

# FIRST RECORD OF THE POTENTIAL NUISANCE ALGA *Codium fragile* ssp. *tomentosoides* (Chlorophyta, Caulerpales) IN ATLANTIC CANADA\*†

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The green macroalga *Codium fragile* ssp. *tomentosoides* was collected for the first time in Atlantic Canada at Graves Shoal, Mahone Bay, Lunenburg County, Nova Scotia, in December 1991. Casual observations in this area during the late 1980s suggest that it was present in 1989, possibly earlier. By late 1992, it had been found widely throughout Mahone Bay and eastward as far as Prospect Bay in Halifax County. The evidently rapid dispersal, large size of plants and abundant production of gametangia indicate that the semiconfined environment of bays on the Atlantic coast of Nova Scotia is favorable to the alga, which in consequence may be a serious foulant and competitor with the indigenous flora. It is probable that *C. fragile* ssp. *tomentosoides* was transported from New England to Nova Scotia either by recreational yacht traffic or in a mass of warmer water driven westward from the Gulf Stream.

La macro-algue verte *Codium fragile* ssp. *tomentosoides* a été collectionnée pour la première fois dans le Canada atlantique, c'est-à-dire, à Graves Shoals, Mahone Bay, comté de Lunenburg, Nouvelle-Ecosse en décembre 1991. Des observations d'occasion dans ce lieux pendant les dernières années '80 suggèrent sa présence en 1989 et même plus tôt. Vers la fin de l'année 1992 on l'avait trouvée largement répandue à Mahone Bay, et vers l'est aussi loin que Prospect Bay dans le comté d'Halifax. La dispersion manifestement rapide, la grande taille des plantes, et la production abondante de gametangia indiquent que l'environnement enfermé à moitié des baies de la côte atlantique de la Nouvelle-Ecosse est propice à l'algue; celle-ci pourrait être une entité salissante importante et concurrencer avec la flore indigène. Il se peut que *C. fragile* ssp. *tomentosoides* ait été amené de la Nouvelle-Angleterre soit par des yachts récréationnels soit dans une masse d'eau plus chaud poussée vers l'ouest et provenant du Gulf-Stream.

## Introduction

*Codium fragile* (Suringar) Hariot ssp. *tomentosoides* (Van Goor) Silva (Fig 1) is a widely distributed (Schneider & Searles, 1991) robust green alga of temperate to warm-temperate waters, considered to be endemic to the northwest Pacific (Silva, 1955). It was first found on the east coast of North America in 1957, at Orient Harbor on Long Island, New York (Carlton and Scanlon, 1985), following accidental introduction from western Europe, and has spread both northward and southward so that its known distribution in the northwest Atlantic in 1991 was from Bar Harbor, Maine (R. L. Vadas, pers comm.) to North Carolina (Schneider & Searles, 1991). Carlton and Scanlon (1985) have reviewed the dispersal of *C. fragile* ssp. *tomentosoides* along this coast, and considered various possible mechanisms of introduction and dissemination.

The spread of *C. fragile* ssp. *tomentosoides* in the northwest Atlantic has caused some concern as the species is a vigorous colonizer, rapidly forming dense stands (e.g.,

\* Dedicated to the memory of Kenneth A. Harrison

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Fig 1. *Codium fragile* ssp. *tomentosoides*. Portion of a large plant. The spongy, repeatedly forked, cylindrical to compressed fronds are unmistakable in the seaweed flora of eastern Canada.

Ramus, 1971; Prince, 1988) in competition with the indigenous flora. Where abundant, it also has been a nuisance to fishing activities, overgrowing valuable shellfish beds and clogging dragnets (Fralick & Mathieson, 1972; Carlton & Scanlon, 1985). In consequence, much attention has been directed to determining factors affecting its growth, reproduction and dispersal in American waters (reviewed by Carlton and Scanlon, 1985).

The northward progress of *C. fragile* ssp. *tomentosoides* through Maine, however, has been relatively slow and populations are disjunct, restricted to bays where water temperatures are warmer than on outer coasts. This has suggested that the species is nearing the northern limit of its distribution in the western Atlantic, and that the cold waters of the Bay of Fundy approaches could prevent its direct passage to Nova Scotia.

We now report on the arrival of *C. fragile* ssp. *tomentosoides* in Nova Scotia, suggest means of introduction, and, in view of the nuisance reputation of this alga, discuss implications of its presence for the local marine flora and fauna.

### Observations

The first collection was made on 1 December 1991, from scallop aquaculture floats at Graves Shoal (44°33'N, 64°12'W) in Mahone Bay (Fig 2). Plants grew densely among mussels 2-4 m below mean low water, and were up to 45 cm long, with gametangia. Specimens were identified as *C. fragile* ssp. *tomentosoides* by the criteria of Silva (1955) and Burrows (1991), and are conserved in the herbaria of the National Research Council, in Halifax (NRCC, No. 10883). Plants had also been noted during 1989 and 1990, but were not collected. Up to late 1991, the species appeared to be confined to the floats, as no specimens were observed attached to natural substrate on Graves Shoal and none was seen in the drift on nearby beaches.

At about the same time, *C. fragile* ssp. *tomentosoides* was found, attached to mussels, on Little Tancook Island (44°28'N, 64°08'W) near the mouth of Mahone Bay. A specimen was submitted for identification to G. J. Sharp (Fisheries and Oceans Canada), who gave it to the Institute for Marine Biosciences (NRCC 10889).

The following spring and summer, incidental observations were made at various sites in Mahone Bay and adjacent shores. At about this time, the large thalli disappeared from the aquaculture system at Graves Shoal and were replaced by a dense growth of younger fronds. Plants of *C. fragile* ssp. *tomentosoides* appeared on several occasions adrift near the head of the bay, and attached thalli were found on several reefs (Fig 2), including Graves Shoal, usually at 1.5-5 m depth on rocky substrate in areas of moderate exposure. Owing to their large size (to 55 cm long), plants were a conspicuous, sometimes subdominant, element of the flora, and on Sheep Ledge (44°30'N, 64°16'W) were estimated to constitute as much as 40% of the cover. Larger thalli had a tendency to detach and accumulate in depressions at maximum depths of about 12 m, forming deposits up to 1 m thick but apparently remaining in healthy condition, at least near the surface of the mass. In these situations, they sometimes verged on beds of *Laminaria*, presumably to the detriment of understory flora and fauna. The easternmost location of the species observed thus far was at Kelly Ledge (44°29'N, 63°46'W), near the mouth of Prospect Bay, Halifax County (Fig 2). Specimens, which were not collected routinely, are deposited in NRCC and at Acadia University (ACAD).

The alga was not observed in sites with a predominance of sand or cobble substratum [Frog Island (44°31'N, 64°17'W); Round Island Nubble (44°29'N, 64°16'W); Little

Duck Island (44°22'N, 64°11'W), A. Windust, Dalhousie University, pers. comm.), although some of these sites were close to flourishing populations.

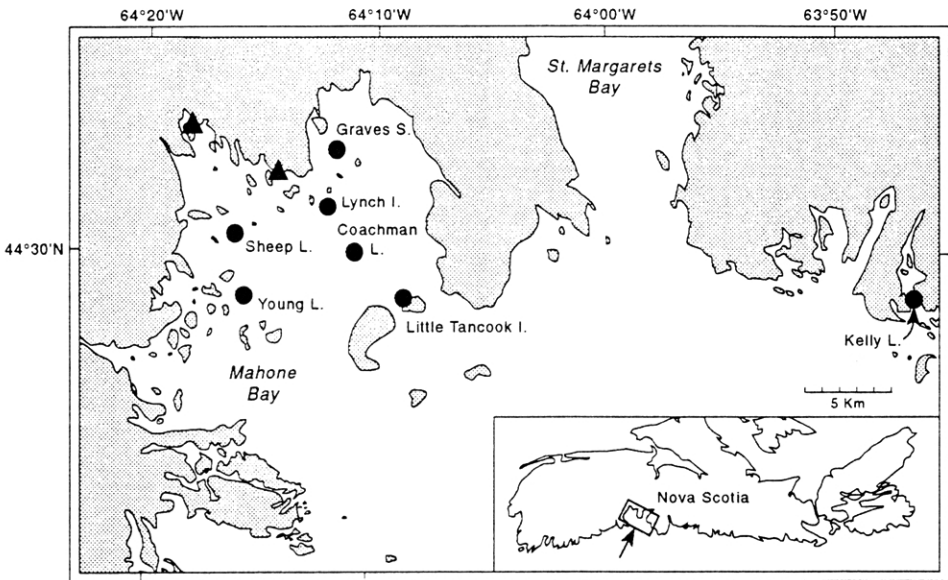


Fig 2. Map of Mahone Bay, Nova Scotia and adjacent coast eastward to Prospect Bay, showing locations of *Codium fragile* ssp. *tomentosoides* recorded up to autumn 1992. ●-attached plants; ▲-drift specimens only. Inset: map of Nova Scotia, showing the area enlarged (arrow).

## Discussion

*Means of introduction.* The means by which a species is introduced into a new region is often a matter of speculation. *Codium fragile* ssp. *tomentosoides* is considered to have been introduced from Europe to New England as a foulant on ship's hulls (Carlton and Scanlon, 1985), although introduction as an epibiont on oysters imported for aquaculture remains a distinct possibility. Given the volume of boat traffic between New England and Nova Scotia, and between Europe and eastern North America, multiple introduction of *C. fragile* ssp. *tomentosoides* should be considered possible. The alga is able to settle on hulls imperfectly coated with antifouling paint, to colonize substrata with minimal surface relief, to survive shear stresses as a basal holdfast, and to tolerate large changes in temperature and salinity (Carlton and Scanlon, 1985). However, introduction via commercial ships is often restricted by the absence of *C. fragile* ssp. *tomentosoides* in harbours, perhaps a result of pollution, and by the lack of opportunity to colonize hulls owing to rapid turnaround time. Although the species has been present in Bar Harbor since the late 1970s or early 1980s (R. L. Vadas, University of Maine, pers. comm.), it evidently has not been transported to Yarmouth, Nova Scotia, by the regular ferry because it has not been seen in recent surveys of the algal flora (G. J. Sharp, Fisheries and Oceans Canada, pers. comm.). Smaller craft, for

example yachts arriving in Nova Scotia from various bays along the eastern American seaboard, are a possible means of introduction, although attachment of *C. fragile* ssp. *tomentosoides* to such vessels would require an uncharacteristic neglect of the hull. The ability of propagules of *C. fragile* ssp. *tomentosoides* to survive passage in ballast or bilge water has not been investigated.

Relocation of shellfish bearing primordia or residual holdfasts of *Codium* to new culture sites is thought to be a major mechanism of dispersal along the American coast (Carlton and Scanlon, 1985). However, the mussel and scallop stocks currently being cultivated in Mahone Bay are of domestic origin (C. T. Enright, N. S. Dept. of Fisheries, pers. comm.), and the history of the aquaculture floats from which the first specimens were collected precludes their being the vector for introduction. Despite the sanitation and quarantine requirements for live shellfish imported across international boundaries, it is possible that *C. fragile* ssp. *tomentosoides* was brought to Nova Scotia by casual importation of contaminated shellfish.

Importation of *Codium* as a packing material for live fishery products such as lobsters and baitworms has been proposed as a means of dispersal (Carlton and Scanlon, 1985), and we have no information on the incidence of this usage for fishery products being imported into Nova Scotia. However, there are few if any facilities in Mahone Bay for reception of such products, and movement of fishery products in this area is largely or wholly in the opposite direction. *Codium fragile* ssp. *tomentosoides* arriving this way is more likely to have been discarded from the provisions of a private vessel.

A final potential mechanism for introduction is the occasional westward movement of eddies from the Gulf Stream to the Nova Scotian coast. These masses of warm water, which have been arriving more-or-less regularly since at least the early 1900s (J. Gilhen, Nova Scotia Museum, pers. comm.), contain more southerly species (e.g., Markle et al., 1980; Gilhen and Coad, 1991), and if they penetrate coastal waters to a suitably warm environment, can effect introductions. Water temperatures along this coast were frequently about 2°C above normal during the mid-1980s (R. H. Loucks Oceanology Ltd. et al., 1991) and, in outer St. Margarets Bay, near-surface maximum temperatures in 1990 were 19-21°C (Gregory et al., 1991), well above the average maximum of  $14.3 \pm 3.2^\circ\text{C}$  for the general area (R. H. Loucks Oceanology Ltd. et al., 1991). Such incursions of warmer water may well have brought *C. fragile* ssp. *tomentosoides* to our shores.

*Codium in the Nova Scotian environment.* It is evident that *C. fragile* ssp. *tomentosoides* has become permanently established in Nova Scotia, and has probably been here since the late 1980s. The implications for the resident flora or fauna in habitats preferred by the alga are as yet undetermined. In New England, it is classified as "weedy" (Kingsbury, 1969), "invasive" (Prince and LeBlanc, 1992), and "a serious pest" (Gosner, 1978), and has rapidly colonized rocky areas stripped of kelp by sea urchins, to form dense stands (Prince, 1987, 1988). However, there is little evidence of wholesale permanent displacement of other algae from such habitats. To the contrary, the population of *C. fragile* ssp. *tomentosoides* at Boothbay Harbor, Maine apparently has declined in abundance from levels noted shortly after invasion (Fralick and Mathieson, 1972; Prince, 1988). In addition, recent studies on sea urchin herbivory (Prince, 1991; Prince and LeBlanc, 1992) have shown that *C. fragile* ssp. *tomentosoides* is itself readily grazed by green sea urchins, and this may help to keep populations in check.

Temperature is the primary factor affecting growth and reproduction of *C. fragile* ssp. *tomentosoides* (Fralick and Mathieson, 1973). The reported minimal temperatures for vegetative growth are 10° to 13°C, and for formation of gametangia are 12° to 15°C

(Carlton and Scanlon, 1985, and references therein), and these must be sustained for sufficient lengths of time in order for the species to become established. It is evident from the slow northward progress of the sub-species through the Gulf of Maine, its restriction there to the warmer waters of bays (Carlton and Scanlon, 1985), and its reduced growth rates compared to more southern localities (Fralick & Mathieson, 1973) that the alga is approaching the northernmost limit of its distribution in eastern North America. On the other hand, if it penetrates the southern Gulf of St. Lawrence where summer surface water temperatures are relatively high, it may become more widespread unless the protracted ice cover and low temperatures of winter in this area discourage its survival. However, Prince (1988) noted that *C. fragile* ssp. *tomentosoides* at Appledore Island, Maine was flourishing in a thermal regime considered suboptimal for the species, and the increased incidence of fragmentation during colder months (Fralick and Mathieson, 1972) could in fact encourage the spread of the alga in such situations, via dispersion of gametangial thalli. Comparison of northern and southern populations has shown that selection for the different thermal regimes has occurred, with the formation of cold-water ecotypes in Maine (K. C. Malinowski, in Carlton and Scanlon, 1985). Notwithstanding this thermal plasticity, temperatures in Mahone Bay satisfy the requirements of more southerly populations, being suitable from early May to late October for vegetative growth and from mid-May to late September for formation of gametangia.

Reproduction of *C. fragile* ssp. *tomentosoides* occurs via monoecious gametangia containing anisogametes (Prince, 1988) and by vegetative propagation. We have noted abundant gametangia on plants collected from August to December (cf. Burrows, 1991), although we do not know whether they were uniformly functional during this period. The regenerative capacity of this alga is a significant factor in the success of the species. The cushion-like base can regenerate erect fronds detached by turbulence, and the regrowth of small thalli on the aquaculture apparatus from which the original collections were made was probably due to regeneration from basal residua. In addition, detached fronds are capable of reattaching themselves to solid substrate via their basal filaments, although the reattachment process is much retarded by the lower temperatures that foster fragmentation (Fralick and Mathieson, 1972).

As the environment inhabited by *C. fragile* ssp. *tomentosoides* is also used for marine aquaculture, we expect that one of the most significant adverse effects of this species will be as a foulant on aquacultural apparatus. The species is notable for its ability to colonize vacant substrate indiscriminately (Carlton and Scanlon, 1985). Rapid and luxuriant growth of thalli can severely clog mesh containers and impede water circulation. Once established, plants are difficult to eliminate as their spongy texture resists desiccation, and residual holdfast filaments will readily regenerate. To retard the spread of plants to other areas, measures should be taken to ensure that culture apparatus and shellfish are free of this species before relocation to new sites.

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