is, Scott Point, and the Noises Is support the hypothesis that this is a native taxon, and

unlikely to have been introduced to New Zealand as a result of human-mediated transport.

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