THE ROLES OF *SPARTINA* SPECIES IN NEW ZEALAND

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SUMMARY: The distribution and rates of spread of different growth forms of *S. townsendii* and of *S. alterniflora* in New Zealand are discussed and rates of sedimentation measured in *Spartina* plantations in Northland are compared with those recorded in Southland and in England.

Gross productivities of plantations in Northland are compared with English and American data and problems associated with foreshore protection are considered.

Spartina is undoubtedly a valuable plant aid to land reclamation, but its introduction to new areas should take into account both alternative uses of aquatic environments and problems arising from its uncontrolled spread.

INTRODUCTION

The cord grasses number about 14 species (Clapman, Tutin and Warburg 1958), but of these only the hybrid *S. townsendii* (s.l.) and its North American putative parent *S. alterniflora* Lois. have been introduced to this country. The advent and varying performances of these pioneer salt-marsh plants have been reported upon by Allan (1930), Harbord (1949) and Blick (1965); and many references to trial plantings in estuaries and harbours for coastal defence or reclamation purposes can be found in government files and those of local bodies.

The world resources of *Spartina townsendii* (s.l.) and economic uses of *Spartina* marshland have been reviewed recently by Ranwell (1967) whose information about New Zealand plantations was based on the previously-mentioned papers and correspondence. Since then, more local information about this subject has been assembled in the course of my investigations at the behest of Marine and Agriculture departments.

This came about through concern by the former about, and advocacy by the latter for, the spread in North Island localities of *S. alterniflora*, and disagreement among South Island local bodies over the role of a tall growth-form of *S. townsendii* in various estuaries.

Studies were made throughout N.Z., but most work was concentrated in the vicinity of Kakanui Point (latitude 36° 31′S. longitude 74° 26′E.) on the eastern shore of Kaipara Harbour, Northland, where suitable conditions for comparative studies existed.

The aspects considered in this paper are: Distribution and growth forms, rates of spread, rates of substrate accretion and field rates of growth and management of plantations.

DISTRIBUTION AND GROWTH FORMS

A wide range of life forms of hybrid *S. townsendii* have become established in this country as both flowering and non-flowering variants occur. Though both tall and dwarf forms may be found in estuaries in both islands, plantations in the South Island commonly attain 3 ft. in height, whereas those in the North Island often do not exceed 6 in. in the vegetative state. The general variability is not surprising considering the recent appearance of the species and its assumed origin; but the tendency for one form to dominate the other, apparently in a latitudinal sequence, is more difficult to explain. Chapman (1958) considered temperatures too mild for *S. townsendii* to flourish in the more northern districts; but the history of dispersal is poorly documented and the explanation may be simply the transplanting of the wrong forms there.

Marchant (1967) has positively identified both fertile and sterile forms of *S. townsendii* in England, but attempts to repeat this work under our conditions have not yet been successful, although the existence of clones established from imported seed has been recorded in South Otago (F. M. Corkill pers. comm.). Currently, positive taxonomic descriptions of the naturalised material is

* The work described was conducted in the Botany Department, University of Auckland, while the writer was on leave from the N.Z. Dept. of Agriculture.

lacking and identification must rest upon published descriptions (Goodman *et al*. 1969) from overseas.

S. alterniflora, which is established only in the North Island, may vary in height from 9 in. to 6.5 ft. but commonly attains 3 ft. There is no record of whether the pilose or glabrous form, or both, were introduced, although morphological variants occur. As this species has not been known to set seed in New Zealand, its spread appears to have been principally or wholly vegetative and consequent upon fragmentation or human activity.

In the South Island, colonisation of *S. townsendii* has been most successful in the New River estuary Invercargill, in the Avon-Heathcote estuary Christchurch, where spread is considered undesirable, (P. J. McWilliam pers. comm.) and at Havelock, Pelorus Sound. In the North Island the original plantings at the mouth of the Manawatu River appear to have been the most successful.

S. alterniflora has acclimatised successfully in most of the northern harbours in which it has been introduced and to as far south as Wellington (latitude 41° 20'S.). It was the failure of *S. townsendii* to spread rapidly and perform its intended functions in the North Island which led to the introduction of the North American species.

RATES OF SPREAD

At Bridgwater Bay, Somerset, England, Ranwell (1964) found, by aerial photography, a 2% annual increase in area of clumps of *Spartina townsendii* under conditions of very high tidal range and deposition of silt. This is a much slower rate of increase than recorded by Allan (1930) at Foxton Beach during the first 15 years following establishment. However, spread of this species has generally been slow and only rarely have *Spartina* meadows been formed in New Zealand. No records of the dates or modes of planting in the well-established areas at Thames, Gisborne, or Havelock are available, although natural spread at Havelock and Christchurch appears to have occurred, and meadowing at Gisborne has long been complete.

At Invercargill, where the tall form of *S. townsendii* has grown very successfully, different circumstances apply. Planted initially in 1931 as an aid to reclamation of the estuary for industrial development, offsets were spaced at 3 ft. centres in grid formation. The resultant ground coverage by *Spartina* was almost complete in about three years, but varied in density (F. M. Corkill pers. comm.). After 20 years of continuous plantings the total area thickly covered was about 100 acres. Though about 50 acres were later destroyed by tipping rubbish, by 1966 another 50 acres had been covered by natural spread and by more plantings.

Similar results, however, have not always been obtained. At a site just below high water spring tide level in the Waitemata Harbour, of 200 plugs of the dwarf form planted in 1926–27 only five patches had formed 41 years later and these covered only 0.06 ac. This represents an average annual spread of 12.7 sq. ft. per patch on shallow sand overlying and mixed with peat, probably originating from *Metrosideros excelsa.*

By contrast, measurements of the rates of spread of more than 50 patches of *S. alterniflora* on a sand flat in Kaipara Harbour at levels ranging from 1.5 ft. above M.S.L. to 0.7 ft. below M.S.L. showed an average spread exceeding 550 sq. ft. in four years from single plants. Again, offsets planted at slightly higher elevations and at approximately 33 ft. intervals coalesced to form a continuous block of 0.6 ac. in just under six years. Consequently, the systematic planting of this species in grid formation could result in complete coverage at this site within five to six years — a rapid rate of colonisation.

Rates of spread on muddy substrates are rapid alongside streams or creeks and even in open mangrove swamps, but not in dense ones. At a site along a mangrove-fringed bank of the Kaipara River, 60 percent establishment of transplanted *S. alterniflora* offsets resulted after two years; but at only three or four places adjoining creek outlets from an adjacent mangrove-rush swamp had any merging of clumps (originally spaced at half chain intervals) occurred. However, the growth of all established clumps was very vigorous and clump heights ranged from 3–7 ft. The spreading patterns of almost all clumps were similar, being lateral along the edge of the mangrove swamp and apparently limited landward by two unrelated factors:—

(a) Competition with the much taller mangroves for light and possibly nutrients (but not space), and

(b) Grazing by cattle and probably by pukekos (*Porphyrio melanotus*) which, according to other observers, eat the young shoots.

Riverward spread appeared to be negligible, and overall the pattern in this marsh was along the waterway and could not be considered detrimental to navigation. Similar observations were recorded at Invercargill along the bank of the New River. Here, steepening of the river banks has resulted from formation of cliffs by the dense plantations of tall *S. townsendii,* the further riverward spread of which is considered limited by river velocity. (K. A. Ballinger pers. comm.).

On the other hand, the possible invasion of and occlusion by *Spartina* of shallow inland waterways should *not* be discounted.

RATES OF SUBSTRATE ACCRETION

Considering the value of coastal vegetation in stabilising foreshores and in trapping silt and detritus, few measurements have been recorded of the rate of deposition of sediments in maritime plant associations in New Zealand.

Chapman and Ronaldson (1958) measured very slow mean rates of annual accretion in successive inter-tidal zones of the Auckland isthmus. These rates ranged from 0.062 in. in the mangrove association to less in the *Salicornia* (glasswort) and rush zones at higher elevations over a period of 14 months. Confirmation of the rate of deposition of silt in the mangrove zone was obtained from another locality at Awanui over a two-year period.

Earlier, Harbord (1949) had recorded an average increase of 7.5 in. over a five-year period in a tall-form *Spartina townsendii* marsh in the Waihopai estuary at Invercargill at 11 out of 12 pegged sites. F.M. Corkill (pers. comm.) has confirmed the rate of deposition of mud in places as much faster than 1.5 in. per year, and during a period of 20 years estimated that in one 32 ac. block the silt level was raised at an average rate of 2.5 in. per annum which represents about 200,000 cubic yards of material.

During 1967 measurements by levelling were made at Kakanui on sites ranging from near M.H.W. level to others at 2.5 ft. below it. Bare areas and *Spartina* plantations were compared over one year. Fixed bench marks were established at convenient sites and differences in substrate surface levels were measured with a dumpy level (to 0.005 ft.) or by ruler (to 0.0625 in.) from pegs or pipes set deeply in or alongside areas cut periodically for comparisons of yield.

No changes in substrate levels were recorded at bare ground sites which adjoined those where extreme variations in quadrat accretion occurred, or where mean quadrat differences recorded a slight decrease in elevation (i.e. erosion) over the course of a year. Therefore the differences measured were attributed to the trapping action of the vegetation at sites which included a streamside marsh and plantations growing on mud or on sand.

The densely-matted dwarf form of *S. townsendii* appears to trap more shells and sand than does *S. alterniflora* but its rates of spread is so slow that the much more aggressive *S. alterniflora* is able to colonise and stabilise a much greater area in a much shorter period and thus effectively trap a much greater quantity of material per unit of time.

During the short measurement period the average rate of accretion in *S. alterniflora* stands was four times that in dwarf *S. townsendii* stands and about 14 times the rate found for mangroves (*Avicennia*) by Chapman and Ronaldson (1958); so that the potential value of this species for reclamation and stabilising in salt marshes is apparent.

Clear differences between the accretion rates on muds and sands in the ratio of 2:1 were recorded (Table 1) but these were partly dependent upon tidal influences, as the sandy sites were more frequently covered and subject to erosion by wave action. The largest increments were near small creeks and were about 1.5–2.0 in. over the year in stands of *S. alterniflora.* These results compare well with the values recorded in Poole Harbour, England, by Ranwell (1964a) and with those measured at Invercargill in extensive stands of the tall growth form of *S. townsendii.*

Insufficient data were recorded to correlate sedimentation rates with tidal plane, although a tendency for more deposition to occur at sites lying between 0.5 ft. above and 0.5 ft. below high water neap tide level than at other levels can be seen in Figure 1. (The main exception is at site 5S which is sheltered more by the elevated sites 4S, 4L than is 5L).

TABLE 1. *Mean rates of substrate accretion (in inches) in* Spartina *stands at Kakanui, 1967–68.*

FACTOR	SITES	ELAPSED TIME 9 months	12 months
Muds	8	0.50	0.78
Muds[1]	10	—	0.94
Sands	8	0.38	0.38
Short *S. townsendii*	8	0.33	0.24
S. alterniflora	8	0.50	0.93
S. alterniflora[2]	10	0.40	0.77

[1] Includes tide boards at *Spartina* margins.
[2] Includes extra, more seaward plot 10.

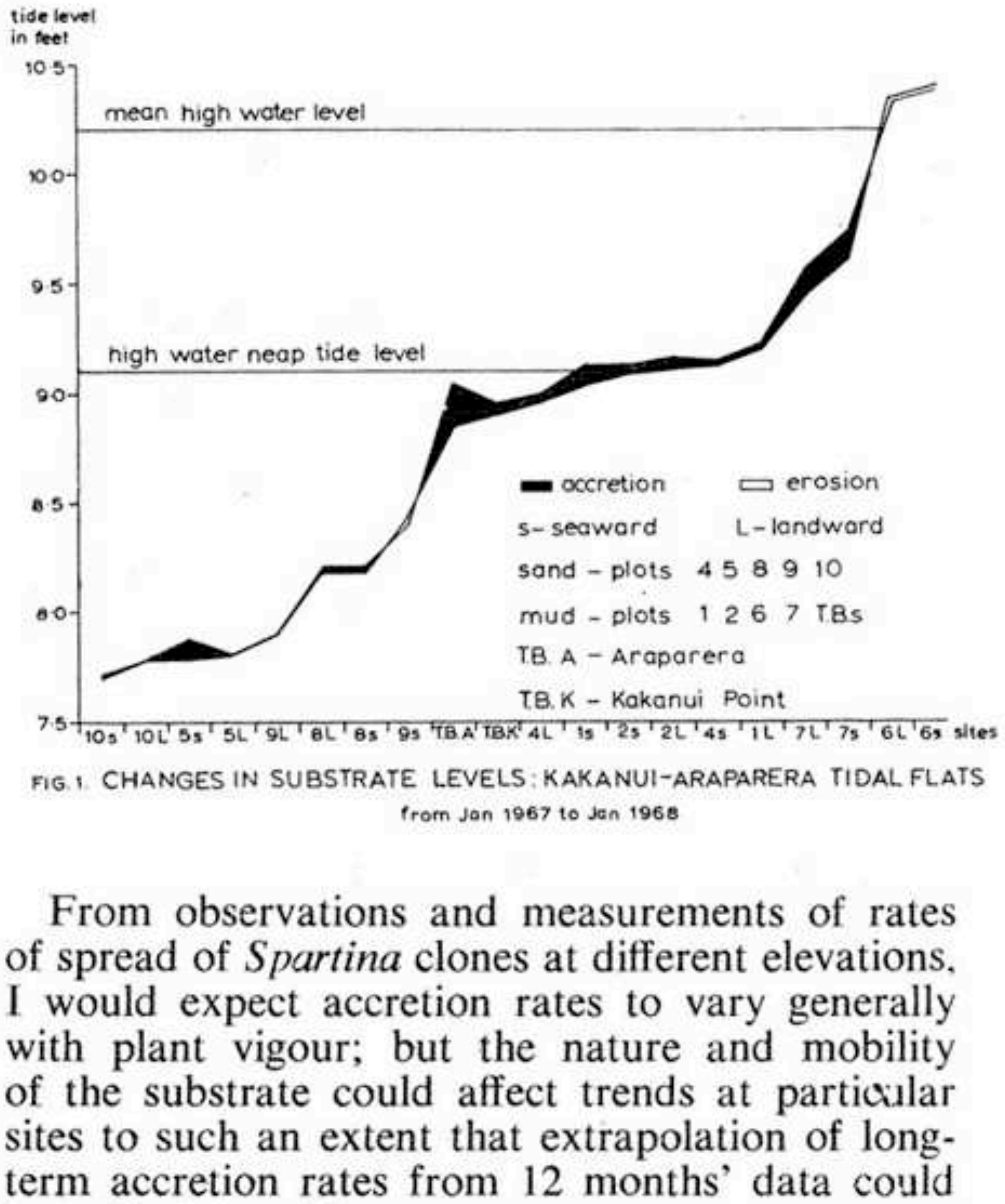

FIG. 1. CHANGES IN SUBSTRATE LEVELS: KAKANUI-ARAPARERA TIDAL FLATS from Jan 1967 to Jan 1968

From observations and measurements of rates of spread of *Spartina* clones at different elevations, I would expect accretion rates to vary generally with plant vigour; but the nature and mobility of the substrate could affect trends at particular sites to such an extent that extrapolation of long-term accretion rates from 12 months' data could be subject to wide errors.

Nevertheless, experience has been that wherever *Spartina* species are well established, substrate stability is greater than on adjoining bare ground, the exception being consolidated sands; so that the benefits to be gained by strategic planting of *Spartina* adapted to particular environments may be considerable. The extent to which large-scale land reclamation would proceed aided by such plantings in an extensive harbour such as the Kaipara, or the Firth of Thames is unknown. It would depend upon factors such as the numbers of rivers discharging into the harbours, the quantities of detritus they transport, and the degree of protection against wave action afforded establishing clones by groynes or sand and shell barriers.

GROWTH AND MANAGEMENT OF SPARTINA PLANTATIONS

Three reasons frequently advanced for the desirability of measuring the rates of growth of field crops are:—

(1) To compare gross productivities of different crops or crop varieties;

(2) To derive productivity indices for different environments, and

(3) To determine the periodicity of growth as a guide to crop use or control.

Yields

Only incidental observations on the growth of *Spartina* in New Zealand have been recorded previously, although detailed studies had been undertaken in England, Canada and U.S.A. Although it would have been desirable to compare the performances of both tall and short forms of *S. townsendii* with that of *S. alterniflora*, this was impracticable because of the scarcity of tall *S. townsendii* in the vicinity of the other species. However, the short form of *S. townsendii* and *S. alterniflora* grow contiguously at Kakanui, Northland, and were compared, though they differ in growth habit; the former is dense and turf-like, the latter erect and open.

Initially, yields of standing crops were measured on sites obviously different, i.e. streamside marshes and zones of high and low elevation corresponding to mudflats and sandflats extending from M.H.W. level to H.W. neap tide level respectively. There were two replicates of a 2 x 2 factorial layout in which substrates were confounded with tidal zones. The means of the results are briefly summarised in Table 2.

TABLE 2. *Yields of standing* Spartina *crops at Kakanui, April 1966 (lb./ac. dry matter).*

Species	*S. alterniflora* Green	Dead	Total	Short *S. townsendii* Green	Dead	Total
On muds	5090	1890	6980	870	500	1920*
On sands	6500	2210	8710	1210	550	1760

* Includes *Salicornia* 550.

The mean yields of *S. alterniflora* at Kakanui agree well with mean maximum productivity estimates of North American marshes discussed by Smalley (1958) and Nicholson and Langille (1965). The American values lie within the range 6,000–8,000 kg./ha. (approximately 5,350–7,140 lb./ac.) except those in North Carolina, where streamside marsh yields were much higher (Williams and Murdoch 1966). The *S. townsendii* yields were considerably lower than those recorded by Ranwell (1961) from mixed stands of the seed-bearing form in Somerset (where weights approaching those of the American marshes were recorded) and would probably be much lower than for the tall form of *S. townsendii* found in the South Island. In all instances, the durations of standing crop production quoted are unknown.

Subsequently, the regrowths of the sample areas were measured, and the cumulative totals for 12 months and for 15, are set out in Table 3.

TABLE 3. *Regrowth yields of* Spartina *at Kakanui, 1966–67 (lb./ac. dry matter).*

Species	*S. alterniflora*			Short *S. townsendii*		
	Green	Dead	Total	Green	Dead	Total
On muds[1]	3700	310	4010	2440	280	2820*
On muds[2]	4010	350	4360	2630	360	3090*
On sands[1]	3530	450	3980	2810	430	3240
On sands[2]	3810	470	4280	3040	480	3520

* Includes *Salicornia* 100.

Analysis of variance: total dry weight[2]

	df	M.S.	F	Sig.
Species	1	632,493.6	18.46	0.1%
Time	7	1,411,140.8	41.19	0.1%
Quadrat Position[3]	1	266,397.3	7.77	1.0%
Substrate × species	1	84,630.7	2.38	N.S.

[1] June 1966–June 1967.
[2] April 1966–June 1967.
[3] Two quadrats per plot meaned for total plot yields. The more seaward quadrats were higher yielding.

The reason why the regrowth yields of *S. alterniflora* over 12 months were about half those of the standing crops, whereas those of short *S. townsendii* were almost double for totals, is not clear and requires further investigation. The crops were slow-growing by pastoral standards and achieved only about a third good pasture production per annum, but this was in the absence of applied nutrients or grazing by animals.

Periodicity

Mean daily rates of growth for green plus dead matter for the two species growing on both muds and on sands during a period of 18 months are shown in Figure 2.

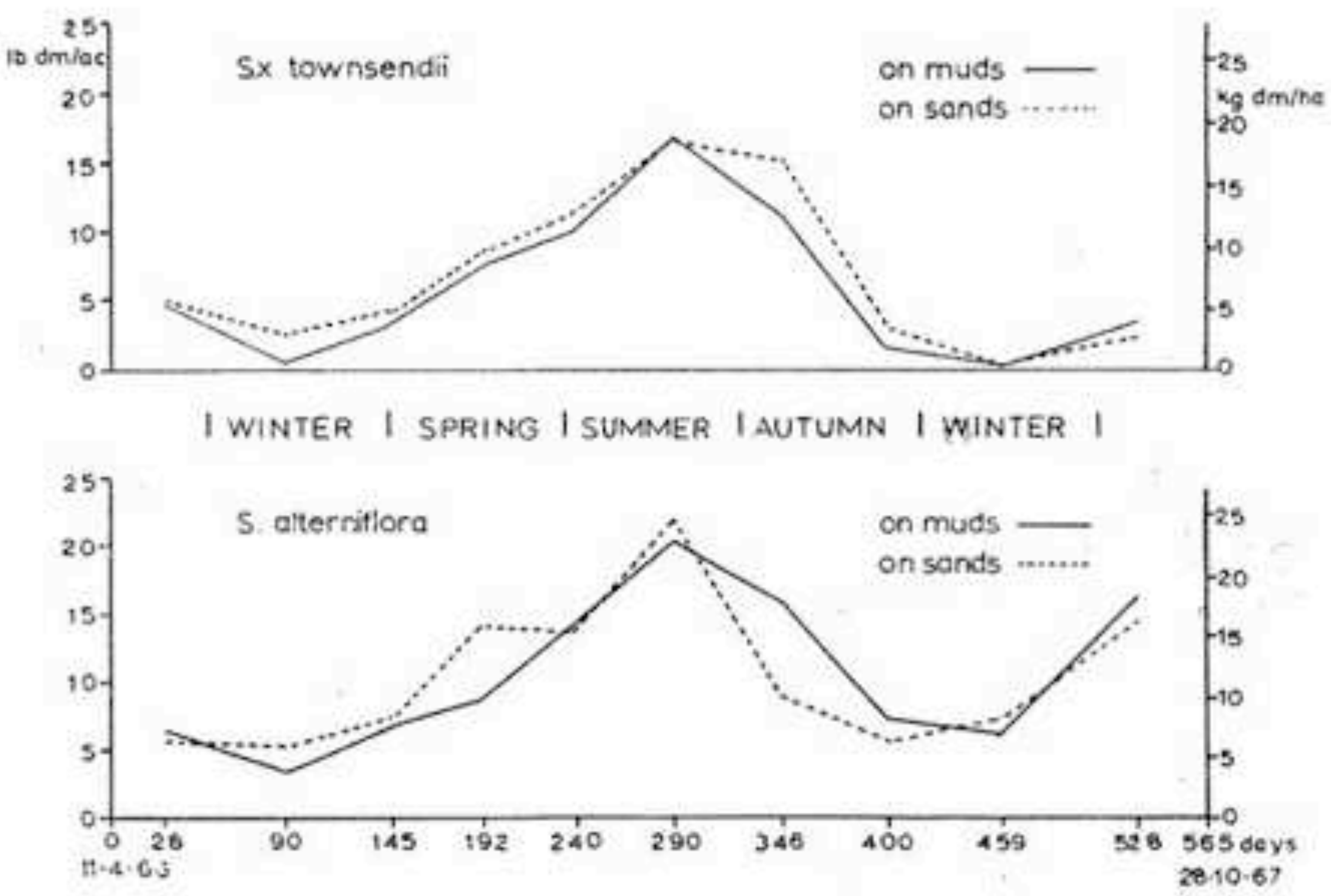

FIG.2 FIELD GROWTH OF SPARTINAS AT KAKANUI: MEAN DAILY YIELDS

The growth rhythms of both species were correlated with temperatures recorded at Dargaville (the only official recording station near Kaipara Harbour) and showed significant positive agreements. (See Figure 3 and Table 4). Both species reached peak growth during mid-summer but *S. alterniflora* was quicker to do so. The two species behaved differently during winter however; *S. alterniflora* continued to produce herbage, although at a slower rate, whereas dwarf *S. townsendii* made extremely little vegetative growth and behaved very much like an annual species.

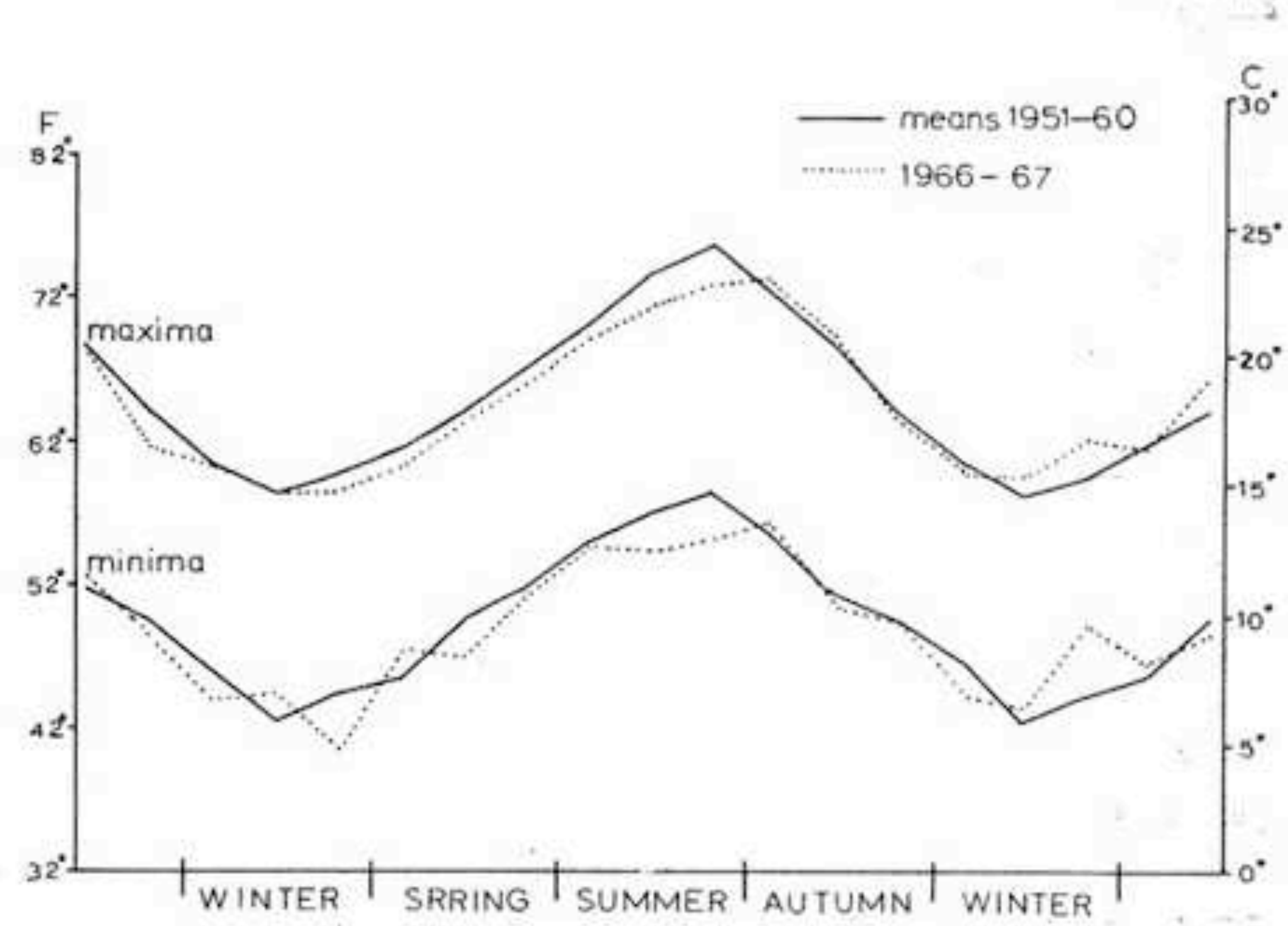

FIG.3 MEAN DAILY TEMPERATURES AT DARGAVILLE

TABLE 4. *Mean daily yields of* Spartina *growth at Kakanui (Apl. 1966–Oct. 1967) correlated with mean daily maximum and minimum temperatures at Dargaville.*

	Mean Min.		Mean Max.	
	1966–67	10-year mean	1966–67	10-year mean
S. alterniflora	0.68	0.68	0.62	0.68
S. townsendii	0.83	0.86	0.79	0.85

Min. r×y value for significance at 5% level 0.64 (Loveday 1964) for 10×y pairs.

By inspection it can be seen that, whereas all correlation coefficients derived were positive, those for *S. alterniflora* just attained or failed to reach significance, but those for *S. townsendii* were all well above the minimum level required for significance.

S. alterniflora was obviously less sensitive to temperature variations and for this reason might acclimatise well under South Island conditions, although mean temperatures where *Spartina* grows are as much as 5.5°C. (10°F.) lower than in Kaipara Harbour.

Heights

Only gross differences in herbage productivity can be measured by height measurements alone, because of variations in crop density. However, as bases for management recommendations, information was obtained on this aspect for comparison with yield and density estimates and to amplify the studies on times of growth.

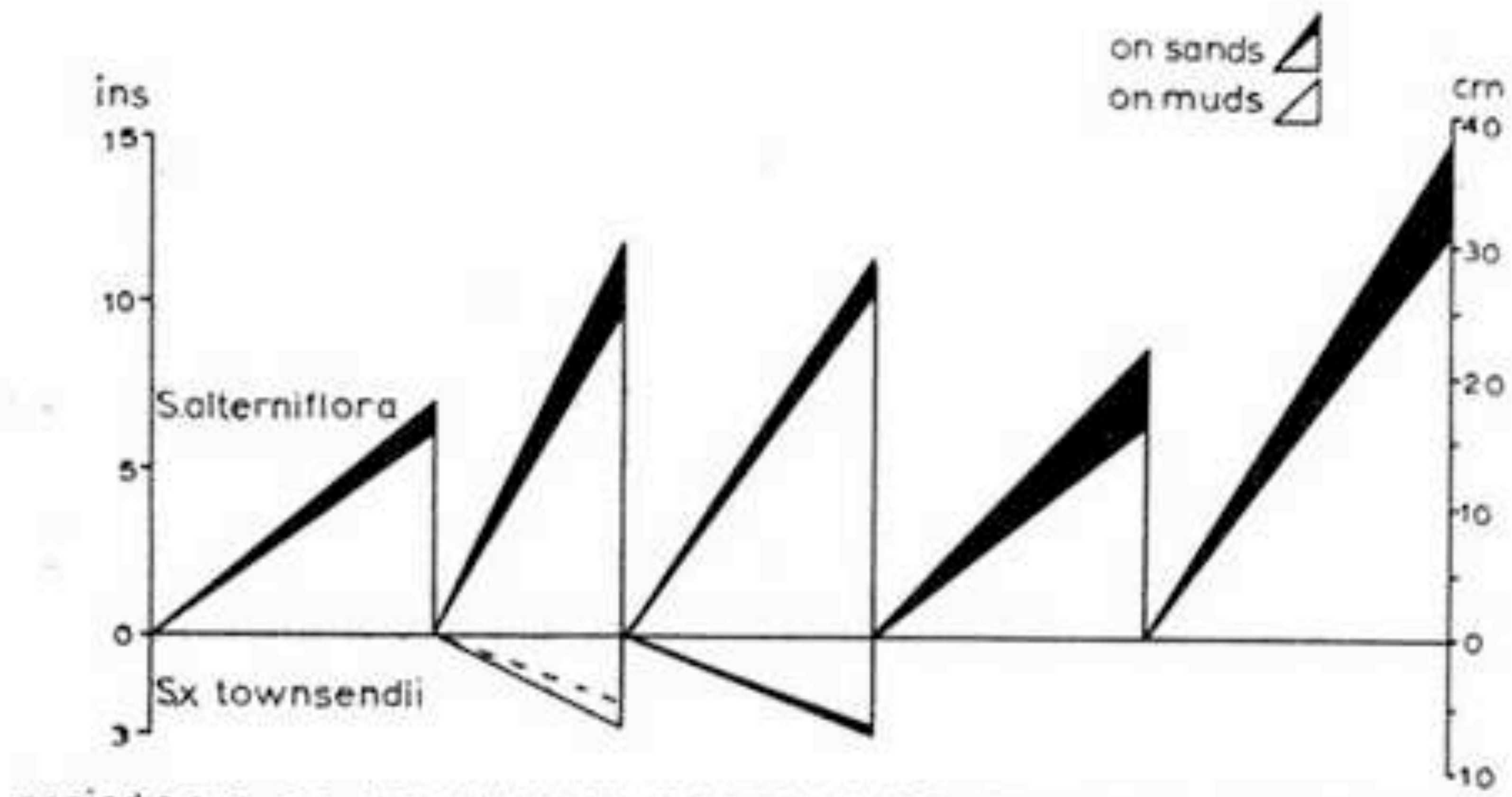

FIG. 4. MEAN HEIGHTS OF SHOOT REGROWTH FROM STUBBLE
Field rates of Spartina growth at Kakanui 1966 – 1967

The heights of shoot regrowths were measured at intervals to the nearest 0.25 in. and means for given periods are shown in Figure 4. Sampling was from 10.8 sq. ft. quadrats and numbers usually exceeded 40 for each species x substrate interaction.

Daily foliar regrowth rates during periods of maximum activity measured 0.20–0.25 in. for *S. alterniflora* compared with 0.05 in. for dwarf *S. townsendii;* but during winter these were reduced to 0.10 in. for *S. alterniflora,* whereas those for dwarf *S. townsendii* were immeasurably small regardless of substrate.

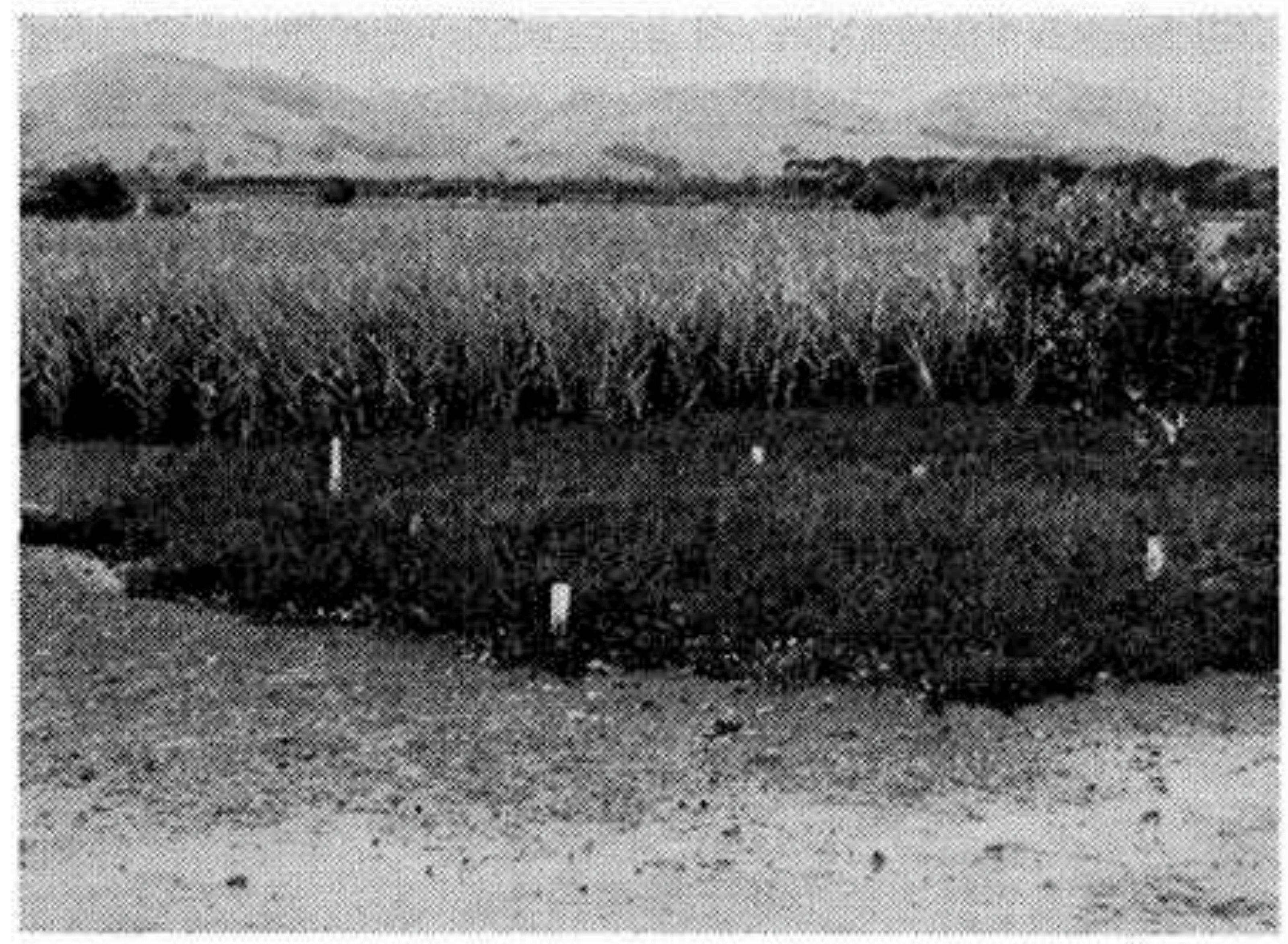

FIGURE 5. Spartina townsendii *(dwarf form) in foreground with* S. alterniflora *and* Avicennia resinifera *in background. The substrate is a sandflat in the zone reached by lowest high water neap tides, midway between mean sea level and main high water level, in Kaipara Harbour.*
Photo, L. D. Bascand

Density

Two interesting features of the patterns of *Spartina* growth recorded at Kakanui related to seasonal changes in ground cover:

During the period from April–October 1967 the density of live dwarf *S. townsendii* herbage as determined by point-quadrat analyses, was reduced by about half, regardless of site or substrate, with equivalent increases in bare ground, and dead matter on untreated areas. (See Table 5). Changes on cut areas were similar but greater.

TABLE 5. *Point-quadrat analyses on dwarf* S. townsendii *shoots*

Substrate	Live		Dead		BG+Lit.*	
	April	Oct.	April	Oct.	April	Oct.
Hits per 100 points on control areas						
Mud	46	24	24	4	26	69
O.S.*	4	3	—	—	—	—
Sand	51	25	36	11	13	64
Hits per 100 points on cut areas						
Mud	50	17	6	1	44	81
Sand	54	20	12	2	34	78

* BG=Bare Ground. Lit.=Litter. O.S.=Other Species.

Over the same period, differences in the pattern of *S. alterniflora* growth were also recorded. In April about one-fifth of the shoots counted on harvest areas were below cutting height, but by October all were above it and the yield difference between the two cuts was proportional to the difference in shoot heights. The total number of shoots remained constant, despite an intervening cut. (See Table 6).

TABLE 6. *Shoot counts on regrowth of* S. alterniflora *numbers per 2.69 sq. ft. quadrat.*

Substrate	Live[1] April	Live[1] Oct.	Live[2] April	Live[2] Oct.	Dead April	Dead Oct.	Total April	Total Oct.
Mud	69.3	74	12.4	1.0	32.3	38	114	113
Sand	32.2	41	11.3	1.7	49.5	47	93	89.7

[1] Above. [2] below, cutting height of 2.5 in.
(By reference to Figure 2 it can be seen that mean daily rates of growth for corresponding periods were 12.4 and 15.3 lb. d.m./ac. respectively.)

Apparently shoot emergence ceased during autumn, and subsequent gross productivity was dependent upon shoot elongation during winter and early spring; whereas at other seasons herbage yields would seem to depend upon changes in both numbers and heights of shoots.

Management

World use of *Spartina* plantations has recently been reviewed by Ranwell (1967) who states *inter alia,* "a wide variety of mammals but few herbivorous birds will eat *Spartina*". In England, Oliver, *et al.* (1929) showed that the dry matter content of *S. townsendii* was equivalent to that of meadow hay in nutritive value, and Hubbard and Ranwell (1966) concluded that *Spartina* silage was comparable with medium quality hay.

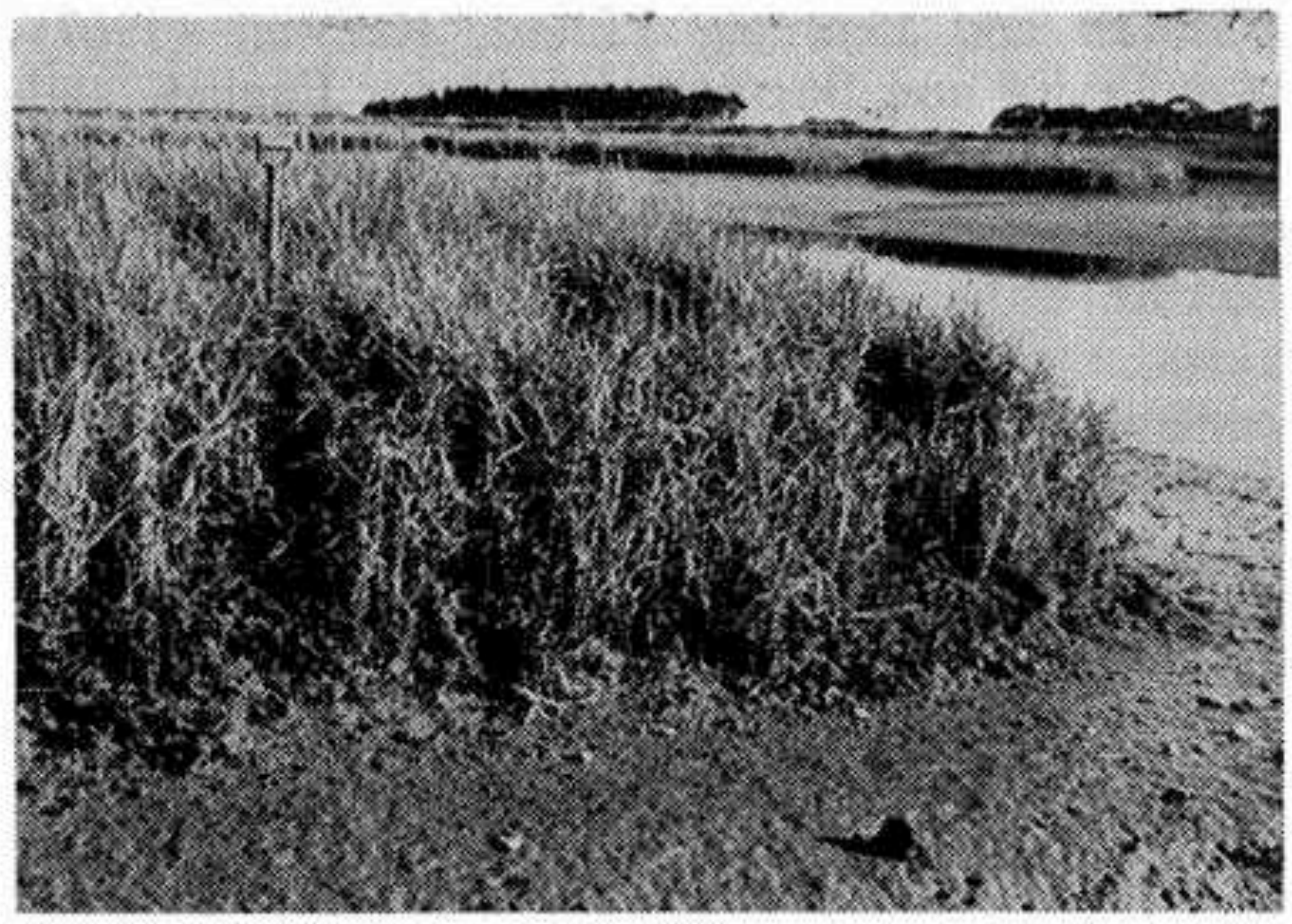

FIGURE 6. Spartina townsendii (*tall form*) *growing on a bank of the New River Estuary, Invercargill. Note the accretion of mud at ground level. This growth is almost completely submerged at high water spring tides.*
Photo, L. D. Bascand

In New Zealand there has been little experience of grazing *S. townsendii,* but *S. alterniflora* recovers well from lax grazing by cattle and could be managed as a greenfeed crop on otherwise wasteland areas in blocks fenced for livestock protection against the hazards of stream-side marshes. Because this species makes some vegetative growth continuously in Northland and seems palatable (possibly because of the salt the plants exude via the leaves), it could provide valuable feed for store and other dry stock during periods of shortage during cold or droughty seasons. Further experience may show that similar use can be achieved in more southern districts, at least during the warmer months.

On the other hand, from observations of trampling damage and from the earlier discussion of shoot production, it seems possible that undesirable landward spread of this vigorous estuarine species could be controlled, if accessible to livestock, by severe grazing in late autumn or in spring.

Hence fears of the *uncontrolled* spread of the more aggressive *Spartina* species are more applicable to aquatic environments where grazing is impracticable.

Control

Attempts at controlling undesirable spread on beaches or in harbours have been described by

Ranwell and Downing (1960), Ranwell (1967) and Taylor and Burrows (1968) for English, and by Bascand (1968) for New Zealand, conditions.

Although encouraging results have been recorded under certain circumstances using herbicides, there have been no reports of extensive control being achieved either here or abroad. Investigations are continuing in South Island estuaries, although known problem infestations are few and transplanting is restricted by legislation.

CONCLUSIONS

It should be clear that the introduction of *Spartina* species for various purposes has not always been successful and that in some situations introduction would be undesirable.

Some of the factors determining growth in New Zealand have been discussed, but a much fuller treatment would be needed to account for the variable performances by the species we have and for their habitat ranges.

When considering the advantages these plants confer as aids to engineering works, more thought must be given in future to the risks associated with their unrestricted spread and to the ecological factors governing their adaptation.

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