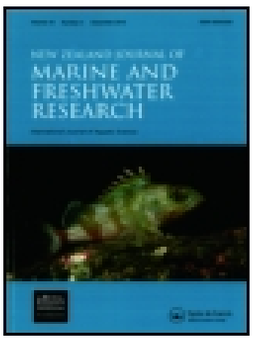

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OCCURRENCE OF *CODIUM FRAGILE* SUBSPECIES *TOMENTOSOIDES* IN NEW ZEALAND WATERS

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ABSTRACT

Codium fragile (Sur.) Hariot subsp. *tomentosoides* (Van Goor) Silva is reported from Auckland Harbour. Although macroscopically similar to native forms of *C. fragile*, the subspecies can be positively identified by utricle anatomy. Its vigorous growth and efficient dispersal by asexual reproduction, and possibly by vegetative fragments, have resulted in a rapid spread to adjacent localities. These features suggest that the plant could be a nuisance to the shellfish industry as it has been in North America. The manner in which this weed was introduced is not clear, but transportation as a fouling organism on ships is most probable.

OBSERVATIONS

OCCURRENCE

On 20 November 1973, some scattered, small plants of *Codium* were found during a survey of a sheltered shore formed by the eastern sea wall of the recently constructed Container Terminal in Auckland Harbour (36° 51′ S, 174° 48′ E). At this time the plants were tentatively

identified from macroscopic appearance as *Codium fragile* var. *typicum* which had previously been recorded by Dellow (1952) from several localities in New Zealand. [Dellow records the New Zealand plants of this complex taxon as *Codium fragile* (Sur.) Hariot var. *typicum* Schmidt. However, very similar, if not identical, forms from Australia have been described by Silva & Womersley (1956) as *C. fragile* subsp. *novae zealandiae* (J. Ag.) Silva, and further research is required to determine the identity of the populations native to New Zealand.] A subsequent survey almost a year later, on 3 December 1974, revealed that the plants had spread extensively over a distance of 70 m along the base of the sea wall. The plants were then up to 20 cm long and extended over a vertical range from 1.3 m above ELWS (extreme low water mark spring tides) to 1 m below ELWS. Densities in the original settlement area were as high as 16 000 $g_{\bullet}m^{-2}$ on a fresh weight basis (=1152 $g_{\bullet}m^{-2}$ dry weight), but much less elsewhere. At this time, the total population was estimated to be in excess of 400 individuals, with some plants attaining 180 g fresh weight.

MORPHOLOGY AND HABIT

This rapid growth and spread of the plants and the high population densities are not characteristic of communities of the native form of *Codium fragile*, which Dellow (1952, p. 134) describes as " . . . plants were few in number and quite far removed from one another". As *C. fragile* had not previously been reported from Auckland Harbour or Hauraki Gulf localities despite several intensive shore surveys (Carnahan 1952; Dellow 1955; Luckens unpublished 1964; Dromgoole unpublished 1965, 1973) and a study of wharf pile fouling (Harger unpublished 1963), it seemed probable that the plants represented a recent introduction. Microscopic examination of utricle anatomy suggested that the plants were identical to a subspecies of *Codium fragile* which occurs throughout the northern hemisphere but has not hitherto been reported from southern latitudes. Collections made in December 1974 were sent to Dr P. C. Silva, who confirmed that they are *C. fragile* (Sur.) Hariot subspecies *tomentosoides* (van Goor) Silva.

The plants consist of one to several erect fronds, 15–20 cm high, abundantly branched in a dichotomous or fastigiate fashion, and attached to the substrate by a broad spongy basal disc (Fig. 1). The branches are terete (sometimes slightly flattened below a major dichotomy); 6–8 mm at the base, tapering to 3 mm at the apices, dark green and generally tomentose just below the apices, with long hyaline hairs. The subspecies *tomentosoides* is virtually identical in general morphology with the native plants described by Dellow. However, microscopic examination reveals that the new plants are quite distinct in that utricles taken from about 2 cm below the tip of a branch typically have a broad median or submedian constriction and the apical point is prolonged into a sharp mucron (Fig. 2B, D). In contrast, utricles taken from an equivalent position from native plants are characterised by a slender cylindrical shape (slightly clavate when older), with apices that tend to be rounded and bluntly mucronate (Fig. 2A, C). Other anatomical features such as

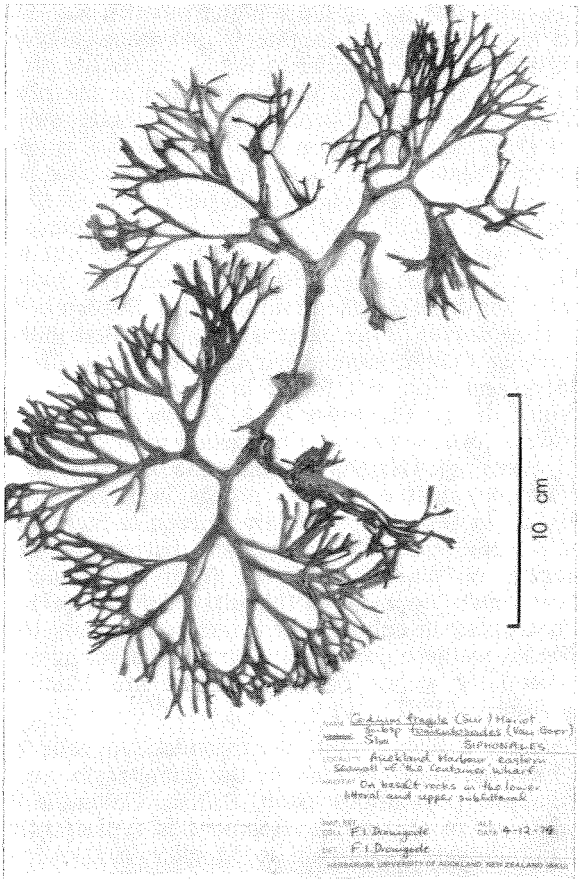

FIG. 1—Photograph of herbarium specimen of an entire plant of *Codium fragile* subsp. *tomentosoides*. Collected 3 December 1974, eastern sea wall of Container Terminal, Auckland Harbour.

utricle dimensions, position of hair scars and insertion of reproductive organs do not appear to be sufficiently distinctive in themselves to separate the subspecies *tomentosoides* from the endemic forms. A complete description and illustrations of utricle anatomy of *C. fragile* subsp. *tomentosoides* are given by Silva (1955, 1957).

REPRODUCTION

Its success as a rapid coloniser may be attributed to at least two methods of propagation. The plants are perennial, proliferating from a persistent basal portion in spring. Wave damage periodically induces accidental fragmentation of the plants, and in this way a large portion

of the erect frond is lost during the summer months. Ramus (1972) has demonstrated the potential for fragments and even isolated utricles of *Codiul fragile* subsp. *tomentosoides* to act as vegetative propagules, and the extent to which this process has contributed to the rapid spread in Auckland Harbour is being investigated. Methods such as winter fragmentation (Fralick & Mathieson 1972) and asexual propagule formation may also contribute to the success of the plants, but have not been observed in the New Zealand plants. The primary method of reproduction is by swarmers, which develop in structures subtended from the utricles. These reproductive structures occur throughout the year, but appear to be more frequent in spring–summer. The swarmers superficially resemble the female gametes described in Borden & Stein (1969), but must develop asexually, as isolation has indicated that germination can occur without fusion; gametangia have not been observed in any collected plants and were not found in a survey of 51 plants at the Container Wharf during December 1974. The swarmers are only weakly motile and have a tendency to remain together after discharge, apparently attached by mucilage. Germlings initiate one or two germination tubes, and further development in culture results in a free-floating tuft of germlings similar to those described by Borden & Stein (1969). These subsequently assume a weakly organised heterotrichous system by mutual adhesion of filaments derived from the same or different swarmers. Further development of this phase into an axis composed of utricles did not occur in culture, but a tuft of filaments from the field, which was similar to those grown in culture, had a young primordium of utricles. These later stages of development are identical to those described by Ramus (1972).

There is strong evidence that the reproductive cells of *C. fragile* function as gametes (with meiosis in the gametangia and subsequent fusion) in Pacific populations from British Columbia, Japan, and Australia, whereas an asexual development is typical of Europe and New York populations (Churchill & Moeller 1972). It is therefore interesting to note that whereas the latter mode of reproduction is the only method noted for *C. fragile* subsp. *tomentosoides* in New Zealand, the endemic forms of *C. fragile* appear to be characterised by the former method, as both male and female gametangia are to be found on either the same or separate plants (Dellow 1952, and my own observations of herbarium material). Further collections of fresh material are being examined to establish whether the reproduction of the endemic forms is indeed distinct from that of the introduced population.

DISCUSSION

The occurrence of *Codium fragile* subspecies *tomentosoides* raises wider issues than just the addition of another entity to the New Zealand marine flora, because the plants have the vigour and adaptability of a weed. This particular subspecies is apparently a native of Japan, but has been reported in recent years as a vigorous adventive in parts of

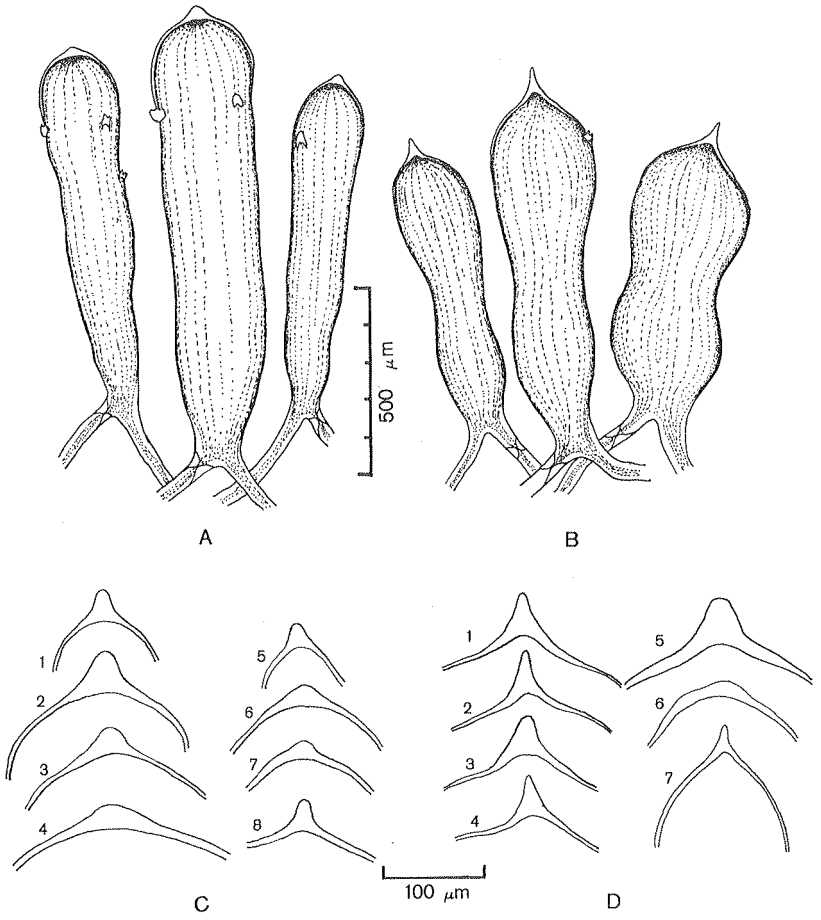

FIG. 2—Utricle anatomy of *Codium fragile* plants from native populations (A, C) and from the adventive *C. fragile* subsp. *tomentosoides* (B, D):

A – Typical utricle form 2 cm from branch tip of *C. fragile* plants collected from Pihama (Herb. Lindauer 8334);

B – Typical utricle form 2 cm from branch tip of *C. fragile* subsp. *tomentosoides* from Container Wharf, Auckland Harbour;

C – Camera lucida drawings of mucron details for native plants. 1–4, collected from Pihama, Taranaki (Herb. Lindauer 8334); 5–7, The Bluff, Ninety Mile Beach (Herb. Lindauer 2050); 8, Long Beach, Russell (Herb. Lindauer A56). 1 and 5 are from young utricles, others from mature utricles taken 2 cm from branch tips;

D – Camera lucida drawings of mucron details for subsp. *tomentosoides*. 1–4, utricles from 2 cm below branch tip; 5 and 6, mature utricles from branch base; 7, young utricles from branch base.

Europe (Silva 1955) and north-eastern North America (Bouck & Morgan 1957, Wood 1962, Taylor 1967). In the latter region, dense growths of the plant attached to living oysters, scallops, and mussels have caused considerable damage to the shellfish industry (Ramus 1971, Galtsoff 1964). Besides physically displacing or blanketing some organisms, the dense growth may indirectly affect others through changes in dissolved gases, nutrient consumption, and sedimentation rates.

The potential success of subspecies *tomentosoides* as a weed in New Zealand is difficult to assess. The introduced plants have a rapid winter and spring growth and show a lack of preference for substrate (driftwood, wharf pilings, rubber tyres, navigation buoys, and plastic refuse as well as rock surfaces can support large fertile plants), but to date they have not obviously competed with natural existing populations of the rock oyster *Crassostrea glomerata*. Nevertheless, the plants could seriously interfere with a future spat settlement if the present vigorous growth and spread of the plants is maintained. The plants appear to be incapable of displacing other algal populations, but where they have become established on bare substrates their prolific growth is sufficient to keep out potential competitors such as *Hormosira banksii, Carpophyllum* spp., and *Sargassum* spp. Malinowski & Ramus (1973) report a similar establishment pattern for New England populations of the subspecies *tomentosoides*.

Laboratory studies of metabolism reveal that photosynthesis is enchanced at temperatures below those prevailing at Auckland, suggesting an even more vigorous growth if the plants spread further south.

Our inability to forecast reliably the effects of this alien plant on indigenous communities and to estimate the possible serious threat it poses to the shellfish industry, particularly for mariculture where fresh substrates are used for larval recruitment, suggests that attempts should be made to eradicate the colonies. Unfortunately, this may prove impracticable as the plants are also well established at other localities (Point Resolution, Judges Bay, West Bastion reef, West Tamaki Head, Tamaki River) in the vicinity of Auckland Harbour.

The manner in which subspecies *tomentosoides* was introduced to New Zealand waters is uncertain. Transportation on the hulls of ships seems most probable, assuming that the densest stands of the weed at the Container Wharf sea wall represent the first settlement. The spread of the plants to and along the north east coast of North America has been attributed to an accidental importation with seed oysters (Wood 1962, Taylor 1967), but this is unlikely to be the origin of the Auckland plants. Preliminary field and laboratory observations indicate that the plants can tolerate a wide range of light and temperature conditions. These features, with their ability to grow on most substrates and a perennial life form, suggest that they are well suited to carriage by shipping. The appearance of *Codium fragile* subspecies *tomentosoides* in New Zealand waters is a further example of the long-range dispersal of marine algae (Druehl 1973, Farnham *et al.* 1973) and shows the need

for regulations to control the accidental introduction of exotic species (by transplantation or by ship fouling) that may be a potential threat to mariculture.

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