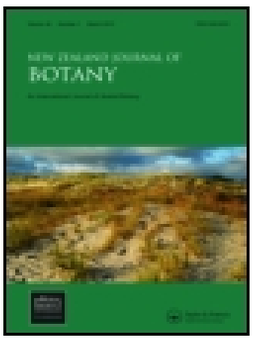

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Schoenoplectus californicus (Cyperaceae) in New Zealand

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Abstract Ecological, taxonomic, and physiological notes are given on *Schoenoplectus californicus*. This species has been recently recorded as naturalised in New Zealand, despite the possibility that it may have been present in the country since c. 1900 and overlooked through confusion with the indigenous *S. tabernaemontani*. This large aquatic reed currently occupies extensive areas along the Wairoa and Waikato Rivers on the west coast of the northern North Island, and has also been planted in artificial wetlands. It grows vigorously and produces viable seed. Unknown factors may be restricting its spread.

Keywords *Schoenoplectus*; *S. californicus*; *S. pungens*; *S. tabernaemontani*; Cyperaceae; artificial wetlands; ecology; physiology; weed; New Zealand flora

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INTRODUCTION

In her synopsis of *Scirpus sens. lat.* in Australia, Wilson (1981) revived the generic name *Schoenoplectus*, applying it to a number of Australasian species (see also Soják 1972, 1979; Connor & Edgar 1987; Mabberley 1997). Two of these species are indigenous to New Zealand. The first, *Schoenoplectus pungens* M.Vahl, has been known here as *Scirpus americanus* M.Vahl and then as *Scirpus pungens* M.Vahl (Moore & Edgar 1970; Healy & Edgar 1980). The second, *Schoenoplectus tabernaemontani* (Gmel.) Palla (Smith 1995), has been known in New Zealand as *Scirpus lacustris* L. (Moore & Edgar 1970) and then as *Schoenoplectus validus* (M.Vahl) A.Löve et D.Löve (Connor & Edgar 1987).

Gardner & de Lange (1996) noted the presence of a third *Schoenoplectus* species in New Zealand, *S. californicus* (C.A.Mey.) Palla, and considered it to be naturalised. Here we furnish a description of *S. californicus* from New Zealand specimens, and review its distribution, habitat, phenology, adventive status, and weed potential within the country. A key to the three species of *Schoenoplectus* in New Zealand is also presented.

TAXONOMY

Schoenoplectus (Rchb.) Palla *Verh. K.K. Zool.-Bot. Ges. Wien* 38, *Sitzungsber.* 49 (1888) *nom. cons.*

TYPE SPECIES: *S. lacustris* (L.) Palla (*fide* Greuter et al. 1993).

Annuals or perennials, sometimes with creeping rhizomes; culms robust, not nodose above base. Leaves reduced to bladeless sheaths. Inflorescences anthelate with elongate rays, or congested into a head, the lowest bract erect, culm-like; spikelets ovoid, ellipsoid, or cylindrical, terete; glumes numerous, imbricate or 2-ranked, all similar and bearing an axillary perfect flower; perianth of 0–6 hypogynous bristles, filiform with fimbriate margins; stamens 1–3; style continuous with ovary; stigmas

2–3. Nuts cream, brown, or black at maturity, plano-convex or trigonous, often transversely wrinkled. A genus of c. 130 species distributed worldwide (Wilson 1981; Wagner et al. 1990; Mabberley 1997).

KEY TO NEW ZEALAND SPECIES OF *SCHOENOPLECTUS*

1 Spikelets 1–4, sessile; hypogynous bristles retrorsely scabrid; culm trigonous throughout, to 1 m tall ..... *S. pungens*
Spikelets numerous, (inflorescence umbellate); hypogynous bristles scabrid or plumose; culm terete, at least towards base, up to 4 m tall *2*
2 Culms glaucous, terete along entire length, usually <2 m tall; hypogynous bristles retrorsely scabrid ..... *S. tabernaemontani*
Culms light to dark green, trigonous in upper third, often >2 m tall; hypogynous bristles retrorsely spreading, plumose ..... *S. californicus*

Schoenoplectus californicus (C.A.Mey.) Palla

DESCRIPTION (Fig. 1, 2): Rhizomes 1.8–2 cm diam., hard and woody, black, covered in loose, papery, dark chesnut-brown scales 1.5–2 cm long; roots numerous, at first white but becoming yellow-brown with age, fibrous, primary growth often nodulated. Culms 1–3(–4.2) m × 10–35 mm, arising in a row along rhizome, terete below, markedly trigonous in upper half, pith spongy, culm surface light to dark green. Sheaths c. 30 cm long, reduced to loose dark brown papery sheaths at base of culms, the abaxial side splitting pinnately into fibres. Inflorescence dense; rays 4–10, pendulous, each with 1–5 spikelets on ultimate rays, primary rays usually 3–10 cm long. Spikelets rusty brown, ovoid-ellipsoid to cylindrical, 5–12 × 2.5–3 mm, acute; glumes brown or pale brown, obtuse, widely emarginate, 2.5–2.8 × 1.7–2 mm, flecked with rusty spots, hyaline margin broad, subentire, sparsely ciliate, apex truncate to weakly retuse, awn usually 0.5–1.0 mm long; hypogynous bristles 2 (2–4 in overseas material), lateral, c. ⅔ as long as nut, flat in lower ⅓, trigonous to terete above, the margins plumose with retrorse (–spreading) cilia to 0.25 mm long; anthers 1–3; stigmas 2. Nut cream to grey, broadly obovate-elliptic, plano-convex, 2.9 × 1.7 mm, apiculate.

DISTRIBUTION: Indigenous to coastal regions of the western and southern USA (Mason 1957) south through Central America to Chile and Argentina (Wagner et al. 1990). The species may also be indigenous to Hawai'i (Wagner et al. 1990), Rapanui (Easter) Island (Zizka 1991), and the Cook Islands (W. R. Sykes pers. comm.). The record for Newcastle, Australia (K. L. Wilson in Gardner & de Lange 1996) remains unsubstantiated.

In New Zealand, *S. californicus* appears to be confined to the west coast of the northern North Island, where it is found on the Wairoa River (from Ruawai to near Dargaville), and on the Waikato River (Port Waikato to Tuakau) (Fig. 1). It grows on the muddy river banks and delta islands within the tidal portion of these rivers. The limited distribution, lack of early collections, and the species' close association with former ports, strongly suggest that *S. californicus* is adventive.

Although specimens of *S. californicus* were not collected in New Zealand until the early 1990s, it is unlikely that this species is a recent arrival. Photographs of the Tokatoka Tavern adjacent to the Wairoa River seem to indicate that *S. californicus* was present there in 1955, and perhaps as early as c. 1900 (B. C. Bernard, Tokatoka Tavern licensee, pers. comm.).

Schoenoplectus californicus may well have arrived in ship ballast dumped on the banks of the Wairoa River during kauri-milling days, in the same way that Manchurian wild rice, *Zizania latifolia* (Griseb.) Stapf (Cumberland 1966), and alligator weed, *Alternanthera philoxeroides* (C.Martius) Griseb. (Champion 1990), seem to have been introduced. Spread to the Waikato may have been by a separate introduction, or the result of subsequent movement of shipping from the Dargaville area.

In addition to its two wild occurrences, *S. californicus* now also occurs at a number of artificial wetlands in the North Island, where it was planted in sites at Maraetai, Parata, Drury, Tuakau, Ohinewai, Hautapu, Te Pahu, Waikeria, and Taumarunui, 1990–1995. These plantings were done before the distinction between this species and *S. tabernaemontani* was appreciated.

HABITAT: Within its native range, *S. californicus* is restricted to almost permanently flooded areas on estuaries, e.g., Napa, California (Mason 1957; Wagner et al. 1990), lower Valdivia River, Chile (Ramirez & Anazco 1982), and Lower Parana River, Argen-

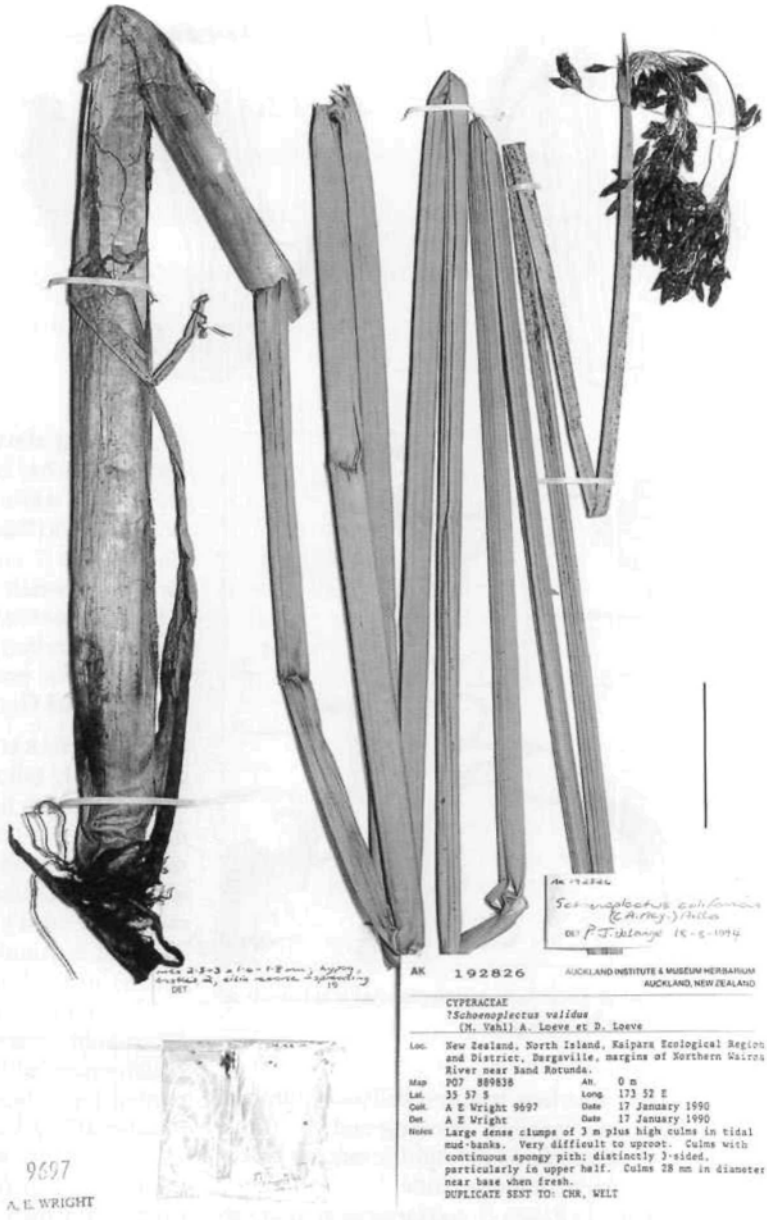

Fig. 1 Herbarium specimen of *Schoenoplectus californicus* (*A. E. Wright 9697*, AK 192826). Scale bar 5 cm. (Photo: R. O. Gardner)

tina (Tur & Rossi 1976; Bonetto et al. 1994). It also occurs in coastal lagoons, e.g., Patos Lagoon, southern Brazil (de Oliveira 1996), and in large freshwater lakes such as Lake Okeechobee in Florida and Lake Titicaca in Bolivia (Richardson et al. 1995; Mabberley 1997). Both Tur & Rossi (1976) and de Oliveira (1996) note that stand vigour (as indicated by culm height and diameter) decreases with rising salinity. Richardson et al. (1995) correlated the distribution of the species with sites that have a long hydroperiod, and with soils of high bulk density (low organic content) that are high in phosphorus but low in nitrogen.

In estuarine situations, *S. californicus* tends to be the dominant species of the deepest-water vegetation type (P. J. de Lange unpubl. data). This habitat preference is reflected in its New Zealand sites (Fig. 1). In the Wairoa River it grows in association with *Zizania latifolia*, often as a narrow band on the channel side of dense monospecific growths of that tall

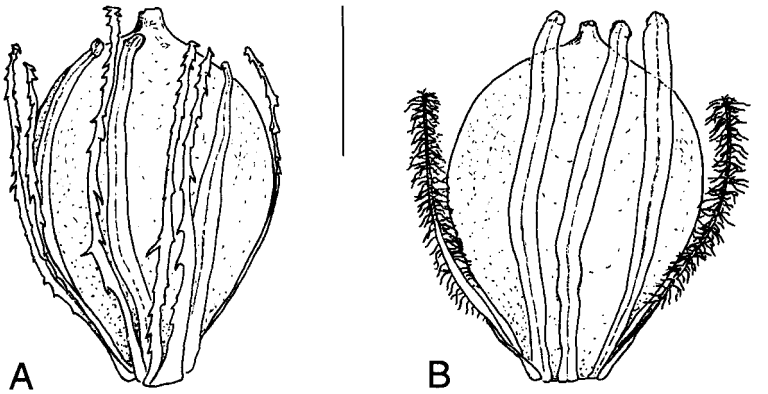

Fig. 2 Nuts of **A**, *Schoenoplectus tabernaemontani* (AK 61825) and **B**, *S. californicus* (AK 192826). Scale bar 1 mm. (Drawing: R. O. Gardner)

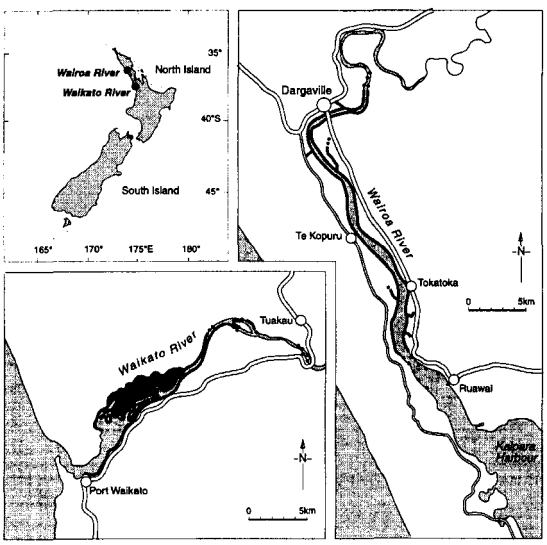

Fig. 3 Distribution of *Schoenoplectus californicus* (bold line and dots) in New Zealand.

grass. It also grows here in drains and poorly drained pasture prone to seasonal flooding and can prove nearly as troublesome as *Z. latifolia*, since it blocks drains and is unpalatable to cattle.

In the Waikato River, *S. californicus* is more-or-less restricted to the lowest 2 km of the river (Fig. 3, 4), where it commonly forms pure deep-water stands within the lower delta of the river (Fig. 5). Along the shore, at Maioro Bay, it forms a deep-water band outside other reed species (*Bolboschoenus fluviatilis* (Torrey) Soják, *Leptocarpus similis* Edgar, *Juncus krausii* var. *australiensis* (Buchenau) Snogerup, *Schoenoplectus pungens*, and *S. tabernaemontani*). Further upstream, *S. californicus* is less common and usually grows with *S. tabernaemontani*.

As noted above, New Zealand material of *S. californicus* has been planted in artificial wetlands created for wastewater-treatment. Trials at inland Waikato sites (Sukias & Tanner 1995, 1996a, 1996b) showed that *S. californicus* had a higher tolerance to ammonia-rich organic wastewaters than did *S. tabernaemontani*, and exhibited less seasonal dieback. Surrency (1993) reported *S. californicus* to be one of the preferred plants in similar trials in Alabama and Georgia, USA.

BIOMASS CHARACTERISTICS: *S. californicus* forms considerably taller stands than *S. tabernaemontani* and has a much higher shoot density. Table 1 summarises above-ground biomass characteristics for natural stands and for stands in constructed wetlands within New Zealand. Live above-ground biomass recorded at Port Waikato was four-fold higher than the seasonal maximum live biomass reported for this species in the Valdivia River (Ramirez & Anazco 1982), and over twice that reported for the Lake Okeechobee marsh ecosystem (Harris et al. 1995). It also exceeded the values of 0.80–1.38 kg m^{-2} recorded for *S. tabernaemontani* in North America (Tanner 1994). Under the higher nutrient conditions of constructed wetlands, the above-ground live biomass of *S. californicus* reached up to 5.4 kg m^{-2} (Table 1), which compares with biomass values of ~0.5–2.0 kg m^{-2} recorded for *S. tabernaemontani* growing in similar conditions (Tanner 1994). Smith (1979) recorded an annual productivity of ~3.1 kg m^{-2} for *S. californicus* growing under tropical conditions in a nutrient-enriched marsh in Hawai'i. The data of Ramirez & Anazco (1982) and Harris et al. (1995) indicate that considerable quantities of standing dead culms are often present in established *S. californicus* stands.

Tissue nitrogen (N) concentrations for natural stands of *S. californicus* (Table 2) were similar at the

Fig. 4 *Schoenoplectus californicus*, Waikato River, Port Waikato, Hood's Landing. (Photo: P. J. de Lange)

two Waikato sites investigated, but phosphorus (P) and potassium (K) concentrations were nearly twice as high in plants growing in silt compared with those growing in sandy sediment. Tissue N concentrations at Port Waikato were similar to those reported for this species by Bonetto et al. (1994) for riverside stands in the Lower Parana River, Brazil, and N and P concentrations were similar to seasonal maximum values reported by Harris et al. (1995) at Lake Okeechobee. Considerably lower N concentrations (5.6 g kg^{-1}) were reported by Bonetto et al. (1994) for severely N-limited floodplain stands in their study area.

Nutrient concentrations recorded for *S. californicus* at Port Waikato were generally within the ranges reported for natural stands of *S. tabernaemontani* in both New Zealand and North America (Tanner 1994), except for sulphur (S), calcium (Ca) (Table 2), and zinc (Zn) (Table 3), which appeared to be notably lower in *S. californicus*.

As expected, tissue nutrient concentrations were markedly higher in *S. californicus* when growing in constructed wetlands (Tables 2 and 3). Under these conditions, tissue nutrient levels were similar to those recorded for *S. tabernaemontani*, and in the moderate to high range recorded for a range of emergent species growing in constructed wetlands (Tanner 1996). Tissue P concentrations were notably high, exceeding those reported by Johnson (1991) for a wide range of emergent species.

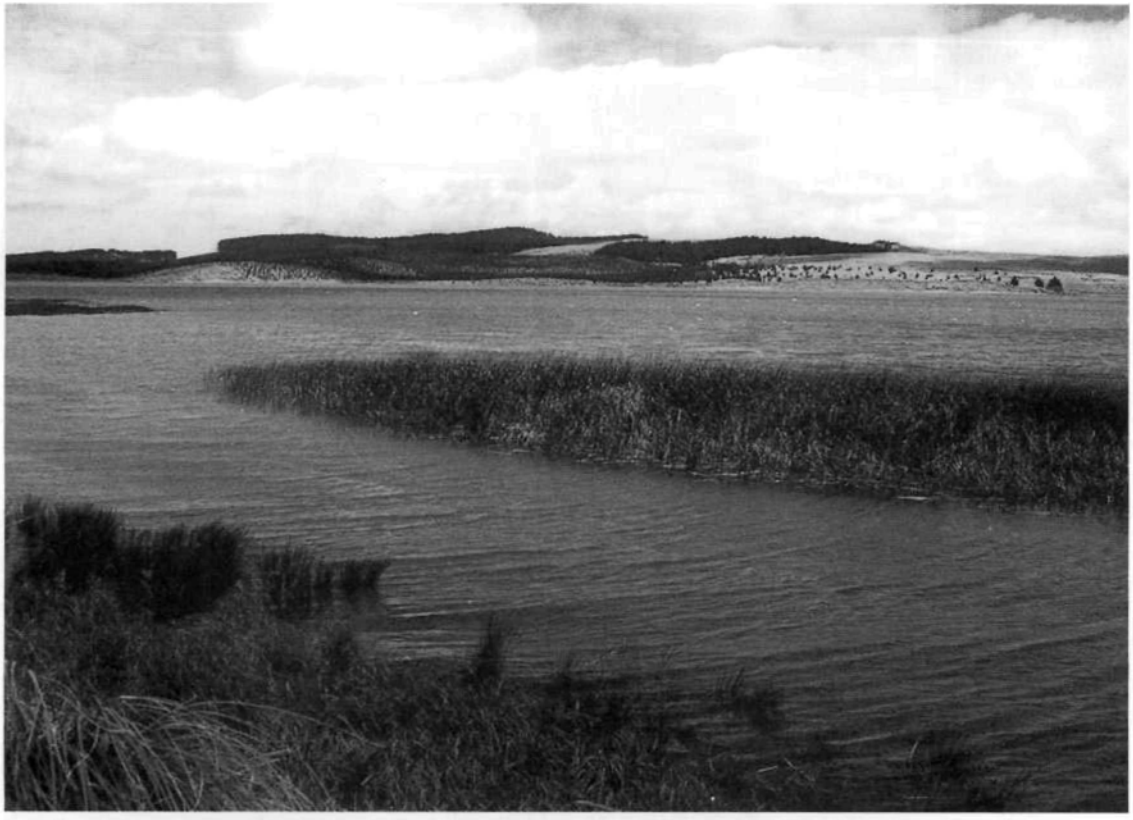

Fig. 5 *Schoenoplectus californicus* in water c. 2 m deep (high tide), Waikato River, Port Waikato. (Photo: P. J. de Lange)

PHENOLOGY: In the Wairoa River, *S. californicus* appears to grow, flower, and fruit throughout the year. At Port Waikato, in contrast, *S. californicus* usually dies back partially during April and May, to recommence growth in September. Flowering and fruiting at this location occurs from late September to April. These seasonal growth patterns are less pronounced than those noted in *S. tabernaemontani* in the North Island (C. C. Tanner unpubl. data), and are very similar to those seen in *S. californicus* in Chile at a latitude of c. 40°S (Ramirez & Anazco 1982).

REPRESENTATIVE SPECIMENS: NEW ZEALAND: NORTHLAND: Dargaville, near band rotunda, *A. E. Wright 9697*, 17 Jan 1990; AK 192826; Junction of Dargaville Road, Wairoa River, *Te Aniwaniwa Hona*, 29 May 1997, AK 232860; Te Kopuru, Wairoa River, *P. J. de Lange 2927 & R. O. Gardner*, 10 Aug 1995, AK 224055; 2 km south of Raupo, *P. J. de Lange 2926 & R. O. Gardner*, 10 Aug 1995, AK 224055; Wairoa River, *P. D. Champion*, 15 Nov 1995, WAIK 15272. SOUTH AUCKLAND: Waikato River, Tuakau Bridge, *P. J. de Lange 2576*, 22 Jun 1994, AK 214187; Port Waikato, *C. C. Tanner*, 10 Feb 1992, AK 224069; Port Waikato, *P. J. de Lange 2577*, 22 Jun 1994, AK 214186; Waikato River mouth, 2 km east of settlement, *R. O. Gardner 7561 & P. J. de Lange*, 2 Feb 1995, AK 224355; Waikato River, Maioro Bay, *C. C. Tanner*, 10 Feb 1995, WAIK 13895; Waikato River, Maioro Bay, Hood's Landing, *P. J. de Lange 3357 & M. McGlynn*, 3 May 1997, AK 233115.

HAWAI'IAN ISLANDS: MAUI ISLAND: vicinity of Kahului, *P. J. de Lange 3310 & G. M. Crowcroft*, Mar 1996, AK 232859.

COOK ISLANDS: ATIU: Tengatangi District, Vai Momori Swamp, *W. R. Sykes 3826/CI*, 26 Jul 1991, CHR 474709. MANGAIA: Veitate District, Lake Titiara, *W. R. Sykes 3242/CI*, 4 Feb 1990, CHR 467721; Lake Tiriara, *J. M. Rowe*, 27 Oct 1992, CHR 507619A; Ivirua Swamp, *A. S. Rowe*, 14 Nov 1992, CHR 507620A.

Table 1 Above-ground biomass characteristics of *Schoenoplectus californicus* growing in natural stands and established constructed wetlands in New Zealand. Means ± standard errors, with the number of samples in parentheses. All sampling done in late summer, close to estimated maximum seasonal biomass.

Provenance		Substrate	Sampling date	Mean above-ground live biomass (kg dry weight m^{-2})	Mean above-ground standing dead biomass (kg dry weight m^{-2})	Live shoot density (no. m^{-2})	Canopy height (m)
Natural stands							
Maioro Bay, Port Waikato	shoreline embayment	sand	February 1992	1.62 ± 0.25 (3)	—	310–330	2.1
	deltaic bar	silt	February 1992	2.10 ± 0.27 (3)	0.61 ± 0.21 (3)	200–220	2.8
Constructed wetlands							
Paerata, South Auckland	piggery wastewater	scoria gravel	February 1993 [range 0.92–3.20]	2.15 ± 0.010 (24) [range 0.65–3.00]	2.18 ± 0.05 (24) [range 112–863]	359 ± 214 (54) [range 2.3–3.3]	1.6 ± 0.26 (20)
Hautapu, Waikato	dairy farm wastewater	flooded soil	February 1995	5.79 ± 0.82 (3)	—	360–690	2.1–2.9
Te Pahu, Waikato	dairy farm wastewater	flooded soil	February 1995	5.44 ± 0.29 (2)	—	470–510	1.8–2.9
Waikeria, Waikato	human sewage	gravel	March 1997	—	—	—	1.6–2.4

Table 2 Above-ground tissue macronutrient levels for *Schoenoplectus californicus* growing in natural stands and constructed wetlands in New Zealand. Sites as for Table 1 except where noted. Where replicate samples have been analysed, the number is noted in parentheses; all others are analyses of bulked samples. Analytical methods as described in Tanner (1996). * Full-scale piggery treatment system as described in Sukias & Tanner (1996a).

Provenance	Macronutrients (g kg^{-1} dry weight)						
	N	P	S	Mg	Ca	Na	K
Natural stands							
Maioro Bay – shore	11.3	1.4	3.3	1.6	1.6	9.2	11.1
Maioro Bay – bar	11.5	2.2	2.8	1.6	1.9	1.5	21.6
Constructed wetlands							
Paerata piggery (8)	11.2–17.3	4.1–6.4	4.0–7.2	1.3–1.7	2.8–3.6	1.6–2.7	43.0–65.0
Hautapu piggery* (2)	29.1, 31.10	3.2	2.9, 3.3	1.1	4.6, 5.1	5.0, 6.0	27.3, 30.6
Hautapu dairy (3)	12.0–16.8	3.2–4.2	2.1–3.0	1.4–1.8	2.2–3.6	3.7–5.4	31.5–33.6
Te Pahu dairy (2)	12.7, 17.3	4.5, 4.6	2.4, 2.7	1.2, 1.5	3.3, 4.8	2.9, 3.3	34.2, 39.6
Waikeria sewage	19.3	3.6	6.4	1.2	4.9	4.6	51.4

AUSTRAL ISLANDS: RIMATARA: *C. Peters*, 1988, AK 234316.

WEED POTENTIAL

In New Zealand, *Schoenoplectus californicus* appears to spread locally mainly by growth from pieces of rhizomes detached in flooding, bank collapse, etc. Seeds of New Zealand plants sampled from Port Waikato, though viable, have not been observed to germinate in the wild (P. D. Champion pers. obs.). Tur & Rossi (1976) found that germination of *S. californicus* seed on the margins of the Rio de la Plata, Argentina (c. 35°S) varied from year to year and that there was an apparently short period of viability during late summer. Germination of *S. californicus* seed in New Zealand field populations needs further investigation.

Within its estuarine habitat *S. californicus* often forms tall, pure stands, but whether it displaces indigenous New Zealand communities is not known. However, casual observation of the Wairoa River population suggests that only adult white mangrove (*Avicennia marina* subsp. *australasica* (Walp.) Everett) can persist amongst it, and that it is not readily invaded by other species. At Port Waikato, we have observed apparent displacement of *S. tabernaemontani*, *S. pungens*, and *Bolboschoenus fluviatilis* to the landward side of *S. californicus* stands. In ecologically similar sites nearby where *S. californicus* is either absent or scarce, these indigenous reeds extend well into the deep-water habitat.

Searches through APIRS (University of Florida) and other overseas weed databases have failed to find references to *S. californicus* as a troublesome plant (P. D. Champion unpubl. data). This may, however, be simply because it is a native species in those countries. We suggest that until the weed potential of this species in New Zealand is properly assessed, it would be advisable not to introduce it to constructed wetlands.

ACKNOWLEDGMENTS

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Table 3 Above-ground micronutrient levels for *Schoenoplectus californicus* growing in natural stands and constructed wetlands in New Zealand. Sites as for Table 1 except where noted. Where replicate samples have been analysed, the number is noted in parenthesis; all others are analyses of bulked samples. Analytical methods as described in Tanner (1996). * Full-scale piggery treatment system as described in Sukias & Tanner (1996a).

Provenance	Micronutrients (mg kg^{-1} dry weight)				
	Mn	Zn	Cu	Fe	B
Natural stands					
Maioro Bay – shore	301	10	2	226	14
Maioro Bay – bar	414	15	2	206	5
Constructed wetlands					
Paerata piggery (8)	220–330	9–15	4–7	45–71	4–9
Hautapu piggery* (2)	227,566	10,12	4, 5	58, 60	9, 12
Hautapu dairy (3)	643–1054	11–14	2–3	74–239	8–9
Te Pahu dairy (2)	252, 291	11	2, 3	64, 94	10, 13
Waikeria sewage	498	25	11	37	12

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