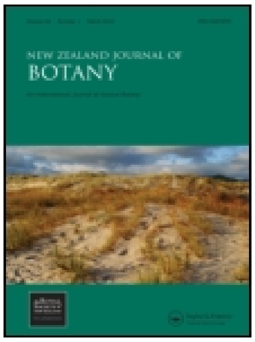

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Rates of spread of *Spartina anglica* and sediment accretion in the New River Estuary, Invercargill, New Zealand

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Abstract Rates of spread of *Spartina anglica* and associated accretion of sediment on sand and mud flats were measured by re-examining transects and a permanent quadrat that were set up 9 years earlier (1973) in the New River Estuary, Invercargill. Spread is slowest where the species nears its lower tidal limit, and where there is erosion of sediment. In recently colonised areas the maximum spread of vegetation is 5.3 m/a. Sediment accretion rates varied from 12 mm/a in dense swards on muddy substrate, to 3 mm/a on sand in areas of turbulent water. One area of erosion is reported.

Keywords *Spartina anglica*; colonisation; growth rates; sedimentation; estuaries; New River Estuary, New Zealand; *Leptocarpus similis*

INTRODUCTION

The maritime species of *Spartina*, commonly known as cord grass, have been used extensively in foreshore protection and the reclamation of estuarine areas (Chapman 1960, Ranwell 1967). The earliest such planting in New Zealand, was at Foxton, in the North Island, in 1913. Accounts of the history of *Spartina* in New Zealand are given by Allan (1924), Bascand (1970), and Hubbard & Partridge (1981).

In 1930, F. M. Corkill planted *Spartina* × *townsendii* along the Waihopai River mouth at Invercargill as an aid to reclaim parts of the estuary for industrial development. Subsequently, *Spartina anglica* was planted, and this species has spread throughout the New River Estuary — the collective name of the 4000 ha estuarine area formed at the confluence of the Oreti and Waihopai rivers. Hubbard & Partridge (1981) present a map of the distribution of *Spartina* based partly on earlier work by Lee (1973). This shows that the species then covered 15% of the mudflats comprising 90 ha of *Spartina* meadow and 270 ha of scattered *Spartina* clumps.

Uncontrolled spread of *Spartina* threatens the biological diversity of the New River Estuary. Intertidal mudflats support a variety of fish and provide the major source of food for 34 species of birds, including 16 species of migratory waders. Dense *Spartina* is little used by animals, and its spread is rapidly destroying habitats formerly occupied by a range of faunal species (Mr R. Sutton, Southland Acclimatisation Society, pers. comm.).

In 1973, 5 permanent transects and a permanent quadrat were established to facilitate measurement of the rate of spread of *Spartina* and the rate of sediment accretion. The transects include sand and mud substrates, *Spartina* meadow, isolated clones, areas planted by man, and areas colonised by natural spread. The transects and permanent quadrat were re-examined in February 1982.

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METHODS

Five transect lines (Fig. 1) were positioned at right angles to the shore and extended to the lower tidal limit of *Spartina*. Wooden pegs, bench marked to a known height above the substrate surface, were placed along the transects to mark the limits of *Spartina* meadows and the centre points of *Spartina* clumps. The length of *Spartina* intercepted by the transect and the diameter of clumps perpendicular to it were also measured.

A permanent quadrat 20.1 × 20.1 m was located at the upper end of Transect 3, adjacent to a creek through the marsh. The average diameter of all the clumps within this area was determined as was the position of each in 1973. This was not feasible in 1982 as clumps had become enlarged and intermixed to the extent that they could no longer be distinguished with certainty. The later alternative method adopted to calculate area was to run 2 sets of 6 lines perpendicular to each other across the quadrat from side to side, and to measure the intercepted length of *Spartina* along these.

Table 1 Rates of spread of *Spartina anglica* and substrate accretion in the New River Estuary, Invercargill. *Leptocarpus similis* is recorded from one site (n.a. indicates not applicable).

		Spartina						*Leptocarpus*
	Year	T1	T2	T3	T4	T5	Mean	T2
Cumulative distance (m)								
along transect	1973	22.3	79.1	7.4	36.5	20.4		6.8
	1982	37.9	115.5	51.4	79.5	20.1		9.8
perpendicular to transect	1973	10.7	n.a.	7.4	26.5	11.4		n.a.
	1982	17.4	n.a.	55.4	54.6	20.9		n.a.
Rate of spread (m/a)								
along transect		1.7	4.0	4.9	4.8	0.0	3.1	0.3
perpendicular to transect		0.7	n.a.	5.3	3.1	1.0	2.5	n.a.
Rate of sediment accretion (mm/a)		12		10	3	−5		
No. of pegs remaining for measurement		1	0	8	11	1		

RESULTS

Rates of spread of *Spartina anglica* and substrate accretion as determined from 5 transect lines are presented in Table 1.

Spreading rates

Transects 1 and 2 were both situated in the Waihopai River Estuary. This is where *Spartina* was planted, but it has since spread to adjoining areas. The substrate is deep, soft organic silt. In 1973, Transect 1 passed through an 8.5 m wide sward of *Spartina* which was against a rock embankment. This band has advanced downslope at a rate of 0.65 m/a, and in February 1982 was 14.4 m wide (Fig. 2). The rate of spread along the line transect was 1.7 m/a. Some previously marked clumps have become part of the sward. Six individual clumps which had established naturally on the mudflats have increased in diameter at a rate of 0.12 m/a. The largest clump, now of 3.97 m diam., should double its area in 16.5 years given unrestricted growth at the same rate. The outermost clumps had died by 1982, only the wooden pegs remain marking their former positions. These pegs were not used to examine sediment accretion.

Transect 2 maintained marginal spread both upslope and downslope of the large continuous *Spartina* meadow on the true right bank of the slow-flowing Waihopai River. As a result of repeated plantings, the sward occupied a zone nearly 80 m wide in 1973. A narrow band of *Leptocarpus similis* along the upper edge of the marsh, has spread out onto the mudflats towards the *Spartina* at a rate of 0.3 m/a. It has not yet been reached by the *Spartina* which is advancing at the faster rate of 1.3 m/a. Spread of *Spartina* towards the Waihopai River channel averaged 3.0 m/a. Overall, it increased along the transect at 4.0 m/a. This included the colonisation of several gaps in the sward in 1973, but the expansion of one large gap, which is now filled with water, more than offsets the closing up of the others.

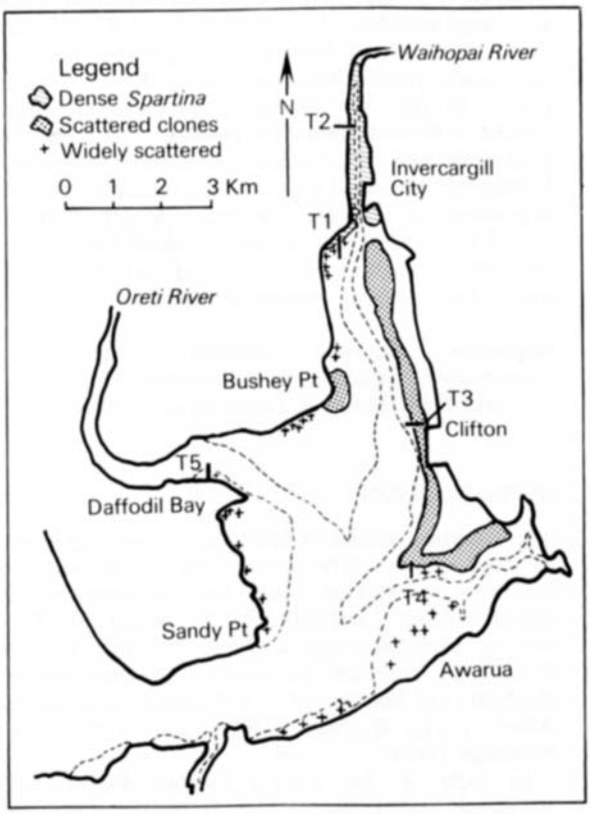

Fig. 1 Location of transects in the New River Estuary. Mudflats are inside broken lines and the distribution of *Spartina* is shown. Adapted from Lee (1973).

Transects 3, 4, and 5 were all on sandy flats, in areas colonised solely by natural spread. Transects 3

Fig. 2 Photographs taken near Transect 1 in February 1973 (A) and November 1982 (B), looking south-west from the Stead Street Causeway in the Waihopai Estuary, Invercargill. An increase in width (8.5–14.4 m) of the planted strip of *Spartina* along the causeway, and the coalescence of some clumps and the disappearance of others that were established well out on the mudflats in 1973 are shown.

and 4, on the eastern side of the estuary south of the Clifton causeway intersected 25 clumps. Of these, 15 had unrestricted growth during the study period with mean diameter increases of 0.48 m/a. The remaining clumps either coalesced or died. Rate of spread along each transect was much faster at 4.0 to 4.9 m/a, primarily because of the establishment of new clumps of *Spartina* in previously bare areas. Clumps of *Spartina* in these areas now average 5.86 m diam.

In the permanent quadrat at the end of Transect 3, there were 23 clumps of *Spartina* with a maximum diameter of 2.0 m in 1973. By 1982 many clumps had coalesced or disappeared so that only about 8 remained. The total area in 1973 was 10.5 m^2, whereas in 1982 it was 207.5 m^2, so the mean annual increase was 21.9 m^2/a.

Transect 5 was on the true right bank and at right angles to the current of the Oreti River. It marked 6 *Spartina* clumps which grew slowly during the study period. Strong currents may have restricted spread along the transect so that the *Spartina* was limited to lateral expansion as shown in Table 1.

Two other short transects were established in 1973 at Daffodil Bay near the upper tidal limit of *Spartina*, on a very sandy substrate, but these were sprayed during herbicide trials in 1980. The size of the dead clumps after 7 years of growth did, however, remain similar to that measured in 1973.

Substrate accretion

The ability of *Spartina* to increase sedimentation rates is well known (Harboard 1949) and confirmed by this study. Results from the transects are presented in Table 1.

Wooden pegs of *Leptospermum scoparium* did not last in the dense swards at Transects 1 and 2. However, a stainless steel peg at one site on Transect 1 indicated an annual increase in sediment of 12 mm/a. There was no evidence of the sinking of pegs which were buried deeply into the sediment. Sediment within clumps of Transect 3 had a fast accretion rate of 10 mm/a, whereas those at Transect 4 were considerably slower at only 3 mm/a. At Transect 5 at the mouth of the Oreti River, sediments were being eroded at a rate of 5 mm/a at the only remaining peg. All accretion is of sediment and not of *Spartina* detritus.

DISCUSSION

Rates of substrate accretion have been recorded previously in the Waihopai River Estuary. Saxby (in Ranwell 1967) noted rates of mud deposition in *Spartina* of 20 mm/a over a 30 year period, whereas both Harboard (1949) and Corkill (in Bascand 1970) recorded rates of 38 mm/a. The latter also estimated an annual rate of 64 mm/a throughout one 13 ha area. The rates of substrate accretion recorded in this study, however, are generally much lower, being less than 12 mm/a.

Measured rates of accretion are dependent upon several variables. Extremely high rates are usually of short duration, e.g., 170 mm/a over 1 year at Bridgewater Bay, British Isles (Ranwell 1964) and 200 mm/a over 5 years at Sloedam, Netherlands (Verhoeven 1951). However, over the longer periods of 37 years for the first location and 22 years for the second (Beeftink in Ranwell 1967), the rates were 50 mm/a and 80 mm/a respectively. Furthermore, sedimentation is dependent not only on deposition, but also settling and compaction. Stearns & MacCreary (1957) measured an addition of 6.4 mm/a in a *Spartina patens*, *Scirpus olneyi*, and *Eleocharis rostellata* marsh in the U.S. but because of compaction, no rise in ground surface resulted.

The rates of 3–12 mm/a obtained in this study are considerably lower than those from *Spartina anglica* marshes elsewhere which range from 20 mm/a (Ranwell 1964, Saxby in Ranwell 1967) to 101 mm/a (Oliver 1920) over a long period. Measurements at New River were, however, almost all obtained on sandy substrates. The markers disappeared, probably by rotting, from the muddy sites. Bascand (1970) suggests that *Spartina* accumulates sediment in sandy areas at only half the rate of accretion in mud. The maximum reading, in this study, of 12 mm/a is for mud. Readings on sand, based on mud equivalent readings of 6 mm/a for Transect 4 and 20 mm/a for Transect 3 would have been comparable with other areas overseas. For Transect 4, the lower value probably reflects the exposure of this site. The sediment load is less (Hubbard & Partridge 1981) as this transect is far from the river course, and tidal water washing over the area would be turbulent, hindering settling, even within *Spartina* beds. In the sheltered areas of Transect 3, greater sedimentation would be expected, matching closely the readings of Saxby (in Ranwell 1967).

In marshes of *Spartina anglica*, sedimentation rates are far greater than in most salt marshes, mangrove swamps, or even for other species of *Spartina*. Within New Zealand, Chapman (1960) recorded 1.0 mm/a for lower marsh of *Salicornia australis* and 0.3 mm/a for *Juncus maritimus/Leptocarpus similis*. Chapman & Ronaldson (1958) recorded only 0.2 mm/a for mangroves (*Avicennia resinifera*) near Auckland. With the exception of a rate of 30 mm/a in low *Salicornia* in Norfolk, British Isles (Oliver 1929), overseas rates of similar habitats are also low, e.g., 2–8.7 mm/a on Scolt Head Island (Chapman 1960). Bascand (1970) recorded no accretion on bare mud adjacent to *Spartina alterniflora*. For other species of *Spartina* apart from *S. anglica*, rates are intermediate between these low values and the high values of *S. anglica*. Chapman (1960) for instance, in Massachusetts, U.S., recorded 13 mm/a for *S. patens* and 6 mm/a for *S. alterniflora* var. *glabra*, lower down in the marsh. The extreme sedimentation rates for *S. anglica* thus demonstrate the trapping efficiency of this species. It also demonstrates the significant changes which have taken place in the sedimentaton in the New River Estuary and the changes which may take place if the spread of *S. anglica* continues.

Measurements of rates of spread of *Spartina* are highly dependent upon the surface area available for expansion. Restricted expansion of a front is probably the reason why most rates are expressed as distance along a line and not area. In this study, the transects express expansion in distance, whereas the permanent quadrat expresses it as an increase in area. It is, however, impossible to interpret the growth of a marginal front in terms of area. Transect 2 covers only a marginal front; Transects 3, 4, and 5 and the permanent quadrat intersect only clumps; and Transect 1 includes a mixture of both, the marginal front also having engulfed several clumps which were separate in 1973.

Despite this, spread at Transect 1, of both the front and the outer clumps, is slower than at the other transects (Table 1). There is, however, only one possible direction of spread, unlike Transect 2, which is advancing both up- and downslope. Even when this is taken into account, the spread of the clumps is extremely slow in the direction perpendicular to Transect 1. At this transect, the outermost marked clones had disappeared by 1982 (Fig. 2), suggesting that the species may be near the limits of its survival in this location, this perhaps being reflected in the slower growth, or that some change has taken place within the estuary. Transect 5 also appears to be in a marginal site as it has only slow lateral spread. Sediment has been eroded from here (Table 1) and this may well restrict spread. The other 2 transects display much faster rates of spread, varying from 3.1 to 5.3 m/a. This is much greater than the 0.4–0.6 m/a average and maximum of 1.0 m/a measured by Chater & Jones (1957), but much less than the 6.1–7.2 m/a of both Oliver (1925) in the British Isles and Allan (1930) at Foxton, New Zealand. Bascand (1970) found growth rates from planting of 1.2 m^2/a over 41 years in Waitemata Harbour, Auckland and 12.8 m^2/a over 4 years in Kaipara Harbour, Northland, these being much lower than the 21.9 m^2/a in the permanent quadrat in this study. He indicated that the habitat at those locations is not particularly suitable, and that the species performs poorly at that latitude, a conclusion supported by its global distribution (Ranwell 1964). The mean annual rate of increase in area of 5.7% is also greater than that measured by Ranwell (1964) of 0.43–2.52% following planting in southern England.

The clumps of *Spartina* in the permanent quadrat at the end of Transect 3 showed several interesting features. Many of those present in 1973 had disappeared by 1982 either having coalesced with faster growing clumps or having died. Certain area of the quadrat with clumps in 1973 were bare in 1982, indicating that death of some had indeed occurred. In particular, the side of the quadrat nearest the marsh creek was completely devoid of *Spartina* perhaps as a result of apparent changes in the creek's position. The absence of new small clones is surprising considering the continued colonisation of the transect nearby.

It appears that in most places in the New River Estuary, *S. anglica* is growing at a rate which enables it to cover large areas of sand and mudflats as was suggested by Hubbard & Partridge (1981). It has not, however, grown at its maximum potential rate as demonstrated by comparisons with certain extreme instances. In some locations it seems to have become, or is becoming slower growing as a result of it reaching the limit of its spread.

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