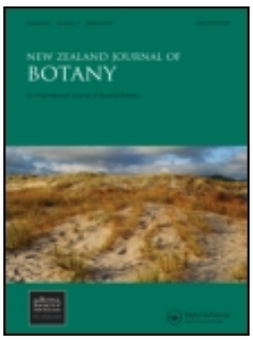

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SHORT COMMUNICATION

Tidal immersion and the growth of *Spartina anglica* marshes in the Waihopai River Estuary, New Zealand

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Abstract *Spartina* was first planted in the Waihopai River Estuary in 1913 and has spread to cover 15% of the mudflats. Tidal inundation was observed to determine possible further spread. Landward spread appears to be limited by the presence of *Leptocarpus similis*. The seaward edge corresponds to the low neap-tide level which appears to be close to the level of most of the mudflat area. Future colonisation seems to depend on the relationship between the neap-tide minimum level and the level of the mudflats. *Spartina* emerges during daylight hours for 887 hr per annum (1973 data) at its lower limit. This value is much lower than periods for marshes in England and is probably the result of the Waihopai having clear estuarine waters.

Keywords marsh ecology; *Spartina anglica;* tidal immersion; colonisation; Waihopai River Estuary, New Zealand

INTRODUCTION

Spartina townsendii H. et J. Groves (sens. lat.) was first introduced into New Zealand by K. W. Dalrymple who in 1913 obtained 13 plants from Southampton Water, England, which he planted near Foxton, North Island. Establishment was successful and it was from Foxton that F. M. Corkill in 1930 obtained plants for the Waihopai River (New River) Estuary, near Invercargill, South Island, where they were planted *c.* 1 m apart on a grid. Continuous plantings had covered *c.* 14 ha by 1939 and the grass had spread naturally to occupy *c.* 28 ha by 1949 (Ranwell 1967). A further stock of *S. townsendii* (sens. lat.) was introduced in 1950 from the Thames River Estuary, North Island.

Specimens of *Spartina townsendii* (sens. lat.) from various marshes in the south of the South Island which were established before 1950 were sent to the Herbarium, Royal Botanic Gardens, Kew. They proved to be confined to the primary hybrid, now known as *Spartina* × *townsendii*, which it is surmised was collected from the type-locality at Hythe, Hampshire, England, and sent to New Zealand. Fertile plants and seed of *S. anglica* were sent from the Essex marshes, England, by J. Bryce in 1955 but the plantings at Waihopai failed to establish, although later plantings were successful.

Information is presented here on tidal immersion and the spread of the *S. anglica* marsh established in the Waihopai River Estuary. Similar studies have been made on *Spartina* marshes on the coast of England (Ranwell *et al.* 1964, Hubbard 1969, Poole Harbour, Dorset; Morley 1973, Bridgewater Bay, Somerset).

The literature on the *Spartina* marshes of New Zealand is fragmentary although species of *Spartina* have been introduced and established around both the North and South Islands during the past 60 years. Allan (1924) described the early introductions of *Spartina* to New Zealand. Ranwell (1967) and Bascand (1970) made reference to the Waihopai Estuary, but the more detailed work of Allan (1924, 1930) and Bascand (1968, 1970) has been confined to the North Island where *S. alterniflora* predominates. Harboard (1949) referred to the value of *S. townsendii* (sens. lat.) for reclamation, citing the Waihopai Estuary as an example.

The nomenclature used here follows Moore & Edgar (1970) except for the genus *Spartina* which follows Hubbard (1968) in which the tetraploid *S. anglica* C. E. Hubbard is distinguished from the diploid primary hybrid *Spartina* × *townsendii* H. et J. Groves (sens. strict.).

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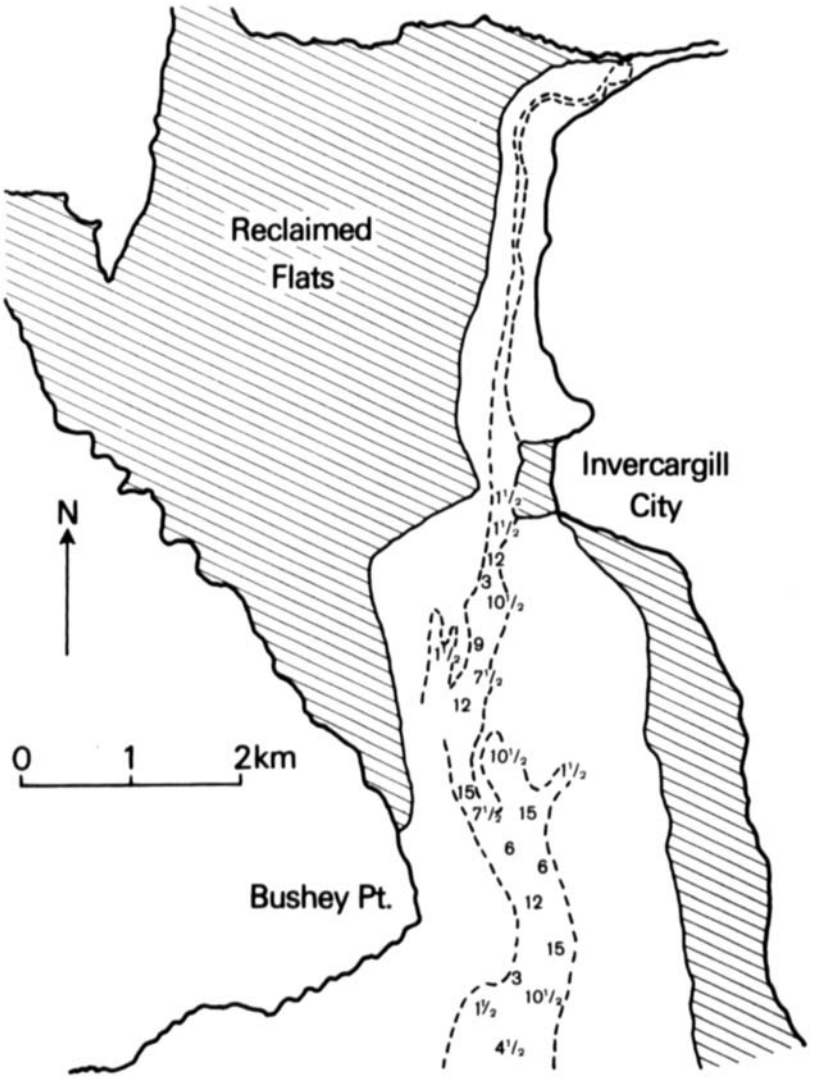

Fig. 1 Upper Waihopai River Estuary showing areas of reclaimed flats and the original river channel, with low tide depths in ft from an 1856 survey.

SITE

The Invercargill Estuary and Waihopai River lie near the southern extremity of New Zealand (46°28′S, 168°28′E). The tidal inlet of sandy mud had an original shoreline (Fig. 1) enclosing over 4000 ha, now reduced by reclamation banks to 2570 ha. Reclamation has probably also considerably modified the original channel depths. Pasture, Invercargill Airport, and a borstal institution now occupy the reclaimed land. The remaining tidal area is subject to continual reduction by the dumping of city rubbish. In 1952 the rubbish covered about half of the 40.5 ha of *Spartina* marsh, but by 1966 the *Spartina* had again spread to cover a similar area (Bascand 1970).

There are now 90 ha of *Spartina* meadow and a further 270 ha of scattered *Spartina* tussocks. These estimates include a small marsh at the mouth of the Oreti River and part of the estuary common to both the Oreti and Waihopai Rivers (Fig. 2). The remaining area consists of bare mudflats, colonies of *Zostera muelleri*, widely-spaced tussocks of *Spartina*, and a community dominated by *Leptocarpus similis* which occurs above the *Spartina* along the shore or on raised hummocks of sediment. An embankment has restricted the Waihopai River to within a narrow channel running north of Invercargill. The water channel is further confined by continuous meadows of *S. anglica*. The east shore of the estuary has

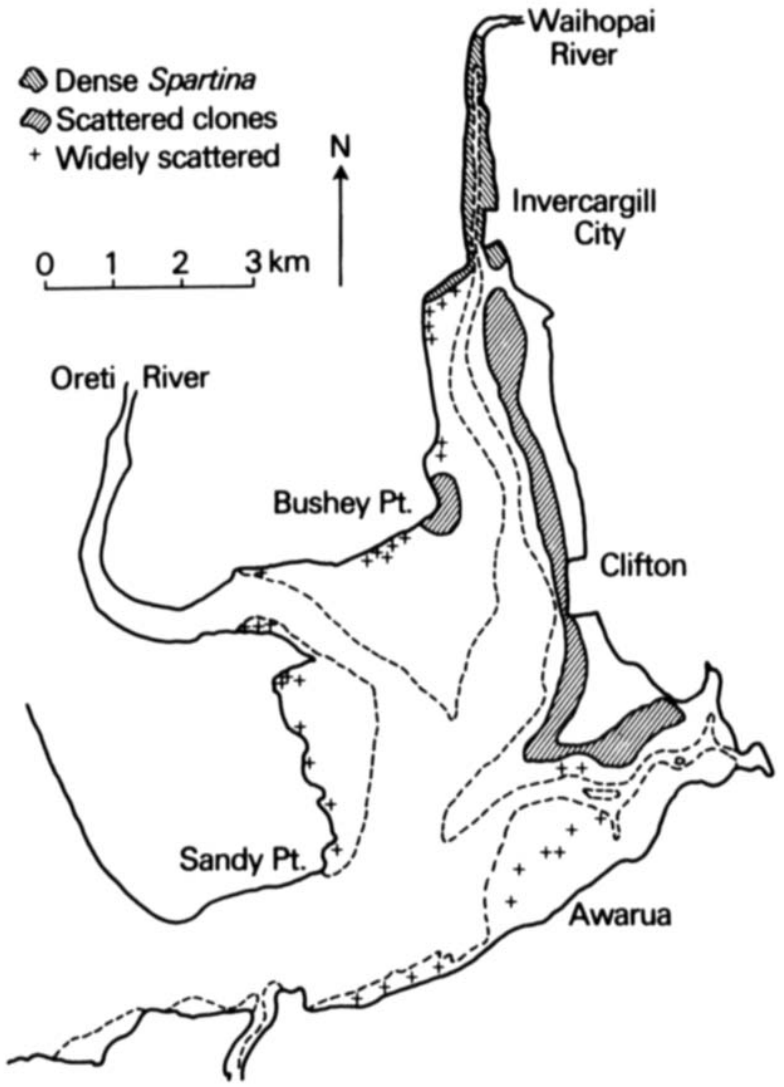

Fig. 2 Waihopi and Oreti River Estuaries showing mudflats inside broken line and areas of *Spartina*. Point A marks the last remaining *Spartina* × *townsendii*. Adapted from Lee (1973).

further concentrations of *Spartina* but it is also the rubbish dump. Deposition is occurring southwards about Clifton where a retaining wall of derelict cars prevents major tidal redistribution of the debris.

Spartina is spreading to the new areas of the estuary, especially along the shore line to Bushey Point, where the tussocks are expanding by vegetative growth and the mud surface had numerous seedlings in summer 1975. Isolated tussocks of *Spartina* are established in mid-estuary but it is difficult to assess the significance of this because of the extremely level surface of the tidal flats. Only a single tussock of *Spartina* × *townsendii* was discovered, growing within the *Spartina* meadow lining the Waihopai River. The *S. anglica* marshes are extremely uniform in appearance.

METHODS AND RESULTS

Daylight observations were made on 25 and 26 February 1975 to determine the period of tidal immersion of the *Spartina* marshes in the Invercargill Estuary. They were made from several points between Bushey Point and Clifton, but the principal site was beside the Old Quay near the road passing the airport. The rising tide was followed up the shore to note the exact time at which the waters flooded across the highest rooting level of *Spartina* and also the time of high water. The same procedure was adopted for the ebbing tide, although it was not possible to observe the lower limit of the tidal cycle as it was within the river channel.

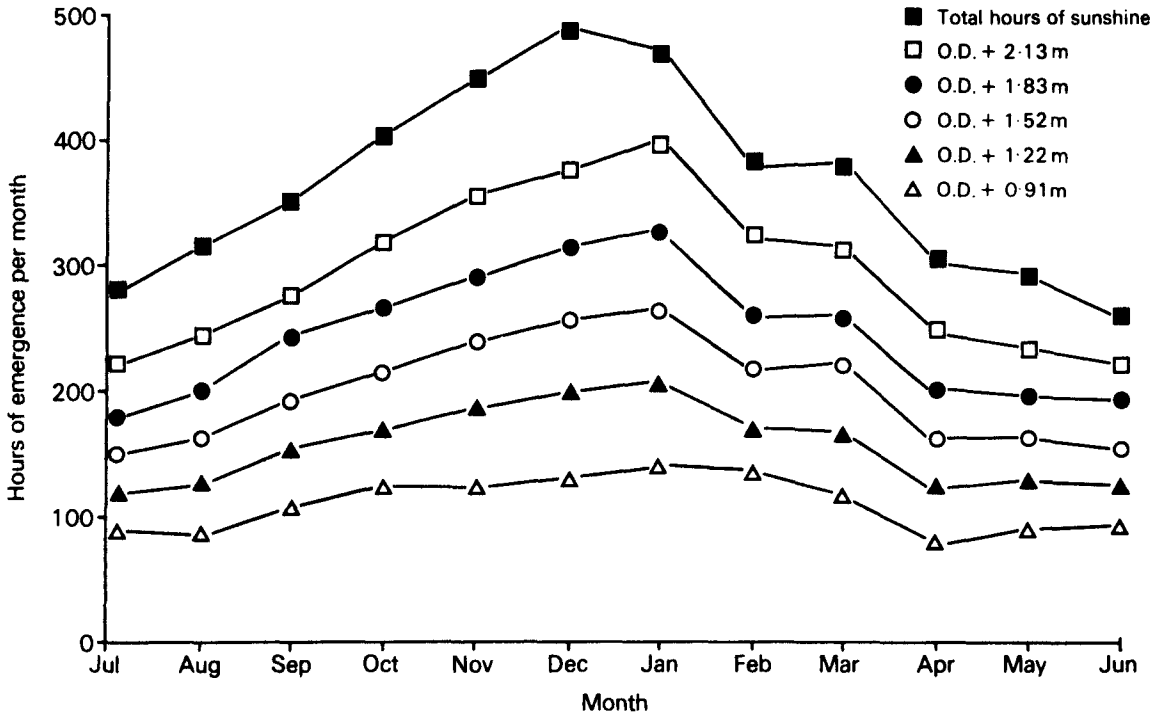

Fig. 3 Tidal emergence of *Spartina* marsh during daylight hours. Total hours of emergence per month are shown in relation to specified levels. Data from 1962. O.D. = Ordinance Datum.

These field measurements were related to readings on the nearest tide gauge at the old port installations at Bluff, 16 km from the sampling site and open to the sea. A local correction in time and level was applied to the readings. During the first day it was possible to observe only maximum and minimum deflections of the gauge needle, without a time factor. The complete trace was obtained for the second day of sampling and the records for the complete year of 1962 were supplied by Bluff Harbour Board.

Small tussocks of *Spartina* growing on sandy mud below the Old Quay were assessed as representing the upper limit of the grass within the estuary. A continual watch was kept on tussocks fringing the shore from a point below the airport to south of the rubbish tip on the eastern shore. High water on the first day occurred at 1255 hr when the sampling site was still 15 cm above the water level, although the remainder of the *Spartina* marshes was immersed. At Waihopai, Borstal Bridge, and below Filleul Street the marshes were, however, completely covered.

High water on the second day occurred at 1400 hr when the *Spartina* sampling point was 25 cm below the water surface. The measurement was 40 cm above the level recorded on the previous day and this was confirmed by the tide gauge. However, the measured times of high water did not agree with the prediction from the tide tables in which the difference between Bluff and Invercargill was given as 40 min; the measurements were identical for trace and sample.

On the second day the tidal waters fell by 15 cm in the first 35 min after high water and the first outlying clumps of *Spartina* were exposed after 1 hr–1 hr 35 min (at 1500–1535 hr). The *Spartina* tussocks below the rubbish dump were clear of water by 1500 hr on the first day (1 hr 55 min after high water). The band of newly developing tussocks and seedlings established near the airport was uncovered by 1600 hr on the first day (+3 hr 5 min) and 1700 hr on the second day (+3 hr). On both occasions water receded to a line immediately below the level of the *Spartina* band in *c.* 30 min. The waters receded from the lower limit of *Spartina* at 1730 hr (+4 hr 35 min) on the first day and at 1845 hr (+4 hr 35 min) on the second day.

An attempt was made from the air on the first day to visually assess and photograph the extent of tidal waters remaining in the estuary when the lower limit of *Spartina* became uncovered. However, by 1810 hr the tidal waters had already receded into the major channels. The time between exposure of the lower limit of *Spartina* and recession of the waters into the channels was 40 min, corresponding to a difference of 18 cm.

The tidal measurements recorded on 26 February were probably at the time of maximum

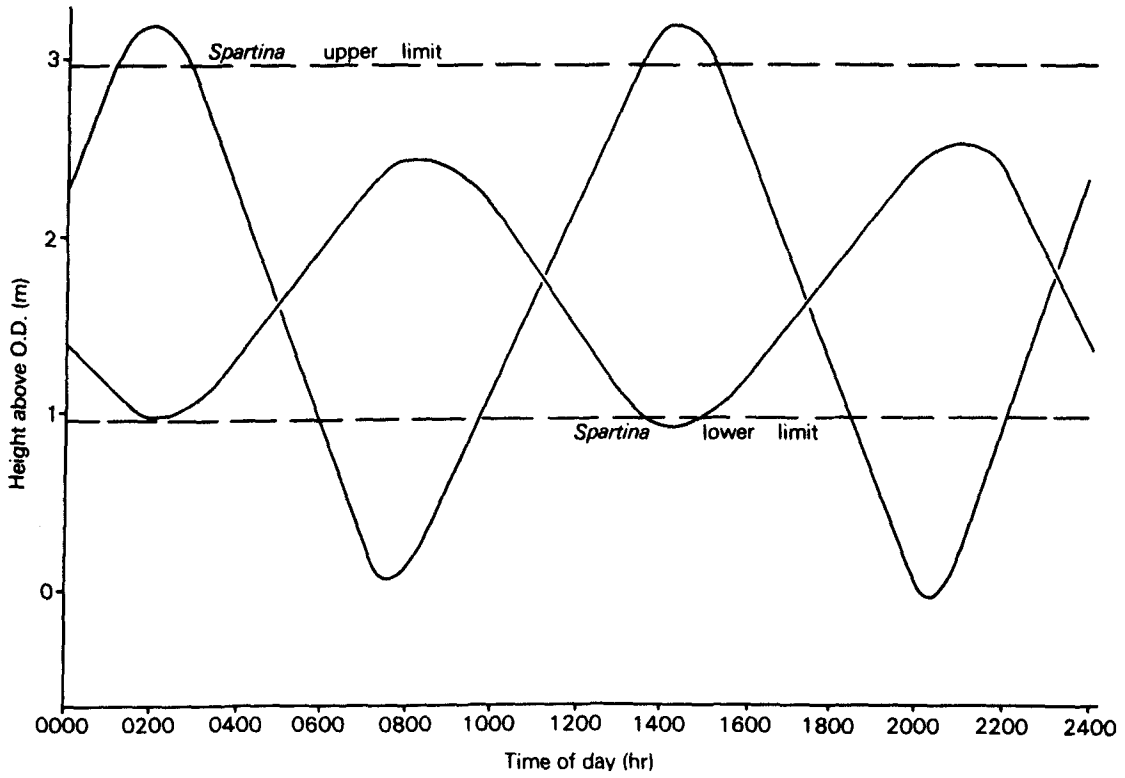

Fig. 4 Distribution of *Spartina* in relation to tides in the Waihopai River Estuary. The tides shown are the maximum spring and minimum neap tides for 1962.

spring tide, as the height of 2.82 m corresponded to a maximum of 2.91 m for 1962. The tidal records for 1962 from the Bluff tide gauge were used to assess the tidal emergence of different levels of *Spartina* marsh during daylight hours (Fig. 3). The distribution of *Spartina* in the Invercargill Estuary has been related to the maximum spring and minimum neap tides for 1962 (Fig. 4). The sudden drop in emergence during daylight hours from January to February is the additive effect of fewer and shorter days; a phenomenon absent from similar curves for the Northern Hemisphere.

The lower limit of *Spartina* corresponds to Ordinance Datum +0.92 m, with the upper limit at Ordinance Datum +2.75 m and a range of 1.83 m. The maximum spring tide for 1962 was 2.91 m, the minimum neap tide was 1.32 m, and the total time of emergence of *Spartina* during daylight hours in 1962 was 887 hr.

DISCUSSION

The purpose of the tidal observations was twofold: to make a comparison with similar observations recorded from the Northern Hemisphere and also to determine the possible spread of *Spartina* across the mudflats of the Invercargill Estuary. The widespread and indiscriminate planting of *Spartina* in suitable localities around the shores of New Zealand is causing concern. Salt marsh is a valuable and scarce resource in the southern part of New Zealand, so that encroachment by *Spartina* is posing a problem, especially to those safeguarding the wildfowl grounds.

The measurements of the lower limit of *Spartina* growing in the estuary must be regarded as crude, but in the absence of a precise survey they indicate the small difference in level between the present extent of *Spartina* and the remainder of the estuarine flats. Undoubtedly, *Spartina* is spreading actively vegetatively and by seed. *Spartina* now occupies *c.* 15% of the mudflats but most of the grass is in the form of tussocks, suggesting its future expansion (Fig. 5). Apparently, much of the mudflats lie within the zone of future colonisation, but the present seaward limit is critical and dependent on a variation in the level of the surface of a few centimetres, between the present limit of the grass and the full extent of the mudflats.

The landward limit of the grass was difficult to assess as the upper estuarine shoreline has been replaced by embankments. *Spartina* and *Leptocarpus similis* grow beside each other within

Fig. 5 Scattered clumps of *Spartina* in the lower Waihopai River Estuary. The widespread distribution of these demonstrates the considerable area of mudflats available for colonisation.

Fig. 6 Extensive areas of *Spartina* in the upper Waihopai River Estuary. A zone of *Leptocarpus similis* occurs adjacent to the road.

the Waihopai Estuary but without obvious competition (Fig. 6). Large areas of *Leptocarpus* occur in the seaward portion of the estuary. Both *Spartina* and *Leptocarpus* were submerged at high water in the Waihopai River.

Tidal inundation has long been suspected as being a limiting factor in the seaward spread of *Spartina anglica*. However, there is still no satisfactory explanation of the processes involved since immersion by sea water influences light intensity, daylength, temperature, respiration, and photosynthesis, etc. The lower limit of *Spartina* growing in the Invercargill Estuary was emergent for only 887 hr of daylight in 1962. This compares with 1440 hr in Poole Harbour (Hubbard 1969) and 2000 hr in Bridgewater Bay (Morley 1973). However, the latter is covered by 4 m of water and the marsh is subjected to considerable redistribution of sediment because of the exceptionally large tidal range. The conditions at Invercargill compare to some extent with those in Poole Harbour where the low neap-tide level corresponded with the seaward limit of *Spartina*. The value of 1440 hr can be explained in terms of reduction of light available for photosynthesis as the sediment load was sufficient to exclude light penetration to the marsh.

The total hours of emergence of *Spartina* marsh in daylight are considerably less in the Invercargill Estuary than in Poole Harbour. Although no sediment load measurements are available they appear to be considerably less in Invercargill than at Poole. The waters of the Invercargill Estuary are very clear, due to a combination of sand-content and shelter and *S. anglica* can grow in clear water (Hubbard 1969). The possible effect of tidal range seems unlikely to be of importance as the range in Poole Harbour is less than at the Invercargill Estuary (Invercargill: 5.4 m spring, 1.5 m neap; Poole: 2.0 m spring, 0.6 m neap).

A factor common to *Spartina* marshes in both Poole Harbour and the Invercargill Estuary is that the lower limit of *Spartina* occurs at the level of low neap tide.

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