Fisheries Research Report No. 202, 2010

Codium fragile ssp. fragile (Suringar) Hariot summary document

Samantha Bridgwood

Government of **Western Australia**
Department of **Fisheries**

Natural Heritage Trust
Helping Communities Helping Australia

Fisheries Research Division
Western Australian Fisheries and Marine Research Laboratories
PO Box 20 NORTH BEACH, Western Australia 6920

Fish for the future

Fisheries Research Reports

Titles in the Fisheries Research Report series present technical and scientific information for use in management processes. Research Reports are subject to full internal refereeing by senior scientists of the Fisheries Research Division, and in many cases, elements of the work are published in international scientific literature.

Correct citation:

Bridgwood, S. 2010. *Codium fragile* ssp. *fragile* (Suringar) Hariot summary document. 2010. Fisheries Research Report No. 202. Department of Fisheries, Western Australia. 12 p.

Enquiries:

WA Fisheries and Marine Research Laboratories, PO Box 20, North Beach, WA 6920
Tel: +61 8 9203 0111
Email: library@fish.wa.gov.au
Website: www.fish.wa.gov.au
ABN: 55 689 794 771

A complete list of Fisheries Research Reports is available online at **www.fish.wa.gov.au**

Cover: *Codium fragile* ssp. *fragile* in Jervis Bay (NSW). Photograph by Ron Hilliard.

ISSN: 1035 - 4549 ISBN: 1 921258 79 9

Contents

1.0 Description

Codium fragile ssp. *fragile* is a large branching green alga which typically grows between 15 to 60 cm tall but can attain almost 1 m in length and weigh up to 3.5 kg. In wave exposed areas the *C. fragile* ssp. *fragile* plants tends to be shorter as they undergo more frequent fragmentation (D'Amours & Scheibling 2007).

- Branching is dichotomous with individual branches between 3 – 10 mm in diameter
- A spongy basal holdfast anchors the plant to the substratum
- Juvenile stages appear as moss-like mats
- Perennial holdfast
- Gametes can germinate with or without fertilization (the later referred to as parthenogenesis)
- Adult thalli may produce vegetative juveniles
- Growth of adult thalli is possible from fragments
- Plant abundance may be seasonal

Synonyms: *Codium fragile* ssp. *tomentosoides* van Goor 1923

Codium fragile ssp. *capense* P.C. Silva 1959

Codium mucronatum var. *tomentosoides* van Goor 1923 and

AcanthoCodium fragile Suringar 1867

1.1 Habitat Preference

Codium fragile ssp. *fragile* (hereafter referred to as *C. fragile*) has wide environmental tolerances including temperature and salinity and is found in estuaries to marine waters (NIMPIS 2002). The environmental and physical tolerance levels set by NIMPIS (2009) are:

- Adult temperature range: -2 to 34°C
- Reproductive temperature range: 10 to 24°C
- Adult salinity range: 12 to 40 ppt
- Reproductive salinity range: 12 to 48 ppt
- Depth: 0 to 15 m
- Tidal range: intertidal and subtidal

This alga attaches to hard surfaces, e.g. rocks, rubble, shells and ship hulls in temperate regions. Vectors for potential introduction of *C. fragile* include aquaculture (i.e. moving of shellfish), fouling of vessel hulls, nets and ropes and natural dispersal mechanisms (NIMPIS 2009; Trowbridge 1999). Schaffelke & Deane (2005) have undertaken preliminary work investigating the potential for *C. fragile* to survive shipboard transport under emersed conditions, that is when fragments of the alga are caught up in ropes, fishing nets etc. Their experimental testing revealed that *C. fragile*, under a combination of emersion and high humidity, was able to survive for up to 90 days (Schaffelke & Deane 2005). *C. fragile* was also able to survive for up to one day on an exposed deck in cool temperatures (Schaffelke & Deane 2005). However, Schaffelke & Deane (2005) acknowledge the hypothesis requires further testing to determine if the thalli can regenerate or reproduce once resubmerged.

1.2 Distribution

Type locality: Japan (Suringar 1867)

The AlgaeBase (Guiry & Guiry 2009) website has listed the current distribution of *C. fragile* as including:

> Ireland, Adriatic, Balearic Islands, Britain, Channel Islands, Corsica, France, Isla de Alborán, Italy, Spain, Turkey, Azores, Canary Islands, California, Connecticut, Maine, Massachusetts, New Brunswick, New Hampshire, New Jersey, New York, North Carolina, Nova Scotia, Rhode Island, Algeria, Tunisia, Namibia, South Africa, New Zealand, South Australia, Victoria

The distribution of *Codium fragile* is widespread, however, there are inconsistencies with regards to its abundance and community dominance at different locations (Chapman 1999). Populations around Europe, although regularly occurring, are small compared to large populations (i.e. in pest numbers) occurring in New England, USA, Nova Scotia and Canada (Chapman 1999 and references therein). Chapman (1999) outlines the attributes *C. fragile* has which potentially make it a successful invader:

- It grows between 15 – 60 cm tall as an adult, but may reach 1 m
- Simple lifecycle, with monoecious adults reproducing either sexually or parthenogenetically
- For both cases the fertilised or unfertilized female gamete gives rise to a juvenile tuft of dissociated filaments from which an erect thalli grows
- The adult thalli can bud giving rise to vegetative juveniles
- Thallus fragments retain the potential for reattachment and regrowth into adult thalli
- The thallus, and holdfast remains, are considered to be perennial and so can persist over several years
- Growth and reproduction are possible between 12 – 24°C
- Has low light requirements, can grow under a wide range of irradiance
- Can survive in oligotrophic to eutrophic waters

Chapman (1999) compared, theoretically, the differing invasive success rates of *C. fragile* across the Atlantic Ocean. Two locations were chosen which represented typical biotic and abiotic conditions under which the alga was found in those two regions. In Nova Scotia the alga occurred in intertidal and subtidal areas, had high abundances and grew to be large plants. Whereas in southern England the alga was found mostly in the low intertidal zone, the plants were short (max 25 cm tall) and occurred as small discontinuous populations. Chapman (1999) proposed 4 reasons why this alga differed in the two regions.

1. Southern England had a much higher floral species diversity which may reflect stronger competition pressure against *C. fragile* thus preventing establishment in the subtidal region

2. Kelp communities of Nova Scotia have a periodic cycle of abundance including periods of barrens. This disturbance may allow suitable conditions for the establishment of the introduced species. Such cyclic changes to kelp communities along southern England have not been documented

3. A bryozoan invaded the kelp beds of Nova Scotia and although it doesn't directly feed on the *C. fragile* it does disrupt the growth and reproduction of the kelp, thus inadvertently favouring the introduced species

4. Although kelp communities were structurally similar across the Atlantic there may have been species-specific interactions between the introduced species, particular to each region

1.3 History of C. fragiles' Spread

Trowbridge (1999) gives a detailed account of the history of this alga's spread from the Northern to the Southern Hemisphere, the following information is taken from this source. In short the first observation of *C. fragile* was in the Netherlands ca. 1900. In the ensuing 55 years its distribution spread to include the majority of the NE Atlantic coastal region and the Mediterranean shores. In 1957 *C. fragile* appeared on the NW Atlantic shores and now has a distribution range from North Carolina to Nova Scotia and possibly Iceland. The species is now also present on the western coast of America.

The identification of *C. fragile* in New Zealand (Port of Auckland) by Dromgoole (1975), in 1973, was the first documented appearance of this alga in the Southern Hemisphere. This alga was subsequently found in two major ports on the NZ east coast and has now spread, and continues to spread, along the east coast of NZ. It is highly likely that the incursion of this alga into Australian waters was from NZ, as a result of trans-Tasman shipping (Trowbridge 1999).

1.4 C. fragile in Australia

There are numerous subspecies of *Codium fragile*, of which two are native to Australia/New Zealand, *Codium fragile* ssp. *tasmanicum* (J.Argardh) P.C. Silva and *Codium fragile* ssp. *novae-zelandiae* (J. Agardh) P.C. Silva. Also numerous congeneric species occur within southern Australian waters which, due to their similar morphology, make the identification of *C. fragile in-situ* unreliable (Trowbridge 1999). Rather, microscopic examination of the thalli is required for reliable identification (Trowbridge 1999). In comparison to Australian native species, which prefer wave disturbed (i.e. moderate to rough) areas, *C. fragile* prefers protected to semi-exposed areas (Silva & Womersley 1956).

Reporting of the first occurrence of *C. fragile* in Australian waters was in 1995 in Corner Inlet, Victoria (Campbell 1999). The alga expanded its distribution to include Port Phillip Bay (PPB) and Western Port (WP), and is now considered widely spread along the Victorian coast where it can form dense stands in both intertidal and subtidal areas and be found attached to mussels and oysters as well as artificial and natural habitats (Campbell 1999; Trowbridge 1999). In PPB densities were noted to be seasonally dependent with maximum densities (10 – 60 plants m^2) and biomass of *C. fragile* occurring from January to May and minimum densities (0 – 5 plants m^2) and biomass from July to December (Campbell 1999). Recruitment of juvenile Codium to an infested site at PPB occurred between February and May. In contrast the WP population showed little seasonality with densities consistently between 50 – 150 plants m^2 (Campbell 1999). Recruitment of juveniles occurs in autumn and again in late winter to spring. This species has also been found in Tasmania where Trowbridge (1999) recorded high densities (40 – 60 thalli m^2) of *C. fragile* in various locations adjacent to populations of Pacific Oysters and a shellfish farm. Overall *C. fragile* tends to demonstrate a seasonal die back on Australian shores (Trowbridge 1999).

1.5 Other Examples of C. fragile Incursions

1.5.1 New Zealand

This species was first noticed in NZ in 1973. In northern NZ the introduced alga was abundant in low intertidal and shallow subtidal areas and high intertidal pools. *C. fragile* died back in autumn/winter and regenerated each spring from perennial holdfast (Trowbridge 1995). The alga was widespread with no correlation between wave exposure, other algal communities, bare space or herbivores (Trowbridge 1995). Local densities reached up to > 200 thalli m^2, however, on the whole densities tended to be low i.e. < 1% of secondary cover where the alga was the most common (Trowbridge 1995). The study areas had salinities of approx 35 ppt. i.e. marine and an annual sea surface temperature of 12 to 21°C. The high intertidal area tended to provide the alga refuge from invertebrate grazers. Field observations and laboratory experiments showed that the resident herbivores exerted little pressure on the *C. fragile*. Trowbridge (1995) predicted the alga would successfully spread to most of the protected to semi-exposed shores of NZ and also to Australia.

1.5.2 Nova Scotia

C. fragile was introduced in Nova Scotia in the late 1980's and is now permanently established at various sites along 1200 km of eastern Canadian waters, forming dense stands in both intertidal and subtidal habitats (D'Amours & Scheibling 2007; Bégin & Scheibling 2003; Kusakina *et al*. 2006). In Nova Scotia cover of *C. fragile* has a seasonal cycle with maximum densities in early autumn (rising sea temperature) and minimum densities in late winter early spring (fragmentation of thalli, decreasing temperature and plant dislodgement) (Schmidt & Scheibling 2007). The alga has replaced kelp meadows in some areas, decreasing abundance of some species and potentially increasing sedimentation rates (Chapman 1999; Benthic Ecology Lab 2001). Kusakina and co-workers (2006) identified an alga population that may have resulted from hybridisation between subspecies of *C. fragile*; this potential interbreeding made possible due to the parthenogenetic properties of *C. fragile* ssp *fragile* however, this could not be determined from their study. Trowbridge (1999) identified this potential of interbreeding as being a possible risk with native Australian conspecifics.

1.5.3 Chile

In Northern Chile the first recorded observation was in 1998; there are no congeners. The alga is now recognised as a pest in Chile having a negative impact on the countries farming of an economically important red alga (Neill *et al*. 2006). *C. fragile* can be found in intertidal and subtidal habitats, growing on both artificial and natural substrata, with maximum densities during the months of warmer sea temperatures (summer/autumn) (Neill *et al.* 2006). Neil *et al*. found a significant long-term trend of increasing abundance over the 5 years at one of their study sites.

1.5.4 Gulf of Maine

In the Gulf of Maine this species is dominant in the subtidal zone with the potential to radically change subtidal community structure, composition and function (Mathieson *et al*. 2003). Levin *et al.* (2002) found that there was a clear link between the incursion of *C. fragile* and a change in the ecology of rock reefs which could be detrimental by impacting on nursery grounds for fish and decapods. The alga can cause significant fouling of aquaculture facilities resulting in increased labour costs and reduced productivity (Mathieson *et al*. 2003).

2.0 Potential Impacts of C. fragile

Potential impacts are wide and varied and include (but are not limited to):

- Smothering of mussels and scallops (prevent valves opening),
- Fouling of nets and ropes (also aids in dispersion),
- Impeding harvesting for shell fisheries (thereby increasing costs during harvesting and processing),
- Fouling of pylons, jetties and beaches (decreasing social amenity),
- Changing the ecology of a location with flow on effects to other species and, potentially, important fishery species.
- Reduction in native biodiversity

3.0 Management Options

Trowbridge (1999 p28.) states "there has been no active management response to the incursion on NW Atlantic shores in the last 40 years and no active response to the incursion on New Zealand shores in the last 25 years". Trowbridge (1999) also conducted a review of different methods for controlling/eliminating *C. fragile* populations. The following information is taken from Trowbridge (1999) and references therein:

3.1 Chemical treatment

Chemical, such as herbicides, need to be in contact with the target alga for extended periods to be effective, large doses are required and available herbicides are not selective enough to target the pest species, thus chemical application, in situ would result in general ecological damage.

3.2 Mechanical Removal

Trawling, dredging, cutting and suction have been suggested as potential methods to reduce biomass of larger macrophytes (e.g. Sargassum muticum). However, these methods have their problems. They are non-selective as to the benthic species they remove and as a consequence of indiscriminate removal may increase the vulnerability of existing communities to further pest incursions. As *C. fragile* can regenerate from fragmentation these methods may accelerate the spread of the alga.

3.3 Manual Removal (by hand)

Although this method may be highly selective it is also labour intensive and time consuming. It has also been shown to be largely in-effective for removal of *C. fragile*. In NZ Trowbridge (1995) found that thalli returned in an intertidal zone the year after it was completely removed. In Australia this method carries a very real risk for the inadvertent removal of morphologically similar native conspecifics or congeners. Trowbridge (1999 p 30) concludes by stating "Eradication is, for this alga, clearly unrealistic…"

3.4 Biological Control

Some species of sacoglossan (sea slug) grazers are known to feed on *C. fragile*. However, the distribution of these grazers can be highly variable so that their effectiveness depends on their population numbers and proximity to the alga. A study in Oban, Scotland, showed their effects to be significant due to high population numbers (an unusual spike in population occurred) of sea slugs resulting in local decimation of *C. fragile* populations (Trowbridge 2002). In contrast the variability in sea slug population and its effect can be seen in a study by Trowbridge (unpublished data) in Victoria where at one site there was severe damage to *C. fragile* thalli due to large numbers of sea slugs but no damage at another site where sea slugs were rarely seen. Trowbridge (1999) suggests that using sea slugs (by artificially increasing populations in the laboratory then releasing) for biological control is potentially viable, however, these sea slugs would be indiscriminate in the Codium that they grazed upon, targeting both the introduced and native species of Codium, alike.

3.5 Quarantine

It has been suggested that preventing this alga's introduction would be far more effective than containing established ones. This would involve ensuring that aquaculture equipment, ropes, nets, boat hulls and any fishery stock (e.g. mussels, oysters) were cleaned and free of *C. fragile* prior to translocation. The difficulty is ensuring all differentiated and undifferentiated (vaucherioid filaments) stages are removed from shellfish, however, this may be achieved using solutions such as 4% hydrated lime for 5 min, or saturated brine for 15 min. The gametes of *C. fragile* are short lived and so viable translocation via ballast water is unlikely. Removal of adult and juvenile stages from aquaculture equipment, ropes, nets and boat hulls can be achieved with thorough cleaning at the site or as close as possible. It is therefore critical that adequate wash-down areas are provided for recreational boat users. The erection of signage would also provide boat users with information regarding the alga and ways they can help to prevent its spread.

4.0 References

Bégin C. & Scheibling, R. E. (2003). Growth and survival of the invasive green alga *Codium fragile* ssp. *tomentosoides* in tide pools on a rocky shore in Nova Scotia. Botanica Marina 46, 404-412.

Benthic Ecology Lab (2001). *Codium fragile* ssp. *tomentosoides* (Dead Man's Fingers). Dalhousie University: Marine Invasive Species in Nova Scotia. Web publication http://myweb.dal.ca/rescheib/codium.html, date of access 27th July 2009.

Campbell, S. J. (1999). Occurrence of *Codium fragile* subsp. *tomentosiodes* (Chlorophyta: Bryopsidales) in marine embayments of southeastern Australia. Journal of Phycology 35, 938-940.

Chapman, A. S. (1999). From introduced species to invader: what determines variation in the success of *Codium fragile* ssp. *tomentosoides* (Chlorophyta) in the North Atlantic Ocean? Helgoländer Meeresuntersuchungen 52, 277-289.

D'Amours, O. & Scheibling, R. E. (2007). Effect of wave exposure on morphology, attachment strength and survival of the invasive green alga *Codium fragile* ssp. *tomentosoides*. Journal of Experimental Marine Biology and Ecology 351, 129-142.

Dromgoole, F. I. (1975). Occurrence of *Codium fragile* subspecies *tomentosoides* in New Zealand waters. New Zealand Journal of Marine and Freshwater Research 9, 257-264.

Guiry, M. D. & Guiry, G. M. (2009). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org, searched on 20 July 2009.

Kusakina, J., Synder, M., Kristie, D .N. & Dadswell, M. J. (2006). Morphological and molecular evidence for multiple invasions of *Codium fragile* in Atlantic Canada. Botanica Marina 49, 1-9.

Levin, P S., Coyer, J. A., Petrik, R. & Good, T .P. (2002). Community-wide effects of nonindigenous species on temperate rocky reefs. Ecology 83 (11), 3182-3193.

Mathieson, A. C., Dawes, C. J., Harris, L. G. & Hehre, E. J. (2003). Expansion of the Asiatic green alga *Codium fragile* subsp. *tomentosoides* in the Gulf of Maine. Rhodora 105 (921), 1-53.

Neill, P. E., Alcalde, O., Faugeron, S., Navarrete, S. A. & Correa, J. A. (2006). Invasion of *Codium fragile* ssp. *tomentosoides* in northern Chile: a new threat for Gracilaria farming. Aquaculture. 259, 202-210.

NIMPIS (2002). *Codium fragile* ssp *tomentosoides* species summary. National Introduced Marine Pest Information System. Eds: Hewitt C.L., Martin R.B., Sliwa C., McEnnulty F.R., Murphy N.E., Jones T. & Cooper S. Web publication http://crimp.marine.csiro.au/nimpis, date of access: 17th July 2009.

NIMPIS (2009). *Codium fragile* ssp *fragile* general information. National Introduced Marine Pest Information System. Web publication http://www.marinepests.gov.au/nimpis, date of access: 21/07/2009.

Schaffelke, B. & Deane, D. (2005). Desiccation tolerance of the introduced marine green alga *Codium fragile* ssp. *tomentosoides* – clues for likely transport vectors? Biological Invasions 7, 557-565.

Schmidt, A. L. & Scheibling, R. E. (2007). Effects of native and invasive macroalgal canopies on composition and abundance of mobile benthic macrofauna and turf-forming algae. Journal of Experimental Marine Biology and Ecology 341, 110-130.

Silva, P. C. & Womersley, H. B. S. (1956). The genus Codium (Chlorophyta) in southern Australia. Australian Journal of Botany 4, 261-289.

Trowbridge, C. (1995). Establishment of the green alga *Codium fragile* ssp. *tomentosoides* on New Zealand rocky shores: current distribution and invertebrate grazers. Journal of Ecology 83, 949-965.

Trowbridge, C. (1999). An Assessment of the Potential Spread and Options for Control of the Introduced Green Macroalga *Codium fragile* ssp. *tomentosoides* on Australian Shores. CRIMP Consultancy Report. CSIRO, Tasmania pp 51.

Trowbridge, C. (2002). Local elimination of *Codium fragile* ssp. *tomentosoides*: indirect evidence of sacoglossan herbivory? Journal of the Marine Biological Association of the UK 82 (6) 1029-1030.