Environment Waikato Technical Report 2001/18

Saltwater Paspalum

(Paspalum vaginatum)

– a Weed Review

Prepared by:
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For:
Environment Waikato
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COROMANDEL

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1 Introduction

Paspalum vaginatum is a saline-tolerant perennial grass which occurs in many estuaries and along coastal foreshores of the northern half of the North Island, New Zealand (Edgar and Conner 2000, Galloway 2000a, Rogan 2000, Waikato University herbarium). The distribution and ecology of this grass, and the impacts it has on the natural values of these areas is not well documented.

This report was commissioned by the Waikato Regional Council (Environment Waikato) in light of anecdotal evidence which suggests that *P. vaginatum* is threatening natural estuarine values in the Waikato region (Graeme 1997, 1998a, 1998b, 1999; Kendal 2000). These impacts appear similar to those of the more well-documented cord grass *(Spartina* spp*.)*.

The brief for this project is to:

- Undertake a survey of literature and expert opinion regarding *Paspalum vaginatum,* particularly as it relates to the New Zealand context.
- Detail the survey results and make recommendations for possible future action.
- Note any other introduced grass species that are potentially threatening the estuarine values of the Waikato Region.

2 Methods

A review of *P. vaginatum* was undertaken through literature, expert opinion and the internet. This review of the current knowledge about *P. vaginatum* included relevant information on *Spartina* spp. *Spartina* is an introduced grass that occupies a similar ecological niche to *P. vaginatum*, and has well documented information about its ecology and impacts around tidal waterbodies in New Zealand.

- A literature search was undertaken in the following places:
  - University library catalogues/indexes/search engines
  - Crown Research Institute publications
  - Department of Conservation (DOC) publications
  - Waikato Regional Council (Environment Waikato) library database

- Information was accessed from the internet using suitable keyword searches in the search engines Yahoo, Altavista and Google.

- Expert opinion was gathered by sending a letter (Appendix 1), generally by e-mail, to scientists, managers, and individuals associated with weeds or the coastal environment. Experts surveyed are associated with DOC, regional councils, universities, Crown Research Institutes, herbariums, or are private ecological consultants.

The information that was gathered is collated within the results section of this report.

3 Results

3.1 Taxonomy

(From Edgar & Conner 2000):

Class:	Monocotyledons
Order:	Graminales (now Poales[1])
Family:	Gramineae (now Poaceae[1])
Subfamily:	Panicoideae
Tribe:	Paniceae
Genus:	*Paspalum*
Species:	*vaginatum* (Sw., *Nov Gen. Sp. Pl.* 21 (1788))

Note: The name *P. distichum* was often applied to specimens of *P. vaginatum* until 1983 when they were officially separated (Edgar & Connor 2000).

Common names used for *P. vaginatum* include:
saltwater paspalum,
seashore paspalum,
saltwater couch,
siltgrass,
sheathed paspalum,
salt jointgrass,
seaside millet, and
sand knotgrass.

There are also many commercial names for *P. vaginatum* marketed as a sports turf grass.

3.2 Morphology and biology

P. vaginatum is a semi-aquatic, saline-tolerant perennial grass, naturalised in New Zealand.

Edgar & Connor (2000) describe *P. vaginatum* as:

> *Decumbent perennials, with numerous, long-creeping stolons, bearing very wide, loose, papery sheaths at nodes; erect shoots often in close tufts, much-branched near the base. Leaf-sheath submembranous, glabrous; apex extended upwards at each margin and fused with the ligule. Ligule 0.5-1 mm, scarcely tapered, shortly bluntly pointed, glabrous. Collar with small tufts of hairs. Leaf-blade 3-8 cm x 1-2 mm, rather stiff, much narrower than sheath, ± inrolled, narrow-linear, glabrous, tapering to acuminate tip. Culm (3)-7.5-18-(30) cm, erect or geniculate-ascending, slender, compressed, internodes glabrous. Panicles of 2-(3) erect to spreading racemes, ± digitate to culm apex. Racemes 2-3 cm, distinctly pedunculate; rachis < 1 mm wide, scarcely winged, ± glabrous, bearing 2 rows of single, subsessile spikelets. Spikelets 3-4 mm, imbricate, elliptic, tapered above to acute or acuminate tip, light green to light brown, glabrous. Lower glume 0, upper = lemma of lower floret, 3-nerved. Lower floret: lemma 3-nerved; palea 0. Upper floret: lemma c. 3 mm,*

[1] These are accepted nomenclature for the Order and Family of grasses (Galloway 2000b).

indurated, faintly 3-nerved, glabrous, shining, light creamy brown; palea = lemma, margins flattened, very slightly incurved; anthers 1.7-1.9 mm, yellow to brownish; caryopsis c. 1.5 mm.

P. vaginatum has a variable morphology as evidenced by the specimens we examined in the Waikato University herbarium. This is also highlighted with work undertaken by Dr R. Duncan who has collected 270 ecotypes from around the world which have varying characteristics (Hall, 1994). This variability can make identification difficult, and *P. vaginatum* can be confused with other similar looking species.

P. vaginatum is very similar in appearance and habit to *P. distichum* (Mercer grass). However, the characteristics in Table 1 differentiate the two species.

Table 1: Differences between *P. vaginatum* and *P.distichum.* (Edgar & Conner 2000, Lambrechtsen 1992, Manisool 1997)

	Paspalum vaginatum	**Paspalum distichum**
Habitat	saline	freshwater
Altitude	0-5m	0-1700m
Climate	tropical to sub-tropical	tropical to temperate
Leaf sheath	pale, papery	reddish-purple tinge
Leaf width	1-2mm	2-8mm

We have found that the leathery texture and grey-green colouring of the leaf blade to be a distinguishing feature of *P. vaginatum*. In comparison *P. distichum* often has a soft, lush green appearance. However, these differences in texture and colour may be due to the differences in saltwater and freshwater environments they inhabit. In the field, the narrow short leaf blade, and the loose papery leaf sheathes of *P. vaginatum* are helpful distinguishing features.

Lambrechtsen (1992) also notes narrower and shorter blades in *P. vaginatum*, and very few hairs at the junction of the blade and sheath.

Some specimens labelled as *P. vaginatum* in the Waikato University herbarium had earlier been labelled as the endemic species *Zoysia minima* or *Z. pauciflora*. These *Zoysia* species are rhizomatous, and have other particular distinguishing features that differentiate them from *P. vaginatum* (Edgar & Conner):

- *Z. minima* - has a shiny striate leaf sheath that is white below and purplish above, a solitary terminal spikelet, and is found from sea level to 600m in coastal and inland sands and gravel throughout New Zealand.

- *Z. pauciflora* – has a blunt leaf tip, a shiny striate leaf sheath that is white below and purplish above, a solitary terminal spikelet, and is often found under scrub or trees in coastal situations of the upper North Island.

Both of these *Zoysia* species are variable in habit, such that confusion with *P. vaginatum* would be easy.

There is little knowledge about the reproduction of *P. vaginatum* in New Zealand. Vegetative reproduction would be possible through animal grazing disturbance and natural physical disturbance of stolons. We have observed *P. vaginatum* flowering in January, but whether the species sets viable seed in New Zealand is undetermined. Ralish (2000) remarks that *P. vaginatum* must be propagated vegetatively in Florida as it does not produce highly viable seed. Hall (1994) highlights that the species has a 'self-incompatibility complex', in that it must have pollen from plants of a different genetic background to be pollinated.

3.3 Distribution

3.3.1 International

P. vaginatum is a cosmopolitan species with a world-wide distribution throughout tropical and sub-tropical latitudes. It is however unclear from the literature where *P. vaginatum* is originally from. The type specimen of *P. vaginatum* described by Swartz was collected from Jamaica in 1788 (Missouri Botanical Garden, 2000). Ralish (2000) states that it is native to East Central South America, and Duble (1996) also records it as native to North and South America. However, Edgar and Conner (2000) record that *P. vaginatum* is native to Europe only, while (Duncan & Carrow 2000) believe it evolved in South Africa and south-east America. The United States Department of Agriculture (USDA) webpage for *P. vaginatum* lists it as being a native species (USDA 2001). The Kew herbarium does not know from which country *P. vaginatum* originates (Williamson 2000).

Closer to New Zealand, *P. vaginatum* grows in summer-moist saline creeks of the Australian wheatbelt; on saline mud-flats in estuaries in the south of Western Australia; and at Dragon Tree Soak in the Great Sandy Desert (Randall 2000). Waterhouse (1997) lists *P. vaginatum* as present in the following Pacific islands: French Polynesia, Kiribati, American Samoa, Western Samoa, Tuvalu and Vanuatu.

3.3.2 New Zealand

The date that *P. vaginatum* arrived in New Zealand is difficult to determine. Many early herbarium records at Te Papa Museum were initially identified as *P. distichum* and later redetermined as *P. vaginatum* (Galloway 2000a). The earliest collection of *P. vaginatum* was from Mercer in 1877.

In a review of the naturalisation of plants in the Auckland region, *P. vaginatum* was assumed to be a native species until 1987 (Esler and Astridge, 1987b). There were no recordings of any *Paspalum* species in these studies until the period 1900-1940 (these being *P. dilatatum* and *P. distichum*). *P. vaginatum* was not mentioned in a detailed survey of saltmarsh vegetation of the Auckland isthmus by Chapman and Ronaldson (1958), suggesting that it had not entrenched itself in the area at this stage.

The introduction of *P. vaginatum* to New Zealand could have been accidental, or as a deliberate introduction via seed or vegetation for the use as a salt-tolerant pasture, lawn or sports turf. Its dispersal mechanisms are not well understood as it is unclear whether it sets viable seed. It seems most likely to be vegetatively spread either deliberately, or by animals or other natural means.

Edgar & Connor (2000) lists *P. vaginatum* as being present in Northland, Auckland and Gisborne. The Auckland and Wellington museum herbariums, and the Waikato University herbarium have records of *P. vaginatum* for Northland, Auckland, Coromandel Peninsula, Northern Waikato, and outlying islands (see Appendix 2). According to Cathcart (2000) it is widespread in Northland. Graeme (1997, 1998a, 1998b, 1999) and Kendal (2000) record *P. vaginatum* as being common in many estuaries of the Coromandel Peninsula.

P. vaginatum therefore seems to be confined in its distribution to the sub-tropical latitudes of the upper North Island. The southern-most record for *P. vaginatum* is for Kapiti Island, where it is noted as being “worse in warmer climates than Kapiti Is.” (DOC, 2000). On the North Island mainland the southern-most records are at Raukumara Beach, Kawhia Peninsula (Auckland Museum herbarium), and at Gisborne on the east coast (Edgar and Connor, 2000). Note that the close relative *P. distichum* grows throughout New Zealand mainland latitudes.

The Cawthron Institute is presently developing a monitoring protocol to assess the condition of New Zealand estuaries (Cawthron, 1999). Included in the Habitat Codes is *P.distichum,* which could possibly be a mis-identification of *P. vaginatum* due to its proximity to the coast. The monitoring programme, if widely utilised, could potentially bring together all the distribution data known for *P. vaginatum* and relate the change in area of the grass to native vegetation communities in estuaries over time.

3.4 Ecology

P. vaginatum is semi-aquatic, being able to withstand frequent inundations of high salinity water. It grows above the mid-tide level of tidal waters, and also around dry inland salt-pan areas. *P. vaginatum* grows in a spreading mat over mud, shingle, sand or amongst boulders in the salt spray zone near the high tide mark. It can form dense swards on open mudflats, and along the banks of creeks to the upper limit of the tidal salt wedge. *P. vaginatum's* salt tolerance allows it to also grow inland where saline conditions occur.

3.4.1 International

In Florida, *P. vaginatum* is eaten by geese, manatees and other wildlife (University of Florida 2000). It is therefore likely that animals would be a dispersal mechanism. The human spread of *P. vaginatum* is associated with its resource use, such as for sports turf.

P. vaginatum is praised by golf course managers for the qualities that make it useful as a golf turf. It is these qualities that defines its ecological characteristics. According to Ralish (2000) *P. vaginatum*:

- can grow in a pH range of 4 to almost 10;
- requires much less nitrogen than other warm season turf grasses; and
- has high shoot densities which make it more competitive than other turf grasses.

Duncan & Carrow (2000) provide further information about *P. vaginatum* including:

- a salinity tolerance up to ocean water salt levels (54 dSm^{-1} or 34,486 ppm);
- it forms both rhizomes and stolons;
- it is capable of rooting and persisting equally well in pure sands, heavy clays, mucks or bogs.

The competitiveness and salt-tolerance of *P. vaginatum* relative to other golf turf species is reflected in the absence of other species in the turfs irrigated with saline water (Duble 1996). However, limited shade tolerances for *P. vaginatum* are reported relative to other turf species (Ralish 2000).

3.4.2 New Zealand

In New Zealand *P. vaginatum* grows on the open coast, but is most widespread in sheltered estuaries, lagoons and creeks that are influenced by tidal fluxes. Edgar & Connor (2000) describe *P. vaginatum* as being found in coastal, often brackish areas. It often forms swards near the edge of mud flats, or on sandy and shingly shores and occasionally spreading into pasture nearby (Ibid). The Auckland and Wellington Museums, and Waikato University herbarium collection notes for *P. vaginatum* (Appendix 2) identify a variety of substrates that it grows on: estuarine mudflats, fine gravel, silty sand, sand; and in dryer situations above the high tide mark along exposed rocky coastlines, in crevices or beside brackish pools. There are no records for inland populations. The dry inland salt pans around Central Otago would be too far south to support *P. vaginatum* climatically, given its southern-most recorded distribution is on Kapiti Island.

From herbarium collection notes and anecdotal evidence (Cameron 2001; Cathcart 2000; Graeme 1997, 1998a, 1998b, 1999; and Kendal 2000) it appears that *P. vaginatum* grows from just above mid-tide level to above mean high water spring

(MHWS) level. This niche begins below the tidal level of most native saline-tolerant vascular plant species, at the top end of the *Zostera* zone (below low tide – mid tide range), and extends across several tidal zones characterised by their native plant associations. These plant zones grade into each other according to variables such as salinity, frequency and duration of tidal inundation, hydrology, substrate, and nutrient availability (Johnson & Brooke, 1998; Adam, 1990). Species diversity generally increases from low to high tide levels (Adam, 1990).

Estuarine vegetation often forms mosaics, but zones of plant associations can be broadly classified. Plant association zones with North Island examples can be described as follows (adapted from Johnson & Brooke, 1998; Wilton & Saintilan, 2000):

Zone 1 = **Mangroves** (mid-tide level) - generally monospecific except where the canopy is tall and patchy allowing sub-canopy growth.

Zone 2 = **Saltmarsh** (split into two communities)

a) <u>rushland</u> - (mid-high tide level) - generally monospecific stands determined by site conditions e.g. *Juncus krausii* subsp.*australiensis*, *Leptocarpus similis*.

b) <u>sea meadow</u>-

   i) (above mid-tide level) - includes prostrate mat-forming plants such as *Sarcocornia quinqueflora*, *Suaeda novae-zealandeae*, *Samolus repens*.

   ii) (high tide level) - includes *Selliera radicans, Leptinella* spp., *Triglochin striata, Isolepis cernua, Schoenus nitens.*

Zone 3 = **Back-swamp** (Spring high tide level and above) - composed of *Plagianthus divaricatus and Baumea juncea, grading up to Coprosma propinqua, Olearia solandri, Leptospermum scoparium, Phormium tenax and Cortaderia toetoe*.

We have observed *P. vaginatum*'s presence throughout all of the above zones on the Coromandel Peninsula.

Research indicates that for saltmarsh vascular plants, competition governs the location of species' upper boundaries, whereas species' lower boundaries are set by their physiological tolerance for submersion in salt water (Adam 1990). *P. vaginatum* in New Zealand seems to fit with this theory. The upper limit of *P. vaginatum* appears not to be determined by the tide, but by the plethora of other non-saline tolerant plant species it must compete with. *P. vaginatum* is only found to grow above the MHWS mark where a saline influence is still present. Its distributional limit inland from the coast is influenced by tides, but also by sand movement, wave spray, and winds extending the saline environment inland.

The Protected Natural Areas survey for the Coromandel records *P. vaginatum* as an associated species in the following 'vegetation types' (Humphreys & Tyler, 1990):

- Spinifex-Shorebindweed Sandfield (Alt 0.5-10m).
  Associated native plants of note – *Pimelea arenaria* and *Desmoschoenus spiralis*.

- Juncus maritimus-Leptocarpus similis Rushland (Alt 0-1m).
  Associated native plants of note - *Mimulus repens*.

Cathcart (2000) notes that in Northland *P. vaginatum* often occupies estuarine areas that have already been disturbed, and where the natural drainage patterns are affected by causeways and artificial drains.

Anecdotal evidence from Cameron (2001) indicates that *P. vaginatum* is spreading at the rate of 1-2 metres per year in the Waikawau estuary. This is based on annually recorded measurements from a fixed point, the data of which is soon to be analysed and reported. The *P. vaginatum* in this estuary seems to be spreading faster than a measured site of *Spartina* sp. in the same estuary (Ibid). Cameron has also noticed some dieback of *P. vaginatum* in places, which seems to be related to occasional natural blocking of the estuary at its mouth, and the resulting inundation of the grass for several days in a row.

3.5 Impacts

3.5.1 International

Grasses are one of only a few plant families that contribute to the majority of weed species in saline areas (Adam, 1990).

In South Africa concern has been expressed about the invasion of *P. vaginatum* and *Pennisetum clandestinum* (Kikuyu grass) on the sand and mud-flats of the Wilderness Lakes wetland (a designated Ramsar site), which are considered to be rendered unsuitable for wading birds due to these grasses (Randall, 1995). HŠfliger & Scholz (1980) list undesirable characteristics of *P. vaginatum* in South Africa as: competition (space, light, water, nutrients); replacing preferred vegetation; obstructive (water flow); and contaminant (seed).

A comprehensive inventory of Australian weeds lists *P. vaginatum* as a “significant environmental weed”, the basis for which is gathered from numerous sources (Randall 1998).

3.5.2 New Zealand

Williams et al. (2000) list the probable impacts of invasive weeds on saline wetlands as being:

- changes in vegetation structure and composition,
- suppression of native species regeneration,
- facilitation of other weed invasion,
- changes in plant and animal biodiversity,
- altered animal/bird behaviour,
- modified hydrological and nutrient regimes, and
- changes in erosion and deposition.

Spartina

In New Zealand, P. vaginatum *appears to have similar impacts to* Spartina*.*

These impacts have been well documented. *Spartina*:

- out-competes native estuarine plant species changing the composition and structure of the natural vegetation associations, and endangers threatened species populations (Nuttall 1993);
- has high stem and root density which excludes burrowing fauna, such as cockles (*Austrovenus stuchburyi*) (Nicolls 1998);
- reduces access to the food and roosting sites of birds (poorly used by estuarine birds – Owen 1994);
- alters fish spawning and feeding grounds (e.g. flounder), (Nuttall 1994);.
- alters estuarine hydrology patterns from the accumulation of sediments, and the associated ramifications of this (e.g. increased flooding which leads to further deposition of fine silts in the estuary, which may be to the detriment of filter-feeding shellfish and the growth of estuarine vegetation) (Swales et al. 2000, Nuttall 1993).

Thanneiser and Holland (1994, in Strahan 1997) note that “New Zealand salt marshes lack the thick matted swards of salt marsh grasses… commonly found in the Northern hemisphere”. *Spartina* is a common Northern hemisphere grass that was introduced to New Zealand for its sediment trapping ability (Partridge 1987, in Strahan 1997).

These combined ecological, and hydrological effects can also compromise the cultural, spiritual, recreational, aesthetic and economic values that people may hold for these estuaries.

P. vaginatum also has the additional following characteristics:

Flora

No research has been found, apart from the present growth studies by Cameron (2001), on the competitive nature of *P. vaginatum* in relation to native New Zealand wetland plants. Our field observations suggest *P. vaginatum* is a significant threat to estuarine ecological values (see Figures 1-9), however without robust scientific studies this can not be substantiated.

P. vaginatum has been noted growing amongst mangroves, rushland, sea meadow and back-swamp zones/communities (Graeme 1997, 1998a, 1998b, 1999; and Kendal 2000).

P. vaginatum's niche crosses the entire zone of many sea meadow species (e.g. *Samolus repens, Selliera radicans)* and therefore could potentially displace these species entirely by overtopping them (see Figure 6).

P. vaginatum is noted as being an proficient climber and can climb into and up rushes, manuka, and saltmarsh ribbonwood (see Figure 9).

Uncommon/Threatened plant species

Reid (1998) notes that out of all the threatened plants in New Zealand, those inhabiting damp, coastal, and seral habitats are most at risk from weeds. Grasses are the most common group of weeds to jeopardise threatened plants, through competing with adult plants and hindering regeneration (Ibid).

P. vaginatum seems to be a greater threat to overall native community assemblages than individual species, although there are a few species that should be noted. These are:

- *Eleocharis neozelandica* – this tiny endemic sedge is found on damp coastal sand and tidal creek beds of localised sites in the North and South Islands (Johnson & Brooke 1998). It is a class B (second priority) threatened plant (Tisdall, 1994). As the range of this species is not restricted to the range of *P. vaginatum* it would only be regionally threatened by *P. vaginatum.*

- *Mimulus repens* – is a creeping, semi-succulent herb found in coastal damp sand or wet muddy margins of estuaries and lagoons. It is found in both the North and South Islands but is localised especially in the North Island (Johnson & Brooke 1998).

- *Suadea novae-zelandiae* – is an endemic scrambling succulent leaved subshrub found in salt marshes within the tidal range, and on coastal cliffs and gravels. It is present in both North and South Islands, but localised in the North Island (Johnson & Brooke 1998). Only two records are known for the Coromandel Peninsula. One small population forms part of a sea meadow patch in Manaia harbour (Graeme, 1998b), and the other occurs on a shingle beach at the Waiorotoroto River mouth (Humphreys & Tyler, 1990).

Fish

The possible effects of *P. vaginatum* on the role of estuaries as fish nurseries and feeding grounds is largely unknown. NIWA is currently undertaking a research programme to investigate the actual role estuaries play as nursery and feeding grounds for marine fish species (Morrison et al*,* 2000). Preliminary results suggest that only certain fish species utilised the higher tidal flats, and many stayed in or nearer the channels. When this research is completed it will provide resource managers with a risk-assessment model to assess likely consequences of habitat loss in estuaries. The results will also determine which fish species are likely to be threatened by *P. vaginatum* in the upper half of the inter-tidal zone.

Figure 1: *P. vaginatum* dominates the foreground of this photo. Graham's Stream arm of Tairua Harbour. June 2000. *Hamish Kendal*

Figure 2: **A clump of raupo surrounded by *P. vaginatum*. Graham's Stream arm of Tairua Harbour. June 2000. *Hamish Kendal***

Figure 3: ***P. vaginatum* lines the banks of this drain in the Graham's Stream arm of Tairua Harbour. June 2000. *Hamish Kendal***

Figure 4: ***P. vaginatum*** **surrounds this old dead mangrove in Hodges arm of Whitianga Harbour. January 1999.** ***Meg Graeme***

Figure 5: **Between the mangroves and coastal forest,** ***P. vaginatum*** **forms a dense lush band at high tide. Onewhero Scenic Reserve. January 1999.** ***Meg Graeme***

Figure 6: **This photograph shows *Sarcocornia quinqueflora, Selliera radicans*, and *Samolus repens* intermingle with *P. vaginatum.* Whitianga Harbour. January 1999. *Meg Graeme***

Figure 7: ***P. vaginatum* edges coastal flax along Whangapoua Point. December 2000. *Meg Graeme***

Figure 8: ***P. vaginatum* extends from above MHWS down to below the water mark of the Pungapunga River lagoon, Whangapoua. December 2000. *Hamish Kendal***

Figure 9: ***P. vaginatum* dominating the Pungapunga River banks (upstream of tidal lagoon) and climbing up through *Leptospermum scoparium*. November 2000. *Hamish Kendal***

3.6 Control Measures

There has been no documented control of *P. vaginatum* in New Zealand. However, there has been considerable review of *Spartina* control in New Zealand and internationally (e.g. Shaw 1999). The *Spartina* work is applicable to the investigation for control of *P. vaginatum* should its control become warranted in New Zealand.

Shaw (1999) has reviewed control options for *Spartina* which include grazing, physical removal, smothering, cutting, steam treatment, burning, biological control, and herbicides. Of these control methods, the use of herbicides has been the most successful, with Gallant® (haloxyfop, Extoxnet[2] 1995) being the most commonly used herbicide in New Zealand recently. These control options would need to be reviewed again for *P. vaginatum*, although it would seem that its ecological similarities with *Spartina* are enough to consider Gallant as the most appropriate control method (taking into consideration other management issues).

The selective eradication of *Spartina alterniflora* with Gallant was successful in Ohiwa Harbour (Shaw & Gosling 1997). Similar control programmes elsewhere in New Zealand are focussing on other aspects of the effects of *Spartina* control, such as rates of plant decomposition and sediment dispersal (Swales et al. 2000).

Champion (1998) screened a variety of herbicides on a selection of introduced and native freshwater plant species (including some rare species). Native estuarine species and *P. vaginatum* were not covered in this study, although species of genus's represented in estuaries and *Paspalum distichum* were assessed. *P. distichum* was selectively controlled amongst the native species with the herbicides haloxyfop and clethodim. A rare grass of coastal swamp habitats (although not limited to these areas) *Deschampsia caespitosa* was affected by all herbicides except the clethodim application. Of note is the elimination of native species in the genus' *Carex, Isolepis, Crassula, Plantago and Juncus* by haloxyfop and clethodim in this experiment. Species of these genus' are represented in estuarine vegetation where *P. vaginatum* occurs. Further investigations of the selective herbicides was considered warranted to determine selective control methods in wetlands amongst rare plants, and field trials were planned for 1998-1999 (Champion 1998). This work provides the basis for further research into the selective control of *P. vaginatum* amongst the native estuarine species it occurs with.

Roper et al. (1996, in Shaw 1999) found that shellfish could accumulate haloxyfop (Gallant's active ingredient), although levels diminish by about 50% per day. A short term ban on harvesting shellfish in the surrounding area was therefore recommended following spraying with Gallant. Shaw (1999) believes further field assessments of the effects of Gallant on shellfish are warranted.

Roberts (1992, in Shaw 1999) has assessed the impacts of Gallant on sediment-dwelling invertebrates, native fish, and non-target plants of Waimea Inlet, Nelson. Gallant did not affect any of these plants or animals. However, there would be a different suite of biota in the northern half of the North Island where *P. vaginatum* occurs which this assessment does not fully cover.

Native saline-tolerant grass species in particular need to be taken into account when considering the control of any adventive saline-tolerant grass species with a grass-specific herbicide. For example, *Puccinellia stricta* is found south of Auckland in saltmarsh, and sandy or stony ground at high tide levels (Edgar & Conner, 2000). Also two endemic *Zoysia* spp. grow in coastal areas, and have been previously mis-identified as *P. vaginatum* at the Waikato University herbarium.

[2] See this website for detailed information about haloxyfop.

P. vaginatum's is present higher up the tidal zone where it often grows amongst other native vegetation, compared with *Spartina* which tends to form relatively monospecific stands. This has operational and management implications for the control of *P. vaginatum* which need to be further investigated.

Grazing does not seem to be a viable option for the control of *P. vaginatum* as it would only encourage an increased root and stem density in the pasture (as documented in the low mowing of golf turfs, Duble 1996), which further excludes the possibility of native vegetation establishing. Grazing would also be likely to spread grass fragments enhancing vegetative dispersal, and possibly via seed passing through the gut.

The potential flow-on effects of control methods need to be kept in mind when designing a control programme for example inanga spawning, bank erosion and sediment release.

The inanga relationship with *P. vaginatum* has implications for the control of the grass, and needs to be investigated more fully. Should there be an active relationship between *P. vaginatum* and inanga then control activities may need to be appropriately timed and staged to avoid the peak spawning season of Autumn. Consideration should be given to restoring the native vegetation which inanga spawn in[3] where *P. vaginatum* is controlled.

3.7 Resource Values

The use of *P. vaginatum* as a utility grass brings many advantages for managers of sports turfs, amenity parks, and roadsides. A major advantage is the considerable cost-savings of not having to irrigate with fresh water, and control weeds. It is for these reasons that there may be pressures for it to be increasingly used in these situations in New Zealand.

3.7.1 Sports turf

Seashore paspalum has been used since the mid-1900s as a salt tolerant turf, but systematic improvement of the species as a turf has been relatively recent (Floridaturf 2000). The variability from ecotypes from around the world is now being experimented with to develop characteristics of the grass for its use as a golf turf in saline environments (Hall 1994).

There is a wealth of literature regarding the use of halophytic grasses as sports turfs, particularly for golf courses. Halophytic grasses are utilised when there is a saline influence on the soil, or as a means of weed control by irrigating the halophytic grasses with saline water (Couillard & Wiecke 1998). *P. vaginatum* is being maintained on golf courses in Asia, South Africa, China, Middle East, South America, Hawaii, the Caribbean Islands, and in the United States (Duncan & Carrow 2000). Duble (1996) notes that it is used as a turf in Australia and New Zealand. To what extent *P. vaginatum* is used in golf courses of the upper half of the North Island of New Zealand has not been determined. *P. vaginatum* and other halophytic grasses are commercially available in the United States[4].

P. vaginatum is being touted as the environmentally sound turf grass for the future by some of its proponents (eg. Duncan 1996), partly due to the reduction in herbicide use where saline irrigation serves as weed control. However, this does not limit the use of fungicides or pesticides that a turf manager may use on a *P. vaginatum* turf (see Duncan & Carrow 2000).

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[3] Inanga would have originally spawned amongst leaf litter, twigs and rush stalks beneath plants such as *Coprosma propinqua*, *Plagianthus divaricatus,* and *Typha orientalis* (Mitchell 2000).

[4] E.g. see: Environmental Turf Solutions, Pineland, Florida – distributors of halophytic turfs. www.etsturf.com

The use of saline water as an alternative to herbicide on *P. vaginatum* turf may have adverse affects on the riparian margins and water courses, where non-target plants and animals are affected by the higher salinity.

3.7.2 Other uses & values

Other uses of *P. vaginatum* reported by Duncan & Carrow (2000) include:

- planting *P. vaginatum* as a buffer along environmentally sensitive sites to help absorb land run-off;
- as bioremediation of unproductive soils (e.g. mine-spoil areas in South Africa);
- for sand dune stabilization and coastal erosion control. It can be used to rehabilitate flood prone areas or physically degraded soils.

Hall (1994) also discusses the use of *P. vaginatum* along road sides that are 'salted' where ice is a problem.

These additional uses are generally not appropriate in New Zealand where native species can be used as an alternative to exotic species. This provides additional native habitat benefits and does not contribute another potential weed problem.

P. vaginatum is also used as a pasture grass in saline lands in Australia, where they are not drought affected (Agriculture Western Australia 1999). This however is not a potential use in New Zealand as the few inland salt pan areas are not within the climatic range of *P. vaginatum*. However, saline reaches of waterways invaded by *P. vaginatum* may be grazed, and farmers may therefore value it.

3.7.3 Inanga

P. vaginatum may provide spawning habitat for inanga (*Galaxiid maculatus).* The inanga spawning zone is within the zone of tidal influence, but also extends upstream from the limits of saltwater penetration (Mitchell 1994). Smaller tributaries are important for inanga spawning (Ibid).

Mitchell (2000) contributed the following information about the relationship between inanga and *P. vaginatum.* Inanga spawn at about the upstream limit of penetration of the salt-water wedge. They spawn in a freshwater layer which is just beginning to float on the saltwater layer. Throughout New Zealand, this zone is often occupied by introduced plant species[5]. If *P. vaginatum* provides a thick blanket of fibrous roots and dead stems, then it may be accepted as spawning habitat by inanga. However, the high osmotic pressures that develop on saline soils over the neap tide period are a factor which will limit spawning in the saline zone.

McDowall (1990) reports that tests have shown inanga eggs to develop and hatch equally well in fresh or salt water. It seems then that the upper limit of *P. vaginatum* would overlap with the lower limit of the inanga spawning zone. Above the saltwater limits *P. vaginatum* is out-competed by other vegetation, and is therefore not an issue for spawning. In comparison the lower tidal niche of *Spartina* spp. makes it an unlikely candidate for inanga spawning ground (Mitchell 2000).

There could be a conflicting factor with the control of *P. vaginatum* where there is inanga spawning, although in most situations inanga may have alternative spawning habitat above the tidal zone if it were controlled. Consideration could be given to thickly revegetating any bare areas left from *P. vaginatum* control when there is no alternative spawning habitat available.

Other *Galaxiid* species spawn further upstream (McDowall 1991), and therefore will not be affected by *P. vaginatum.*

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[5] *Festuca arundanacea, Glyceria maxima, Agrostis stolonifera, Juncus gregiflorus, Mimulus guttatus, Paspalum paspaloides, Lotus pedunculatus, Pennisetum clandestinum*

3.8 Other potential weed species

Environment Waikato is interested in prior knowledge of invasive plant species that may present problems in the Region.

The potential for invasion of New Zealand estuaries by introduced saline-tolerant plant species is enormous. Bicknell (1998) alone lists 155 salt-tolerant plants (mainly native to Australia) for the revegetation of saline sites in Australia. Any of these species, or other salt-tolerant species from around the world have the potential to become weeds of estuaries in New Zealand should they find their way here.

3.8.1 Grasses

In New Zealand, the total of naturalised grass species (226) exceeds that of the native grass species (188) (Edgar & Conner, 2000), and Adam (1990) lists *Poaceae* as one of four plant families that are the main weeds of estuaries. There is potential for other saline-tolerant grasses to contribute to the threat of New Zealand's estuaries, particularly where there is a use for the grasses that encourages their import and establishment.

New Zealand estuaries do not have native representatives of vigorous halophytic grasses, meaning that this group has a high potential invasiveness.
Adventive saline-tolerant grasses that could possibly pose a problem in estuaries and harbours of the Waikato Region include[6] (from Edgar & Conner 2000, Johnson & Brooke 1998):

- *Elytrigia pycnantha* (sea couch): Coastal on foreshore waste land, consolidated sand near dunes, mudflats and roadsides. North Auckland, Bay of Plenty, Gisborne, Hawke's Bay, Wellington, Canterbury (Edgar & Connor 2000).

- *Carex divisa*: Often in brackish water on the coast just above high tide level. Kerikeri Inlet, near Warkworth, Auckland city, Miranda, Kaiaua, Tauranga, Havelock, Maniototo Plain (Healy & Edgar 1980).

- *Critesion hystrix:* Found in low-lying coastal saline flats and inland salty sites throughout New Zealand.

- *Puccinellia distans*: Found in salt marshes, and salt pans in temperate regions throughout New Zealand.

- *Puccinellia fasciculata*: Found in salt marshes and salt pans throughout New Zealand.

- *Parapholis incurva* (sickle grass): Usually coastal, on sand dunes, on shingle and rocks near water's edge, and in saline estuaries, mudflats, and reclamation areas. North Island (north and south Auckland, scattered further south) and South Island (Edgar & Connor 2000).

- *Paropholis strigosa*: Grows in salt marshes and mud flats around Auckland and Coromandel.

- *Polypogon monspeliensis:* in salt marsh throughout the North Island and inland Otago.

- *Sporobolus virginicus:* Edgar & Conner (2000) have one record of its presence in New Zealand.

[6] This list has been restricted to adventive saline-tolerant grasses, as this report's brief is not to undertake a full survey of all plant species that are or could possibly be weeds in New Zealand estuaries.

- *Distichlis spicata:* collected once near Christchurch in the 1870's. No other records.

DePew (1998) exclaims the ecological and physiological virtues of *Sporobolus virginicus* (seashore dropseed) and *Distichlis spicata* (salt grass) for golf turfs in areas of saline water, or salt-affected land. *D. spicata* is of particular concern for New Zealand as it tolerates higher salinity and cooler temperatures than *Paspalum vaginatum*. It may already be utilised as a golf turf in New Zealand given its popularity overseas.

There are many other companies which market halophytic grasses, such as Saltgolf.com: "Our new ecotypes of Seashore Paspalum, (*Paspalum vaginatum*) Seashore Dropseed, (*Sporobolus virginicus*) and Saltgrass (*Distichlis spicata*) are ideally suited for golf course greens, tees, fairways and roughs on the most challenging salt affected sites." (Saltgolf 2000).

Owen (1994) identifies *Elytrigia pycnantha* (sea couch) with *Spartina* as a concern in the Ohiwa Harbour, where both weeds are reducing the area available to estuarine birds. The *Spartina* has since been eradicated (Shaw & Gosling 1997). *E. pycnanatha* is listed as a habitat code in the New Zealand estuaries monitoring project (Cawthron, 1999).

Zedler & Rea (1998) highlight the need for strategic ecological studies to determine the management of wetland weeds. They highlight an example where a weedy grass (*Polypogon monspeliensis*) has dominated native halophytic wetland species where irrigation has increased freshwater runoff into a naturally saline environments. The grass may be controlled by increasing the salinity in this situation where it favours the native halophytic species.

3.8.2 Non-grasses

Ogle (2000) suggests that the following non-grass species are also potential (or presently) halophytic weed species in New Zealand[7]:

- *Schoenoplectus californicus:*[8] This species is thriving at Taumarunui where it was planted in a sewage treatment pond. The material came from the Waikato River estuary, presumably being mistaken for the native *S. tabernaemontani.* There are plans to eradicate the population at Taumarunui (Ogle 2000).

- *Juncus acutus* (sharp rush): A weed just above the *Spartina* zone in the Manawatu estuary. It forms a monoculture that is almost impenetrable (Ogle 2000). North Auckland – Tokerau Beach, Kaeo, Taupo Bay, Whangaroa Inlet, Tinopai, Pouto, Piha; Wellington – near Foxton and Te Horo Beach near Otaki. Grows in conjunction with *Juncus kraussii* (Healy & Edgar 1980).

- *Schedonorus phoenix* (tall rush, = *Festuca arundinacea):* An abundant harmful species. North and South Islands. Widespread along banks of rivers and streams, and on saltmarsh edges (Edgar & Connor 2000).

- *Plantago coronopus* (buck's horn plantain): Extensively naturalised in coastal areas (sand and mud flats in and around estuaries and lagoons). North and South Islands (Webb et al. 1988).

- *Atriplex prostrata* (orache): Very common in dune hollows, also mudflats, coastal streams and shingle banks. North and South Islands (Webb et al. 1988).

[7] This list is not exhaustive.
[8] see New Zealand Journal of Botany 36(3):319-328

- *Aster subulatus* (sea aster): Well established in warm coastal areas. North Island & South Island (Picton and Blenheim) (Webb et al. 1988).

- *Juncus gerardii:* Found on saline flats forming large patches in salt marshes. Auckland city, Miranda, Athenree, Tauranga, Porirua Harbour, Wellington Harbour, and various places throughout the South Island (Healy & Edgar 1980).

- *Tamarix chinensis* (Chinese tamarisk): Occasionally found in river beds, estuaries and sand dunes. North Island (Auckland, Opotiki) and South Island (Webb et al. 1988).

4 Discussion & Recommendations

4.1 Research Directions

Williams & Timmins (1990) acknowledge that there is little understanding of the grasses (which includes *P. vaginatum*) that are abundant in wetlands of the Auckland area, as identified by Esler & Astridge (1987). The following recommendations for research directions aim to help increase our understanding of *P. vaginatum*. They are based on knowledge gaps identified in this report. There are two broad categories where research is required:

1) research to help determine the 'weediness' of *P. vaginatum*; and
2) research into management options should control become warranted.

Note: Much of the research already undertaken for *Spartina* spp. will be applicable to understanding the ecology, and developing management plans, for *P. vaginatum.*

1) Aspects of *P. vaginatum'*s requiring research to determine its weed status:

   BIOLOGICAL CHARACTERISTICS:
   a) Distribution
   b) Reproductive mechanisms
   c) Dispersal mechanisms
   d) Growth rates
   e) Root morphology

   ECOLOGICAL CHARACTERISTICS:
   a) Interactions with native plants and animals
   b) Conditions for successful invasion
   c) Species/communities at risk
   d) Physical/hydrological effects

2) Research into management/control of *P. vaginatum*:

   a) Identify management options (i.e. do nothing, site-led control, species-led control)
   b) Potential for eradication
   c) Identification of priority areas
   d) Land tenure / cross boundary issues
   e) Research selective control options
   f) Determine direct and indirect biological and physical effects of control
   g) Investigate on-going management options
   h) Investigate the resource values of *P. vaginatum* (which may see its (re-)introduction)
   i) Research international management of *P. vaginatum*

P. vaginatum can easily be confused with other species (*P.distichum* and *Zoysia* spp.). An awareness and correct identification of *P. vaginatum* by field researchers is required to ensure a true picture of its distribution is gained.

Should field investigations be undertaken, the following tidal waterbodies are already heavily infested with *P. vaginatum* and would be suitable study sites: Waikawau estuary, Pungapunga Stream (Whangapoua), Tairua Harbour, Taputapuatea Stream (Whitianga) (see Figures 1, 2, 3, 8, & 9).

The on-going management of *P. vaginatum* will be important to ensure that the areas controlled for the weed are not reinvaded. Options such as revegetation with dense native plantings following removal of *P. vaginatum* require investigation.

Finlayson et al. (1997) propose a management and research strategy for rehabilitation and monitoring of weed-affected wetlands. A strategy such as this should be employed for *P. vaginatum*:

- Quantify distribution
- Monitor adverse ecological changes
- Ascertain introduction, use and spread
- Develop control programs
- Undertake ecological risk assessments of control techniques

4.2 Management Options

Wetlands and coastal habitats are amongst the community types most vulnerable to weed invasions as they are generally low-stature communities and are often small, narrow, disturbed remnants (Timmins & Williams 1991). It seems unlikely that *P. vaginatum* would be overcome by natural successional processes, particularly in areas where there is no naturally occurring native vegetation. Therefore, there is a need for management intervention to safeguard the ecological values of these habitats. Indications are that *P. vaginatum* would be difficult to control as a species-led strategy, and therefore site-led control in areas of significant conservation value may be a more appropriate strategy.

Land ownership around the coast is determined by the MHWS level. DOC administers the foreshore and seabed within the CMA[9] under the Foreshore & Seabed Endowment Revesting Act 1991. Land above MHWS is in private or public ownership (e.g. DOC or local authority). This complicates management of *P. vaginatum* where it crosses these boundaries. Regional Councils administer Regional Pest Management Stategies (RPMS) which define the legal control requirements for pest species within each region. *P. vaginatum* is not presently covered by any RPMS's.

The Department of Conservation has produced a database for ecological weeds on land administered by the Department (Owen 1996, reproduced in Williams 1997). This ranks weed species for management priority through two scoring systems:

1) weed effects on natural systems (EOS), and
2) weed biological success ratings (BSR).

Although there is no listing for *P. vaginatum*, the entries for the freshwater equivalent *P. distichum* provide a guide to a weediness score for *P. vaginatum*.

For *P. distichum* the EOS = 9 (out of a possible 9), and BSR = 15 (out of a possible 21). A total score of 24 ranks highly amongst the weediness rankings of other ecological weeds in this table. This gives an indication of the weediness of *P. vaginatum*, although when more is known about the ecological effects of *P. vaginatum* a definitive EOS/BSR score can be assigned. Timmins (1997) recommends that the EOS and BSR scores should be used to help determine priorities for research.

Areas of Significant Conservation Value (ASCV), as defined in regional plans, will be useful in determining priority areas for *P. vaginatum* management. There needs to be collaboration between DoC, Regional Councils, and private landowners to develop a research strategy and a wider management strategy. This should take into account other local management plans.

Timmins (1997) believes that new methods of weed control need to be tailored to suit the varying situations that weeds occur in, and to be appropriate for the native communities. This applies to *P. vaginatum* where it crosses land/sea boundaries and intermingles with native vegetation.

[9] The Coastal Marine Area (CMA) is defined as the area from MHWS out to the 12 nautical mile territorial limit.

Regional Councils[10] allow the use and discharge of hazardous substances (e.g. herbicides) in the CMA through resource consent application. When applying for resource consent for undertaking control of *P. vaginatum*, the side-effects of the control method needs to be taken into account. Issues such as sediment movement, and the impact on non-target plant species and animals will need to be documented.

The use of *P. vaginatum* as a resource will need to be surveyed, and areas identified where resource use and environmental objectives potentially conflict. For example the Regional council will need to assess development of saline marginal or 'waste' land where introduced halophytic grasses are proposed to be used. This will most likely be golf course developments.

There is not enough known about *P. vaginatum* to clearly identify its threats to the estuarine ecosystems of northern North Island. The evidence we have compiled here suggests that it may be a significant threat, and it therefore requires further investigation. A thorough knowledge of *P. vaginatum'*s biology and ecological effects is required before effective management strategies can be developed.

[10] For the Waikato Region, this is pending acceptance of a proposed variation to the Regional Coastal Plan.

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Appendix 1: Letter to experts

NATURAL SOLUTIONS
Marine & Terrestrial Ecologists
RD 2, COROMANDEL
Ph: (07) 866 0770
Email: natural.solutions@wave.co.nz

10 November 2000

To Whom It May Concern,

Paspalum vaginatum

We are conducting a survey of literature and expert knowledge about *Paspalum vaginatum* on behalf of Environment Waikato. This grass appears to be a problem in estuaries in the upper half of the North Island. However, there is little information available about this species.

We would appreciate any contribution you could make to the knowledge of this grass in New Zealand. The attached information sheet gives a brief description of *P. vaginatum,* and the type of information we require.

The results of this survey will be widely available. Please let us know if you would like a copy of the final report.

Also, any information about other potential estuarine weed species (except *Spartina*) of the Waikato region would be appreciated.

Thank you.

Yours sincerely

Megan Graeme & Hamish Kendal
NATURAL SOLUTIONS

(Appendix 1 continued)

***Paspalum vaginatum* – a weed of New Zealand estuaries?**

Paspalum vaginatum (seashore/saltwater paspalum) is a warm climate perennial grass that is native to tropical and subtropical regions of America. It has been introduced to New Zealand as a pasture and golf turf species for its tolerance to high salinity. *P. vaginatum* spreads vegetatively by stolons and possibly by seed.

P. vaginatum is found in brackish water around the margins of river mouths and estuaries. It is reported as being widespread in many estuaries of the Coromandel Peninsula and Bay of Plenty (see photos pg. 4).

Information on this species in New Zealand is limited, although the apparent impacts of *P. vaginatum* on the estuarine environment are of concern.

Environment Waikato has commissioned a survey of literature and expert opinion to determine the actual and /or potential threats of *P. vaginatum* to the coastal environment, and options for management. The purpose of this letter is to gain expert knowledge on *P.* vaginatum so that knowledge gaps can be determined and research priorities identified.

Weed potential

To the best of our knowledge there have been no studies undertaken in New Zealand on the effects of *P. vaginatum* on estuarine fauna and flora, hydrodynamics or sedimentation rates. Therefore it is difficult to state whether this grass is a problem or not.

Anecdotal evidence would suggest that it is a significant threat to estuarine ecological values:

- *P. vaginatum* occupies a niche that overlaps with *Spartina* spp. but extends higher up to the extreme high water spring mark. Like *Spartina* spp., *P. vaginatum* seems to cause sediment build-up and change open sandy/mud flats into vegetated areas.

- *P. vaginatum* competes with other estuarine plants. It grows amongst mangroves, sea meadow communities, and sometimes into the rush zone. Of particular concern is *P. vaginatum*'s competitiveness with native low-growing sea meadow species including *Samolus repens*, *Selliera radicans*, and *Sarcocornia quinqueflora*. These species often inhabit only a thin band of the saltmarsh on estuary margins, and are therefore at risk of being completely out-competed by *P. vaginatum.* In American turf literature *P. vaginatum* is praised for producing uniform turf with a complete absence of other grass species. This reflects the competitiveness and salt tolerance of *P. vaginatum* in saline conditions, which is not beneficial to native estuarine plant communities.

(Appendix 1 continued)

Knowledge – Can you help?

To make an assessment of the actual and potential threats of *P. vaginatum* we need information about this species in New Zealand.

We would appreciate anecdotal or scientific information about *P. vaginatum*, especially in the following categories:

- General observations e.g. where have you seen ***P. vaginatum***
- Biology/ecology of the species
- Impacts on native ecosystems
- Control measures
- Any value of the species

If you know of any literature on *P. vaginatum* we would appreciate you sending us the references.

Any information you can give us will be gratefully received. Would you mind us following up any information by phoning you?

Please do not hesitate to call us, or send your reply to:

NATURAL SOLUTIONS
Marine & Terrestrial Ecologists
RD2
COROMANDEL
Ph: (07) 866 0770
Email: natural.solutions@wave.co.nz

Thank you for your help,

Megan Graeme & Hamish Kendal
NATURAL SOLUTIONS

Appendix 2: Herbarium collection notes

Auckland War Memorial Museum Herbarium collection notes for *P. vaginatum* (Rogan 2000):

AK 109331 Eco.Code 06.01
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland and Islands Ecological Region and District, salt marsh at Waikare, Kawakawa-Russell Road Q05 2--5-- Lat. 35 2- S Long. 174 1- E Coll. R Cooper Date 08 04 1966 Det. R Cooper Date

AK 109851 Eco.Code 09.01
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Rodney Ecological District, Leigh R09 72-44- Lat. 36 17 S Long. 174 48 E Coll. L B Moore Date 17 02 1934 Det. Date. Sandy flat about high tide level in small creek. Equal quantities with Salicornia

AK 109852 Eco.Code 06.02
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland Ecological Region, Taranga Ecological District, South West Chicken [=Araara Island] R07 64-87- Lat. 35 54 S Long. 174 42 E Coll. L B Moore, L M Cranwell Date 02 12 1934 Det. Date

AK 109853 Eco.Code 11.01
Paspalum vaginatum Sw.
New Zealand, North Island, Waikato Ecological Region, Meremere Ecological District, Waikato River R13 Lat. 37 2- S Long. 174 4- E Coll. L M Cranwell Date 01 1932 Det. A Chase Date

AK 109854 Eco.Code 10.03
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Colville Ecological District, Coromandel Peninsula at Port Charles T10 3--1-- Lat. 36 32 S Long. 175 28 E Coll. L M Cranwell Date 06 04 1931 Det. A Chase Date Depauperate

AK 109855 Eco.Code 09.08
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Hunua Ecological District, Maraetai Beach S11 92-78- Lat. 36 53 S Long. 175 02 E Coll. J H Ronaldson Date 26 12 1934 Det. A Chase Date Damp rocky foreshore

AK 11131 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Waitemata R11 Lat. 36 5- S Long. 174 3- E Coll. T Kirk Date Det. A Chase Date Herbarium T Kirk

AK 127166 Eco.Code 10.06
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Tairua Ecological District, Tairua T11 64-61- c.1 m Lat. 37 01 S Long. 175 51 E Coll. R C Cooper Date 17 04 1967 Det. R C Cooper Date Nom. rev. August 1999. High water mark

AK 1277 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Harbour R11 Lat. 36 5- S Long. 174 4- E Coll. T F Cheeseman Date 03 1880 Det. A Chase Date Hackel number 1006 Remounted over two sheets (AK 1277 and 212334), April 1993 Herbarium T F Cheeseman

AK 1278 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Harbour R11 Lat. 36 5- S Long. 174 4- E Coll. T F Cheeseman Date Det. A Chase Date ex Herbarium T F Cheeseman

AK 135323 Eco.Code 10.06
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Tairua Ecological District, Mercury Bay, estuary of Ake Ake River T11 53-86- 0 m Lat. 36 47 S Long. 175 47 E Coll. A E Wright 589 Date 14 08 1974 Det. A E Wright Date 08 05 1978 Nom. rev. August 1999

AK 136945 Eco.Code 10.04
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Mercury Islands Ecological District, Great Mercury Island, just above high tide around rocky coast T10 6--0-- Lat. 36 37 S Long. 175 48 E Det. A E Wright Date

AK 138571 Eco.Code 10.03
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Colville Ecological District, Motutapere Island S11 27-88- Lat. 36 47 S Long. 175 26 E Coll. A E Wright 474 Date 08 11 1975 Det. A E Wright Date 08 05 1978 Growing amongst boulders at high tide level. Nom. rev. August 1999

AK 139631 Eco.Code 04.01
Paspalum vaginatum Sw.
New Zealand, North Island, Aupouri Ecological Region and District, off Karikari Peninsula, Moturoa Group, Green Island O03 43-13- 2-3 m Lat. 34 46 S Long. 173 21 E Coll. A E Wright 1255 Date 14 05 1976 Det. A E Wright Date Growing in rock crevices on exposed coastal rocks

AK 139638 Eco.Code 04.01
Paspalum vaginatum Sw.
New Zealand, North Island, Aupouri Ecological Region and District, off Karikari Peninsula, Moturoa Group, Rocky Island O03 47-13- 2-3 m Lat. 34 46 S Long. 173 23 E Coll. A E Wright 1259 Date 15 05 1976 Det. A E Wright Date Growing on edges of brackish water pools among exposed coastal rocks

AK 139665 Eco.Code 04.01
Paspalum vaginatum Sw.
New Zealand, North Island, Aupouri Ecological Region and District, off Karikari Peninsula, Moturoa Group, Sugarloaf Island O03 44-12- 2-3 m Lat. 34 46 S Long. 173 21 E Coll. A E Wright 1243 Date 14 05 1976 Det. A E Wright Date Growing in crevices on exposed coastal rocks

AK 139738 Eco.Code 04.01
Paspalum vaginatum Sw.
New Zealand, North Island, Aupouri Ecological Region
and District, off Karikari Peninsula, Moturoa Group, Whale Island O03 45-12- 3m
Lat. 34 47 S Long. 173 22 E Coll. A E Wright 1188 Date 10 05 1976 Det. A E Wright
Date Saltmarsh community in brackish water among coastal rocks

AK 140140 Eco.Code 05.03
Paspalum vaginatum Sw.
New Zealand, North Island, Western Northland Ecological Region, Tutamoe Ecological District, Waipoua State Forest, shoreline below Kawerua Hut O06 50-18-
Lat. 35 37 S Long. 173 26 E Coll. A E Wright 1411 Date 02 09 1976 Det. A E Wright
Date

AK 141231 Eco.Code 05.02
Paspalum vaginatum Sw.
New Zealand, North Island, Western Northland Ecological Region, Hokianga Ecological District, North Hokianga, Te Rewa Point, salt marsh beside road O06 45-39- Lat. 35 27 S Long. 173 23 E Coll. A E Wright 1648 Date 17 01 1977 Det. A E Wright Date

AK 144034 Eco.Code 05.03
Paspalum vaginatum Sw.
New Zealand, North Island, Western Northland Ecological Region, Tutamoe Ecological District, Waipoua State Forest: Amongst boulders on upper beach below Kawerua Hut O06 50-18- Lat. 35 38 S Long. 173 26 E Coll. A E Wright 2659 Date 13 05 1978 Det. Date Very few flowering specimens seen

AK 149605 Eco.Code 06.01
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland and Islands Ecological Region and District, Cavalli Island Group, Panaki Island P04 979914 Lat. 34 58 S Long. 173 56 E Coll. A E Wright 3062 Date 05 01 1979 Det. A E Wright Date Large clumps in disturbed ground around collapsed petrel burrows at east end of island Offshore Island Research Group Expedition December 1978 - January 1979

AK 149685 Eco.Code 06.01
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland and Islands Ecological Region and District, Cavalli Islands, Motukawanui Island P04 9--8--Lat. 35 00 S Long. 173 57 E
Coll. A E Wright 3106 Date 06 01 1979 Det. A E Wright Date Growing in sand on upper beach Offshore Island Research Group Expedition December 1978 - January 1979

AK 151269 Eco.Code 03.01
Paspalum vaginatum Sw.
New Zealand, North Island, Te Paki Ecological Region and District, North Cape, saltmarsh on shores of Parengarenga Harbour at mouth of Te Wharau Stream N02 086436 0m Lat. 34 31 S Long. 172 58 E Coll. A E Wright 3265 Date 18 11 1979
Det. Date Growing in sand bank

AK 153355 Eco.Code 10.06
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Tairua Ecological District, Coromandel, Hot Water Beach T11 62-75- c.1 m Lat. 36 53 S Long. 175 49 E Coll. R O Gardner 2920 Date 21 02 1981 Det. Date Open swards among small boulders in seepage at base of sea cliffs.High water mark. Nom.rev. August1999

AK 153602 Eco.Code 09.01
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Rodney Ecological District, Hatfield's Bay .R10 62-14- 0 m Lat. 36 34 S Long. 174 41 E Coll. G Straka 300 & S J * Date 04 1981 Det. Date * Straka Growing on bank of tidal estuary. Covered by salt water at high tide. Nom. rev. August 1999 DUPLICATE sent to: BISH, CM, Z

AK 153766 Eco.Code 10.04
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Mercury Islands Ecological District, Cuvier Island, growing on boulders at top of beach in Northwest Bay T09 59-25- Lat. 36 26 S Long. 175 46 E Coll. A E Wright 3590 Date 25 05 1980 Det. E Edgar Date 24 03 1986 DUPLICATE sent to: AKU, BISH Auckland University Field Club Scientific Expedition May 1980

AK 156739 Eco.Code 06.01
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland and Islands Ecological Region and District, Bay of Islands, Motukiekie Island: Kiekie Bay Q05 20-64- Lat. 35 13 S Long. 174 12 E Coll. R E Beever 80160 Date 09 01 1980 Det. Date Rocky slope with seepage at foot of cliffs Offshore Island Research Group Scientific Trip January 1980

AK 159235 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland, Hobson Bay, by Shore Road R11 714802 0 m Lat. 36 52 S Long. 174 48 E Coll. E K Cameron 1312 Date 18 03 1982 Det. A E Wright Date 30 06 1982 Extensive patch (+/- 8 x 10m) amongst low mangroves DUPLICATE of AKU 12681

AK 160982 Eco.Code 10.02
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Great Barrier Ecological District, Unknown Island (between Great Barrier and Aiguilles Island) S08 26-70-at. 36 02 S Long. 175 24 E Coll. A E Wright 5472 Date 06 01 1983 Det. E Edgar Date 24 03 1986 Offshore Island Research Group Expedition December 1982 - January 1983

AK 161090 Eco.Code 06.01
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland Ecological Region, Eastern Northland & Islands Ecological District, Ririwha (Stephenson) Island, coastline * P04 819925
Lat. 34 58 S Long. 173 47 E Coll. A E Wright 4902 Date 22 08 1982 Det. E K Cameron Date 12 1993 * just south of Charles Bay

AK 179361 Eco.Code 12.02
Paspalum vaginatum Sw.
New Zealand, North Island, Tainui Ecological Region, Kawhia Ecological District, Kawhia Peninsula, Raukumara Beach R15 678514 sealevel Lat. 38 01 S Long. 174 47 E Coll. P J deLange Date 14 05 1988 Det. A E Wright Date 31 05 1988 On moist turf at edge of small brackish lagoon

AK 182016 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland City, Onehunga Waterfront R11 69-73- Lat. 36 56 S Long. 174 47 E Coll. D J Court Date 04 02 1975 Det. D J Court Date 04 02 1975 Salt marsh
Herbarium D J Court number 0208

AK 183134 Eco.Code 02.01
Paspalum vaginatum Sw.
New Zealand, Three Kings Ecological Region and Ecological District, Great Island, North west Bay . L01 320832 3 m Lat. 34 09 S Long. 172 08 E Coll. A E Wright 8772 Date 03 03 1989 Det. A E Wright Date 03 03 1989 Dense thickets amongst boulders at easternmost end of bay. DUPLICATE SENT TO: AD, CM, HO, WAIK, WELT

AK 184144 Eco.Code 10.02
Paspalum vaginatum Sw.
New Zealand, Great Barrier Island, Miners' Cove, banks of stream behind beach S08 222665 1 m Lat. 36 04 S Long. 175 20 E Coll. A E Wright 8460 Date 01 01 1989 Det. A E Wright Date 01 01 1989 Forming extensive swards on fine gravel banks near tidal stream-mouth; growing with ›4Selliera radicans›5 DUPLICATE SENT TO: HO, WAIK

AK 185476 Eco.Code 12.01
Paspalum vaginatum Sw.
New Zealand, North Island, Tainui Ecological Region, Raglan Ecological District, Matira, Otehe Point .R14 667989 c. 5 m Lat. 37 36 S Long. 174 46 E Coll. P J de Lange Date 26 09 1989 Det. A E Wright Date 14 11 1989 Abundant in dry situations, amongst limestone, siltstone boulders and on nearby cliffs.
DUPLICATE OF WAIK 11620

AK 193957 Eco.Code 06.01
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland and Islands Ecological Region and District, off north side of Moturoa Island, Outer Little Rat Island Q05 106661 12 m Lat. 35 11 S Long. 174 05 E Coll. A E Wright 9742 Date 23 01 1990 Det. A E Wright Date 23 01 1990 Abundant in rock crevices around margins of island

AK 195828 Eco.Code 03.01
Paspalum vaginatum Sw.
New Zealand, North Island, Te Paki Ecological Region, Te Paki Ecological District, Motuopao Island M02 776479 15 m Lat. 34 28 S Long. 172 38 E Coll. L J Forester Date 04 02 1990 Det. L J Forester Date 04 02 1990 Seepage amongst rocks above coast

AK 200154 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Harbour R11 Lat. 36 5- S Long. 174 4- E Coll. T F Cheeseman Date Det. A Chase Date This specimen renumbered 30 January 1991 as AK 1278 unavailable. Remounted over two sheets (AK 200154 and 212335), April 1993 Herbarium T F Cheeseman

AK 200155 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Harbour R11 Lat. 36 5- S Long. 174 4- E Coll. T F Cheeseman Date 03 1880 Det. A Chase Date This specimen renumbered 30 January 1991 as AK 1277 unavailable. Remounted over two sheets (AK 200155 and 212946), August 1993 Hackel number 1006 DUPLICATE for H H Allan: 1942 Herbarium T F Cheeseman

AK 206866 Eco.Code 10.03
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Colville Ecological District, Waikawau Bay, upper Waikawau Estuary T10 348088 sea level Lat. 36 36 S Long. 175 30 E Coll. E K Cameron 6817 Date 11 05 1992 Det. E K Cameron Date 11 05 1992 Abundant as floating mats in front of ›4Juncus maritimus›5 and ›4Baumea

juncea›5 on tidal margin of Waikawau River. This species is abundant along the tidal margins of the whole estuary, turf forming

AK 207420 Eco.Code 10.02
Paspalum vaginatum Sw.
New Zealand, Coromandel Ecological Region, Great Barrier Ecological District, Great Barrier Island, northern Whangapoua Estuary S08 277606 c. 0 m Lat. 36 8 S Long. 175 25 E Coll. E K Cameron 6781 Date 02 04 1992 Det. E K Cameron Date 02 04 1992 Locally common forming mats on margin of shallow
tidal ditch amongst ›4Sarcocornia, Selliera›5 and ›4Triglochin›5

AK 211278 Eco.Code 09.08
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Hunua Ecological District, Hunua Range: Kawakawa Bay S11 02-70- sea level Lat. 36 57 S Long. 175 09 E Coll. I L Barton Date 30 01 1972 Det. E K Cameron Date 13 08 1993 Salt marsh
Auckland Regional Authority Herbarium 552

AK 212334 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Harbour R11 Lat. 36 5- S Long. 174 4- E Coll. T F Cheeseman Date 03 1880 Det. A Chase Date Hackel number 1006 Remounted over two sheets (AK 1277 and 212334), April 1993 Herbarium T F Cheeseman

AK 212335 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Harbour R11 Lat. 36 5- S Long. 174 4- E Coll. T F Cheeseman Date Det. A Chase Date Remounted over two sheets (AK 200154 and 212335),
April 1993 Herbarium T F Cheeseman

AK 212946 Eco.Code 09.03
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Tamaki Ecological District, Auckland Harbour R11 Lat.36 5- S Long.174 4- E Coll. T F Cheeseman Date 03 1880 Det. A Chase Date Remounted over two sheets(AK 200155 and 212946),
August1993 Hackel no. 1006 DUPL for H H Allan: 1942 Herbarium TF Cheeseman

AK 216855 Eco.Code 06.01
Paspalum vaginatum Sw.
New Zealand, North Island, Eastern Northland Ecological Region, Eastern Northland & Islands Ecological District, Urupukapuka Island Q05 2--6-- Lat. 35 13 S Long. 174 14 E Coll. A E Esler Date 21 02 1973 Det. Date Open pasture
Herbarium A E Esler, presented 1989

AK 216859 Eco.Code 09.07
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Manukau Ecological District:Weymouth. R11-12 7-Lat37 03 S Long174 52 E Coll. JM Dingley Date 01 1971 Det. EK Cameron Date 16 05 95 Estuary Herbarium A E Esler, presented 1989

AK 220180 Eco.Code 09.07
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Manukau Ecological District, Mangere Inlet, Favona, near Tararata Creek R11 710710 c.0.5 m Lat. 36 57 S Long. 174 48 E Coll. A R Jamieson Date 22 11 1993 Det. E K Cameron Date 28 02 1994 Growing in silty sand around mean high water mark

AK 229656 Eco.Code 09.06
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Awhitu Ecological District, Manukau Harbour, Te Hakano Creek, on sand R12 608448 0 m Lat. 37 11 S Long. 174 42 E Coll. A R Jamieson Date 25 02 1994 Det. E K Cameron Date 25 10 1996 Growing at around high tide mark near a private boat ramp DUPL. SENT TO: CM

AK 230890 Eco.Code 08.01
Paspalum vaginatum Sw.
New Zealand, North Island, Kaipara Ecological Region and District, Moturemu Island, spit on north-east corner Q09 356302 0 m Lat. 36 25 S Long. 174 24 E Coll. G A Taylor Date 07 01 1997 Det. E K Cameron Date 17 01 1997 Adjacent to mangroves, locally common (large patch) with ›4Atriplex prostrata›5 (AK 230889)

AK 237831 Eco.Code 10.03
Paspalum vaginatum Sw.
New Zealand, North Island, Coromandel Ecological Region, Colville Ecological District, Waikawau Bay, south side estuary T10 355088 c.0.2 m Lat. 36 36 S Long. 175 31 E Coll. E K Cameron 9356 Date 15 07 1998 Det. R O Gardner Date 03 1999 Locally abundant. In raupo/Carex wetland which grades into the estuary, north side of disused(?) airstrip

AK 250262 Eco.Code 13.02
Paspalum vaginatum Sw.
New Zealand, North Island, Northern Volcanic Plateau Ecological Region, Tauranga Ecological District, Omokoroa Peninsula, south side U14 782903 <1 m Lat. 37 39 S Long. 176 02 E Coll. R O Gardner 10153 Date 16 02 2000 Det. R O Gardner Date 16 02 2000 Common on low sand bat (No Zoysia seen here)

AK 27841 Eco.Code 09.02
Paspalum vaginatum Sw.
New Zealand, North Island, Auckland Ecological Region, Waitakere Ecological District, Huia, Huia Stream Q11 49-66- Lat. 37 00 S Long. 174 34 E Coll. K Wood Date 21 01 1950 Det. Date Auckland Botanical Society Botany of Auckland Collection, number 5293

Te Papa Herbarium collection notes for *P. vaginatum* (Galloway 2000):

WELT SP069236 - first id as P digitaria
Lower Waikato, Mercer
D Petrie, 2.1877

WELT SP069222 - first id as P distichum
Auckland Harbour
TF Cheeseman, 4.1884

WELT SP069224 - first id as P distichum
Auckland, Hobson Bay
D Petrie, 12.1894

WELT SP069223, SP069228 - first id as P distichum
Auckland, "The Thames" [presumably Auck. Province, Thames]
D Petrie, 4.1903

WELT SP069225/A &/B - first id as P distichum
Bay of Islands, Russell
D Petrie, 3.1920

WELT SP016003 /A & /B - first id as P distichum

Tauranga Harbour, Waikareu Estuary; saltmarsh
WRB Oliver, 5.4.1920

WELT SP06924 & SP016006 - first id as P distichum
Maunganui Bluff; sand dunes
WRB Oliver, 3.1923

WELT SP069232 - first id as P distichum
Houhora; sand outside dunes
WRB Oliver, 17.2.1929

WELT SP039156 - indet. before E Edgar det as P vaginatum
Waipu, Langs Beach
WRB Oliver, 1952

WELT SP071078 - first id as P vaginatum
Three Kings Islands, Great Island, NW Bay; amongst boulders
AE Wright 3.3.1989

N.B. 1. We also have a T Kirk specimen from the Waitemata, but it is undated (must be pre-1898 though).

Waikato University herbarium collection notes for *P. vaginatum* (abridged)*:*

Crater rim Is. off Moturoa Is. Bay of Islands. 1990. alt:2m – over basalt rocks at base of seepage

Kaitoke stream, GBI. alt:0m. Common on muddy ground with Leptocarpus. 1990.

Three Kings Is. (Auck. Herb. Copy) dense among boulders. Alt:3m. 1989.

Miners Cove, GBI (Auck. Herb copy) extensive swards on fine gravel banks. near tidal stream mouth, with selliera radicans. 1989.

NW Beach, Cuvier Is. Small area gravel beach, adjacent to stream outlet. Alt:0m.

Otehe P. vaginatum, Matira, Nth Raglan. (duplicate in Auck. herb). Cliffs, boulders and scrub. Alt:5m. 1989.

Ngatutura Pt. Kaawa, Port Wakato. V. common amongst dry boulders on beach front. Alt 15m. 1988.

Omaha sandspit. Buried amongstr sand on sandspit. Alt:0m. 1986.