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A Preliminary Survey of the Distribution of the Introduced Macroalga, *Undaria pinnatifida* (Harvey) Suringer on the East Coast of Tasmania, Australia

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Abstract

On 29 January 1988 plants of *Undaria pinnatifida* (Harvey) Suringer were found washed up at Rheban, on the east coast of Tasmania by J. C. Sanderson and D. Steane. Anecdotal evidence suggests colonization of this coast by the alga since 1982. Results of this survey show the alga to extend for 10 kilometres of coastline from Triabunna to Rheban. The critical temperatures affecting the essential events in the life history of *Undaria pinnatifida* indicate that it has the potential to colonize the southern Australian coastline from Cape Leeuwin in the south-west to Woolongong in the south-east. The alga is most prevalent on rocky reefs that would normally support few macroalgae such as 'urchin barrens', on sheltered coasts subject to the influence of oceanic waters. Circumstantial evidence indicates ballast waters of cargo vessels transporting woodchips from Triabunna to Japan as the most likely source of invasion.

Introduction

On 29 January 1988, several specimens of the plant *Undaria pinnatifida* were found by J. C. Sanderson and D. Steane on the beach at Rheban on Tasmania's east coast. This species is an endemic of Japan and adjacent coasts. Recently however, plants have been found in France at Etang de Thau, (1971, Perez *et al.* 1984) and in Wellington Harbour, New Zealand (1987, Hay and Luckens 1987). Introduction of the species to France is believed to have been with spat of the Japanese oyster, *Crassostrea gigas* Thunberg while in New Zealand it is thought that the introduction was via Japanese fishing boats. The most likely vector for the introduction of this alga to Tasmania is the ballast waters of ships that transport woodchips from the mill at Triabunna to Japan (Sanderson 1988). Anecdotal evidence suggests that the introduction may have occurred as early as 1982 (J. Bostock, abalone diver, personal communication). A preliminary survey was conducted to determine the extent of distribution.

Method

On 16 July 1988 and 10 August 1988 a series of 'drop' dives using 'Hookah' diving apparatus were conducted from a dinghy at regular intervals up and down the coast from Orford (see Fig. 1a–c). Approximate quantities of *Undaria pinnatifida* and the depth range were noted and samples collected. Voucher specimens were retained from each of the sites where plants were located and are lodged at the Tasmanian Herbarium.

Results

Figure 1a–c indicates the distribution of the alga *Undaria pinnatifida* on the east coast of Tasmania determined as a result of these dives, namely from the vicinity of the Triabunna woodchip mill, south to Rheban along approximately 10 kilometres of coastline.

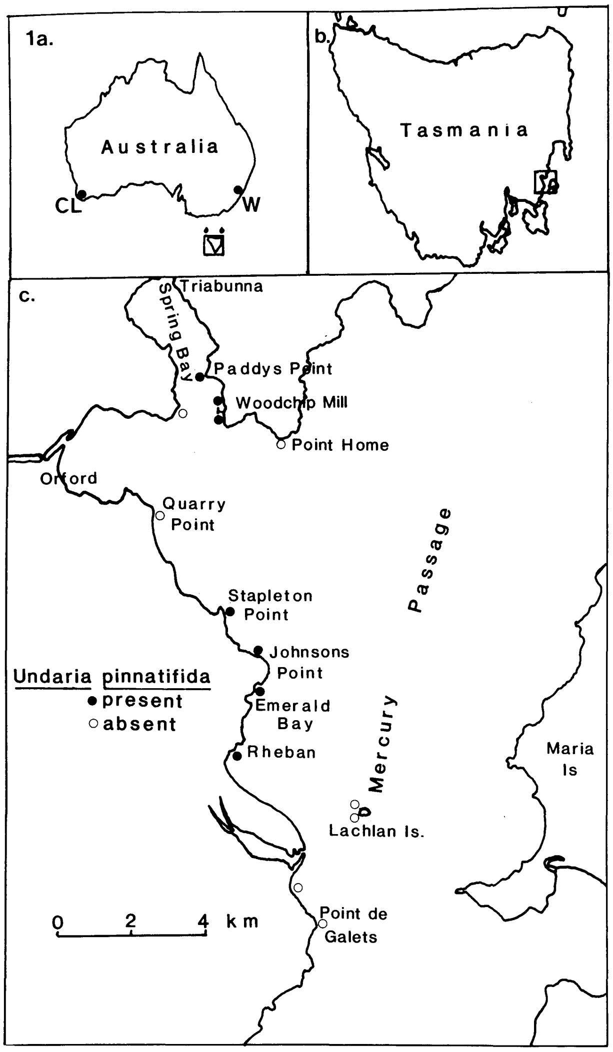


Fig. 1.a Map of Australia including predicted northern extremes of distribution of *Undaria pinnatifida*. CL — Cape Leeuwin; W — Woolongong. b, c Maps showing distribution of *Undaria pinnatifida* as determined in this preliminary survey.

Rock type changes from sandstone north of Orford to Dolerite to the south. However this did not seem to influence distribution within the region, for plants were found attached to a variety of substrata other than on rocky reefs, including the blades of the seagrass *Heterozostera tasmanica* Mert. *ex* Asch. in Spring Bay.

The depth distribution of *Undaria* was similar over its entire range. Plants were found from mean low water to the limit of available substratum, a maximum of 12 meters in the Mercury Passage. In rocky reef areas, apparently previously uncolonized by macroalgae, the cover of *Undaria* although patchy, often obscured the bottom. When there was an abundance of native vegetation, occurrence of *Undaria* was restricted.

These areas of bare rock coincided largely with the activities of the urchin *Heliocidaris erythrogramma* Valenciennes and the distribution of this herbivore appeared to be correlated with the degree of exposure to wave action. Areas that were exposed to higher wave action, such as Johnsons Point, The Quarry and Crabtree Point had an abundance of local vegetation, few urchins and only isolated individuals of *Undaria.* Areas more protected from direct swell such as Rheban, Emerald Bay, Stapleton Point and Spring Bay had much bare rock, many urchins and were colonized extensively by *Undaria*.

It was not uncommon to observe urchins sitting on fragments of *Undaria* and many plants showed evidence of grazing activities. Presumably the spring to early summer growth of *Undaria* exceeds the rate of control by the urchins.

Size and shape of the plants varied depending on maturity (Fig. 2) and position in relation to environmental conditions such as exposure to wave action and depth. The largest plant found measured 1.70 m in length and had fully developed sporophylls. This plant was found in the vicinity of the wharf at the woodchip mill. Plants in this area were more mature than plants south of Orford. Larger plants may be expected to be found later in the year (October—January) as more reach maturity, the majority of the plants found in this survey were no greater than 50 cm.

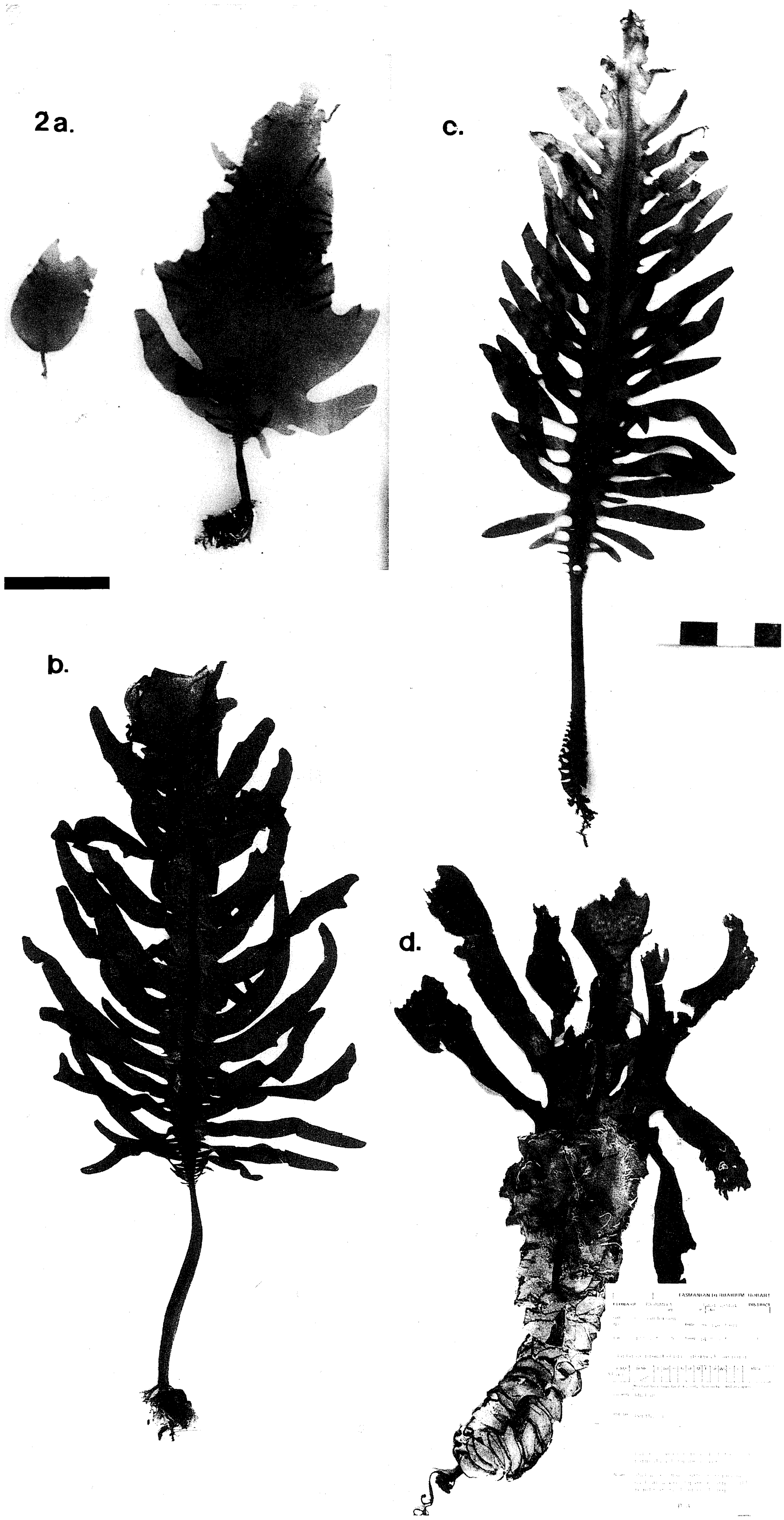
Discussion

Potential distribution within Australia

Hoek (1982) inferred, with some degree of success, phytogeographic boundaries of a number of species of benthic algae from experimentally determined critical temperatures limiting essential events in their life histories. For a temperate species, boundaries used were similar to those stressed by Hutchins (1947) for marine benthic animals. These are:

(1) The 'northern lethal boundary'. This corresponds to the highest summer temperature a species can survive during a period of 2—4 weeks.

Fig. 2. Series depicting development a, b, maturity c and senescence d of sporophyte of *Undaria pinnatifida* in Tasmanian waters. Plants presented here were collected in August 1988; a, b, December 1988; c and January 1988; d at Emerald Bay in 2—6 m. depth. Scale: Solid bars adjacent to respective plants are 5 cm long.


2a.
b.
c.
d.

(2) The 'northern growth boundary'. This corresponds to the highest winter temperature which, over a period of months, permits growth.

(3) The 'northern reproductive boundary'. This corresponds to the highest winter temperature which, over a period of several months, permits reproduction.

(4), (5) and (6) corresponding southern boundaries.

Table I details maximum and minimum temperature tolerances and optima obtained from the literature for gametophytic and sporophytic generations of *Undaria pinnatifida*. Using this information it is possible to extrapolate as to the probable potential distribution for *Undaria pinnatifida* within Australia.

Seawater temperatures of oceanic waters off southern Australian coastlines (from Rochford 1984, Loewe 1957) indicate a potential colonization from Cape Leeuwin in the south west to Woolongong in the east (see Fig. 1a).

Bardach *et al.* (1982) recorded *Undaria* as growing in waters of salinity ranging from 27 to 33‰. This precludes *Undaria* from occupying estuaries.

Table I. Temperature tolerances and optima for the sporophytic and gametophytic generations of *Undaria pinnatifida*.

	Sporophyte	Gametophyte
Lethal temperatures	$<0°$, $>25°$	$<-1°$, $<30°$
Growth boundaries	3.5° to 20°	10° to 24°
Reproductive boundaries	$<7°$, $>23°$	$<10°$, $>24°$

(From Akiyama 1965, Akiyama and Kurogi 1982, Arasaki and Arasaki 1983, Saito 1975 and Zhang *et al.* 1984)

Introduction of Undaria pinnatifida

Information on the direction of currents in the Mercury Passage suggest a predominantly southerly direction (Tasmanian Department of Sea Fisheries, personal communication) this, and the present distribution of *Undaria* are consistent with an initiation of infection in the Triabunna region. Ships that pick up woodchips for Japan dock at Triabunna and prior to taking on cargo, discharge ballast waters in quantities which may exceed 25 000 tonnes. This can include sediment from the bottom of the holds.

Undaria pinnatifida is a common alga throughout coastal Japan except for the the north and east coast of the north island (Funahashi 1974). Woodchip carriers trade in areas colonized by this alga and take on ballast waters in port close to shore (Carlton 1975). These waters are likely to include spores or fragments of plants.

Cargo ships have been proven as a potential vector for the introduction of species of fish, amphipods, crabs and shrimps to Australia (Williams *et al.* 1988) and have been implicated in introductions of many exotic species including recently, the toxic dinoflagellate *Gymnodinium catenatum* Graham (Hallegraef *et al.* 1988), and the 'aggresive alien' mussel *Musculista senhousia* Benson (Willan 1987). Introduction via ballast waters of cargo ships would appear to be the most likely vector for the introduction of *Undaria pinnatifida* to Tasmanian waters.

The introduction of large quantities of this plant to the coastline will not be without some longer term effects and an assessment of the likely impact of this species is required. Eradication of this alga is out of the question due to the elusive, microscopic gametophytic stage of the alga and the extent of colonization.

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