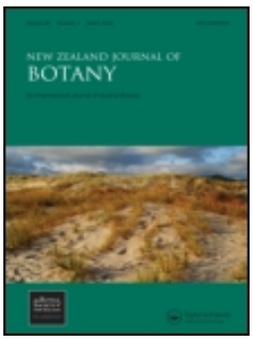

New Zealand Journal of Botany

ISSN: 0028-825X (Print) 1175-8643 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzb20

Taxonomy, ecology, and conservation of Atriplex billardierei and A. hollowayi sp. nov. (Chenopodiaceae) in Australasia

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To cite this article: P. J. De Lange , D. A. Norton & G. M. Crowcroft (2000) Taxonomy, ecology, and conservation of Atriplex billardierei and A. hollowayi sp. nov. (Chenopodiaceae) in Australasia, New Zealand Journal of Botany, 38:4, 551-567, DOI: 10.1080/0028825X.2000.9512704

To link to this article: http://dx.doi.org/10.1080/0028825X.2000.9512704

New Zealand Journal of Botany, 2000, Vol. 38: 551–567
0028–825X/00/3804–0551 $7.00

Taxonomy, ecology, and conservation of *Atriplex billardierei* and *A. hollowayi* sp. nov. (Chenopodiaceae) in Australasia

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Abstract A new, endemic species *Atriplex hollowayi* (Chenopodiaceae) is described from the North Island, New Zealand. It is distinguished from the Australasian *A. billardierei* by its smaller stature; sturdy, erect, heavily branched shrub habit; distinctly irregular sinuate-dentate leaves; weakly fused chartaceous bracteoles; and smaller seeds. A detailed description of *A. billardierei* is provided to distinguish both species and a lectotype selected. The status of *A. chrystallina*, treated as a synonym of *A. billardierei*, is discussed and the name typified. *A. billardierei* and *A. hollowayi* are similar ecologically. Both are strand plants and show marked year-to-year variation in numbers. Germination is significantly better in seed that has been first soaked in salt water. Both species are considered to be at risk from competition with naturalised strand plants, browsing animals, sand mining, and, in the case of *A. hollowayi*, over-collecting. *Atriplex hollowayi* is rated as Critically Endangered and *A. billardierei* as Declining.

Keywords *Atriplex*; *A. billardierei*; *A. chrystallina*; *A. hollowayi*; *Theleophyton*; taxonomy; ecology; reproductive biology; conservation; Australasian flora

INTRODUCTION

Atriplex billardierei (Chenopodiaceae) is an annual herb of the coastal sandy beaches of southern Australia, Tasmania, and New Zealand (Cheeseman 1906; Wilson 1984; Walsh 1996; de Lange et al. 1997a). The species is unique within *Atriplex* due to the orientation of the seed, which, in common with other *Atriplex* species, first arises parallel to the bracteoles but at maturity twists 90° to fit within the pouched bracteole bases. It was largely on account of this novel behaviour that Moquin-Tandon (in de Candolle 1849) erected the monotypic genus *Theleophyton* for the species. However, acceptance of *Theleophyton* has not been universal with some authors preferring to treat the species within *Atriplex* (Hooker 1847, 1853) or as subgenus *Theleophyton* within *Atriplex* (Volkens 1893; Wilson 1984; de Lange et al. 1997a). Aside from the unique orientation of the mature seed, the species shares the same base chromosome number (n = 9) as the majority of *Atriplex* (de Lange et al. 1997a; Murray & de Lange 1999) and has no other morphological differences to justify its generic segregation (Volkens 1893; Wilson 1984). For these reasons, we follow the Flora of Australia treatment (Wilson 1984) in retaining the species within *Atriplex*.

Within New Zealand, *Atriplex billardierei* was formerly widespread in the North Island, southern South Island, Stewart (Rakiura) Island, and Chatham (Rekohu) Island (Cheeseman 1906, 1925; Allan 1961). Although it was always considered uncommon, the possibility that it may be threatened in New Zealand was first discussed in detail as recently as

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Received 13 January 2000; accepted 6 June 2000

1981 (Given 1981). Since then, subsequent assessments of the New Zealand threatened vascular plant flora have treated the species as "Endangered" (Cameron et al. 1993, 1995) or more recently as "Declining" (de Lange et al. 1999).

Due to the scarcity of *A. billardierei* and the lack of ecological information about the species, one of us (PdeL) undertook a herbarium study of *A. billardierei* in 1990. From this study it soon became apparent that two forms were present in New Zealand: one was distinguished by its normally much larger, entire leaves and larger bracteoles and seeds, whereas the other had generally smaller, irregularly sinuate-dentate leaves and smaller bracteoles and seeds. The form with the sinuate-dentate leaves was confined to the North Island, whereas the other form historically ranged from the southern South Island and Stewart Island to Chatham Island. Within the mainland Australian and Tasmanian range of *A. billardierei*, the form with entire leaves and larger seeds and bracteoles mainly represented the species. However, a few collections, including the type of *Atriplex chrystallina*, differed in their smaller habit and smaller, more frequently lobed leaves. This discovery resulted in the exchange of specimens and discussions with Paul Wilson (PERTH) who had treated *Atriplex* for the Flora of Australia (Wilson 1984) and Alex Buchanan (HO) who had much field experience of the species in Tasmania. Following these discussions and herbarium studies, field work was undertaken in Australia, Tasmania, and New Zealand, and specimens of North Island, Chatham Island, and Tasmanian plants of *A. billardierei* were cultivated. These plants confirmed that the North Island form of *A. billardierei* formed a true-breeding, morphologically distinct entity. Here we describe this taxon as a new species, *A. hollowayi*, endemic to the North Island of New Zealand, and discuss aspects of its ecology and conservation. A circumscription of *A. billardierei* is also provided, and we discuss the status of *A. chrystallina*.

MATERIALS AND METHODS

The decisions reached in this paper were based on a thorough assessment of herbarium specimens held at AD, AK, AKU, BM, CANU, CHR, CNB, FI, HO, K, MEL, NSW, P, PERTH, WAIK, WELT, and WELTU. This was supplemented by field work, and nine years of cultivation under uniform conditions of plants from Tasmania, Chatham Island, and northern New Zealand within the senior author's garden, and the facilities and growth rooms of the University of Canterbury, Auckland Regional Council Botanic Gardens, and Percy Reserve (Wellington). Where possible, measurements and comparisons were made using fresh material or from plants preserved in FAA. However, dried and rehydrated material was also used for measurements. This was necessary because the majority of *A. billardierei* and *A. hollowayi* herbarium specimens are from locations where it is no longer to be found. Leaf, bracteole length and width, and seed diameter were measured using a Mitutoyo digimatic calliper. In addition, specimens were scored for the presence of leaf lobes and the texture of their bracteoles (chartaceous versus coriaceous). For all measurements only mature leaves, bracteoles, and seeds were used.

We compared leaf and bracteole dimensions and ratios and seed diameter of *Atriplex billardierei* and *A. hollowayi* using single factor analysis of variance. The data were based on the herbarium specimen measurements (643 in total) with 1 to 10 measurements made per herbarium sheet depending on the number of leaves, bracteoles, and seeds present. The average values per herbarium sheet were used as input data into the analyses.

The ecology of *Atriplex billardierei* populations was examined on Tasmania at Cockle Creek (43°34′S, 146°54′E) and on Chatham Island at West Waitangi (43°46′S, 176°51′E), Petre Bay (43°52′, 176°36′E), and Kaingaroa (43°44'S, 176°14′E) beaches, and of *A. hollowayi* at Waikuku (34°25′S, 173°00′E) and Whareana (34°27′S, 173°00′E) beaches, near North Cape, North Island. A monitoring programme for *A. hollowayi* was initiated at Waikuku and Whareana Beaches during November 1990 and both beaches were carefully searched for plants during November of each subsequent year.

Germination of *Atriplex billardierei* and *A. hollowayi* seed was assessed with respect to light levels and pre-treatment. The experiments were undertaken with fresh seed collected from Kaingaroa (Chatham Island) and Waikuku Beach (North Cape). Fruiting bracteoles (hereafter referred to as seeds) were left intact for the germination trials as this was thought to better simulate natural conditions. Seeds were subjected to two pre-germination treatments. In the first, seed was soaked in sea water for 3 months; in the second, seed was stored in sand moistened with fresh water for the same time period. Both were stored at room temperature under normal light/dark conditions. Seed was then germinated in both fresh water and sea water under three light treat-

ments: no light, 50% light, and 100% full growth-cabinet light. The seeds were germinated on moist filter paper in a Contherm Scientific 630 growth cabinet under a day length/temperature cycle comprising 10 hr dark at 15°C and 14 hr light (c. 35 E m^{-2} d^{-1}) at 25°C, corresponding approximately to spring/summer conditions. Each treatment comprised four replicates of 25 seeds. Differences in the total percentage germination between *Atriplex* species, storage conditions, and light levels were assessed using a 3×2×2 factorial combination of treatments analysis run using PROC ANOVA in SAS (version 6.12). Tukey's range test was used to compare germination between the three light treatments. Percentage germination data were arcsine-square root transformed prior to analysis.

TAXONOMY

Atriplex L., *Sp. Pl. 2*: 1052 (1753)
Type species: *A. hortensis* L. (*fide* NcNeill et al. 1983).

Key to *A. hollowayi* and *A. billardierei*

1 Adult leaves irregularly dentate, (2–)6(–12) × (1–)3(–6) mm, bracteoles chartaceous, seeds (0.9–)1.5(–2) mm diameter ... ***Atriplex hollowayi***
Adult leaves entire, (5–)10(–20) × (2–)5(–7) mm, bracteoles coriaceous, seeds (1.8–)3(–4) mm diameter ..... ***Atriplex billardierei***

Atriplex hollowayi de Lange et D.A.Norton, sp. nov.

DIAGNOSIS: Differt *Atriplex billardierei* staturae parviore, habito suberecto ramosissimo, foliis parvioribus irregulater sinuatis-dentatis, bracteolis chartaceis parvioribus, semine parvioribus.

Differs from *Atriplex billardierei* by the smaller, erect, heavily branched habit, smaller, distinctly but irregularly, sinuate-dentate leaves, and by the smaller papery bracteoles enclosing a smaller seed.

HOLOTYPUS (Fig. 1): New Zealand, North Island, Te Paki Ecological Region and District, North Cape, Waikuku Flats, Waikuku Beach, near outlet of Te Kanakana Stream, in mobile sand amongst rotting seaweed and other flotsam, 34°25′S 173°00′E, *P. J. de Lange*, 15 Jan 1996, AK 225956 (dry collection). Isotypi: AK 225314 (wet collection), CHR 536636 (wet collection).

DESCRIPTION: Erect to decumbent, densely branched, succulent, leafy, monoecious, annual herb, forming circular mounds within sand 0.8–1.2 m diam. Branches 10–50 mm long, succulent, creamy yellow, rooting at nodes; exposed surfaces coated with deciduous, watery, spherical, glistening papillae. Cotyledons 2–4 × 3–4 mm, succulent, pale yellow, margins entire. Leaves without discernible juvenile phase (2–)6(–12) × (1–)3(–6) mm, oblong-obovate, ovate, elliptic, or lanceolate, green to glaucous-green, succulent. Petioles short, 0.2–0.5 mm. Leaf surface glabrous, sparsely to densely covered in deciduous watery, spherical, glistening papillae; apex and base obtuse; margin distinctly irregular-dentate. Male flowers axillary, in clusters of 2–4, rarely single; occasionally with rudimentary stigma; perianth lobes 5, green or pale-cream, 0.8–1 mm long, elliptic-oblong, apex inflexed, cucullate, margins ± crenate, abaxial surface densely covered in watery papillae; stamens 5, filaments 0.6 mm long, white, anthers 0.2 mm long, oblong, apicifixed; pollen sulphur yellow. Female flowers minute, (0.8–)1(–1.2) mm, shortly stipitate, borne in leaf axils, either solitary, or in pairs, usually accompanied by a short shoot with one pair of reduced leaves. Peduncles minute, 0.15 mm long. Perianth absent; bracteoles, fused for ± ½ their length, lips triangular obtuse, 0.4 mm, laciniate, fimbriate or entire; external bracteole surfaces entirely covered in watery, spherical, glistening, papillae 0.15–0.19 mm diam.; styles 2 not at all connate, stigmas 2, 0.7–1 mm, white, upper half exserted, tapering-terete, 0.1–0.2 mm diam., exserted portion with antrorse papillae. Ovary flattened at right angles to lips, 0.4 mm diam., sessile or almost so. Fruiting bracteoles (2.8–)3.3(–4) × (1.5–)2(–2.3) mm, straw-yellow, subsessile or shortly stipitate; urceolate, valves weakly fused for ½ of their length, somewhat swollen toward base, distinctly chartaceous, frequently torn or frayed so as to expose seed, with an entire margin, apex fimbriate or entire, outer surface densely coated in watery papillae 0.2–0.3 mm diam. Seed circular in outline, convex, (0.9–)1.5(–2) mm diam., testa at first chestnut-brown, maturing to purple-brown, and fading to black with age, surface matt, ± smooth, finely pitted or rugose; radicle lateral, erect. FL Oct–Apr; FT Nov–May.

REPRESENTATIVE SPECIMENS: NEW ZEALAND: NORTH AUCKLAND: Spirits Bay, *W. R. B. Oliver*, 20 Feb 1929, WELT 51807; "North Cape", *J. Buchanan*, n.d., WELT 517976; Waikuku Beach, *H. E. Powell*, 26 Jan 1950, AK 44890; Te Kanakana Stream, Waikuku Beach, *P. J. de Lange 1239 & G. M. Crowcroft*, 30 Jan 1992, AK 207163; Whareana

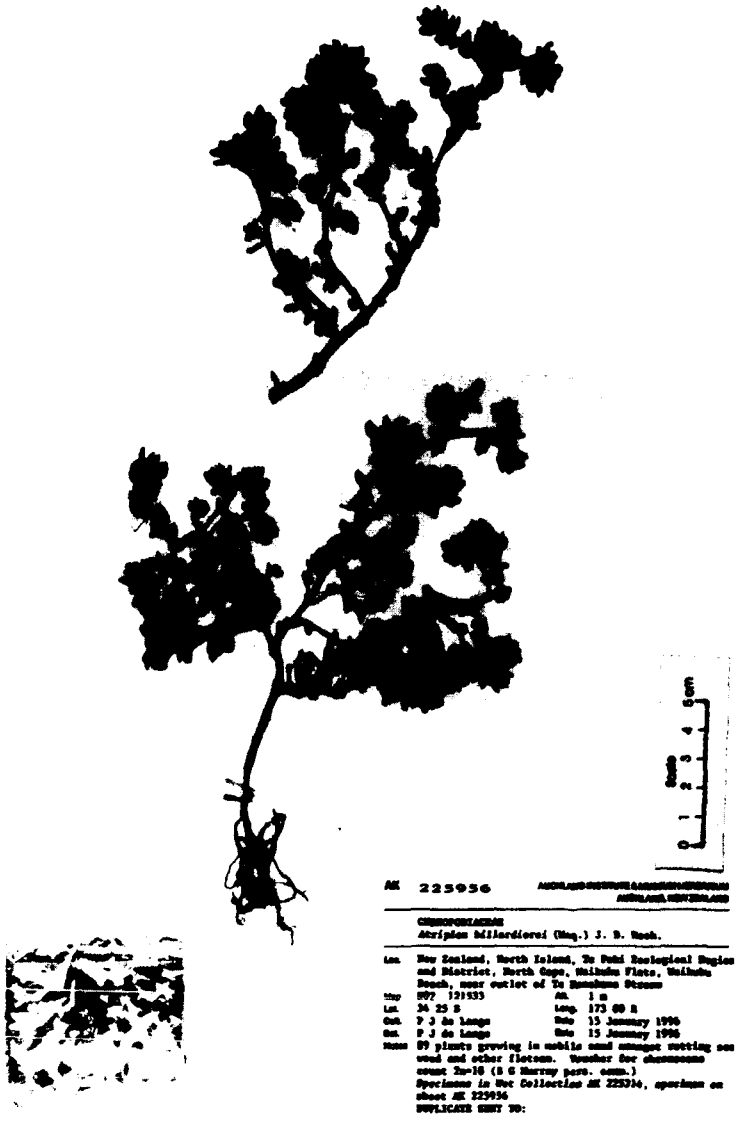

Fig. 1 Holotype of *Atriplex hollowayi* (*P. J. de Lange*, AK 225956).

Beach, *H. E. Powell*, 20 Jan 1950, AK 44889; Houhoura, *A. E. Esler 3604*, 22 Dec 1971, CHR 227502; Rangaunu Harbour, *H. Carse*, Jan 1915, AK 3963; Karikari Bay, *R. Mason & N. Moar 286*, 30 Nov 1949, CHR 69618; Whangaruru, *W. Colenso*, n.d., WELT 22521; Takou Bay, *T. F. Cheeseman*, Nov 1889, AK 3962; Great Omaha, *T. Kirk*, 10 May 1864, WELT 51802, P. GREAT BARRIER (AOTEA) ISLAND: Whangapoua Sands, *T. Kirk*, 19 Dec 1867, WELT 51801, BM. SOUTH AUCKLAND: Mayor (Tuhua) Island, *L. Cockayne*, Feb 1905, WELT 51803; Mt Maunganui [Beach], Tauranga, *F. H. Spencer*, Jan 1890, AK 3965. WELLINGTON: Lyall Bay, *T. Kirk*, 18 Mar 1875, WELT 43401.

CHROMOSOME NUMBER: $n = 9$, AK 225314, 225956, as *A. billardierei* (de Lange et al. 1997a).

DISTRIBUTION: Endemic to the eastern North Island of New Zealand (Fig. 2). Formerly a widespread but local species ranging from Te Paki to Hicks Bay, with one outlying record from Lyall Bay, Wellington. Now reduced to two small populations on Waikuku and Whareana Beaches near North Cape.

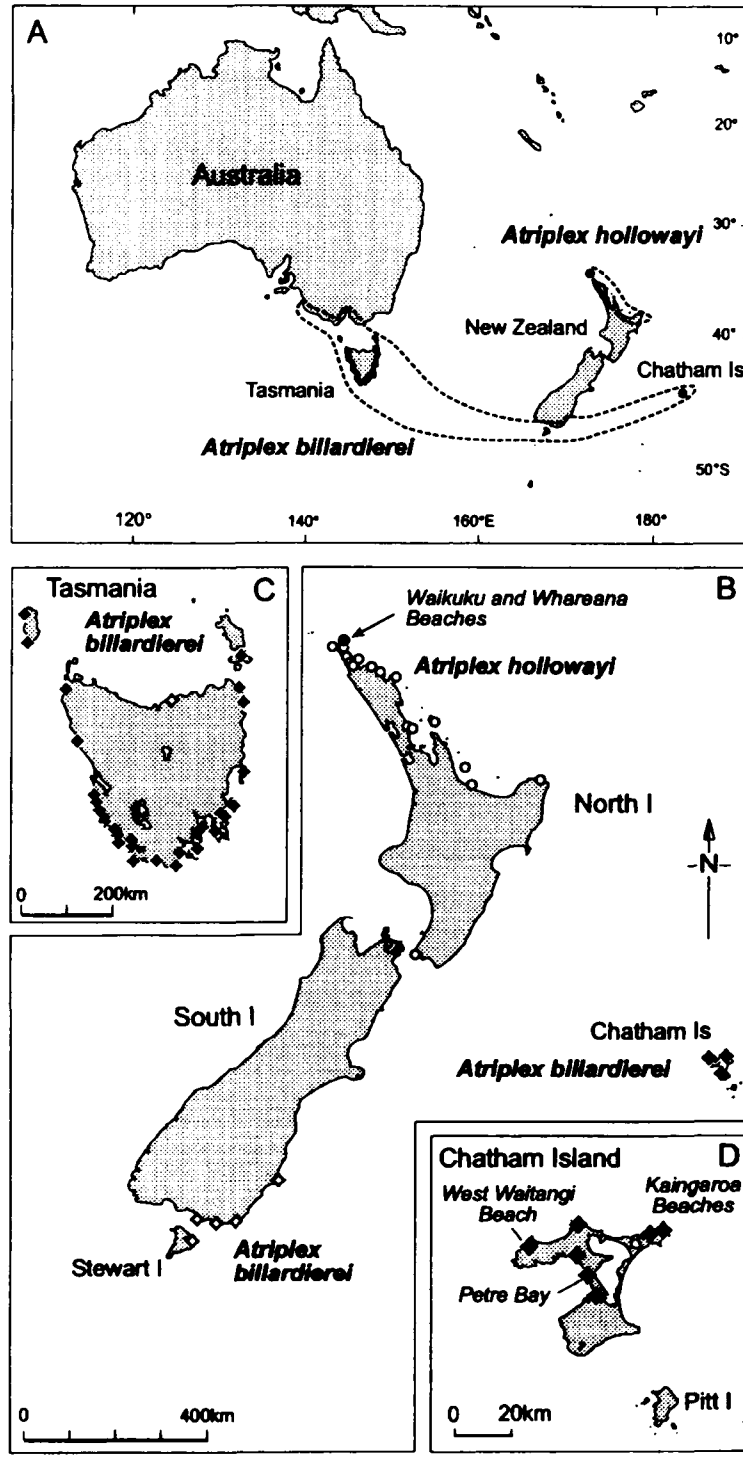

Fig. 2 Distribution of *Atriplex billardierei* and *A. hollowayi*. **A**, generalised distribution of *A. billardierei* and *A. hollowayi* in Australia and New Zealand (dotted lines indicating former range, black sites current range); **B**, distribution of *A. hollowayi* (circles) and *A. billardierei* (diamonds) showing current (black) and former (open) occurrences, and location of study areas used for *A. hollowayi*; **C**, distribution of *A. billardierei* in Tasmania (black indicating current; open indicating former occurrences); **D**, distribution of *A. billardierei* and location of study areas on Chatham Island.

ETYMOLOGY: *Atriplex hollowayi* is named in honour of the late John Stevenson Holloway (1944–1999), former Director of Science & Research, Department of Conservation, and a staunch advocate for threatened plant biosystematics, research, and conservation.

ILLUSTRATIONS: Sawyer et al. (1998, p. 27). Also illustrated in error for Stewart Island as *Theleophyton billardierei* by Wilson (1982, fig. 197), based on a specimen of *A. hollowayi* from Houhoura (*A. E. Esler*, CHR 227502) (H. D. Wilson pers. comm.).

Atriplex billardierei (Moq.) Hook.f. *Fl. Nov. Zel. I*: 215 (1853)

≡ *Obione billardieri* Moq. *Chen. Mon. Encyl.*, 72 (1840).

LECTOTYPE (here chosen, see below): "Novae Hollandiae", P 94219! Herb. Labillardière in Herb. Moquin-Tandon (Fig. 3).

ISOLECTOTYPE: "Novae Hollandiae et Terra Diemen", FI (Herb. Webbianum No. 155980!).

≡ *Theleophyton billardieri* (Moq.) Moq. in DC. *Prodr. 13*: 116 (1849).

NOTES: As there are at least two sheets or specimens of *Atriplex billardierei* gathered by J. J. H. de Labillardière and bearing evidence that they were examined by Moquin-Tandon, lectotypification is necessary. From a perusal of specimens held in his herbarium, it is apparent that Moquin-Tandon routinely detached pieces from specimens in other collections, used these fragments to describe his new taxa, and annotated his sheets accordingly. In the case of *Atriplex billardierei*, Moquin-Tandon apparently detached material from a specimen held in Herb. Labillardière, which at that stage was in the possession of Philip Webb (1793–1854), who allowed Moquin-Tandon access to it for use in his studies of the Chenopodiaceae (Steinberg 1977). Of the two sheets annotated by Moquin-Tandon, P 94219 is lodged in the Herb. Moquin-Tandon. This sheet consists of a small flowering and fruiting piece (Fig. 3), besides which are mounted a series of pencil sketches executed by Moquin-Tandon depicting male and female flowers, an anther, bracteoles, fruits, and an embryo. The sheet is annotated by Moquin-Tandon "Obione Billarderi nova hollandiae herb. Labillard.". This sheet we designate Lectotype. The second sheet, *J. J. H. de Labillardière* Sheet No. 155980, considered an isolectotype, is from the Herb. Labillardière held at FI (see Steinberg 1977). On this sheet is mounted a large flowering and fruiting piece, which is accompanied by a detailed diagnosis in J. J. H. de Labillardière's handwriting. The sheet is annotated in Moquin-Tandon's handwriting "Obione Billardieri Moq.".

= *Atriplex chrystallina* Hook.f. *London. Jour. Bot. 6*: 279 (1847).

LECTOTYPE (here chosen, see below): Tasmania, George Town, *R. C. Gunn 875*, K! (piece labelled B) (Fig. 4).

ISOLECTOTYPES: Tasmania, *R. C. Gunn 875*, K! (specimen labelled C); MEL 607065!; P! (3 sheets).

NOTES: We have located five herbarium sheets labelled *A. chrystallina* by J. D. Hooker. One of these, the sheet in K, is a mixed specimen. Accordingly, lectotypification is necessary. In selecting the lectotype we have worked only with those specimens bearing evidence of Hooker's usage.

The most suitable choice for lectotype is the specimen in the Hooker herbarium at K. The specimen consists of three pieces (labelled here A, B, C) (Fig. 4), and a series of handwritten labels and drawings of which the most significant ones are those of R. C. Gunn and J. D. Hooker. Of the three pieces mounted on the sheet at K, piece A is a specimen of *A. billardierei* sens. str. and is excluded. The bottom two pieces (B & C) are morphologically identical with each other, fitting Hooker's diagnosis of *A. chrystallina*, and match his protologue as to locality and collector. We therefore designate piece B the lectotype. The remaining piece, C, is considered an isolectotype. The three sheets in P plus MEL 607065 are also considered isolectotypes because they are morphologically consistent with the type material at K, and all are labelled by J. D. Hooker as "*A. chrystallina* Hook."

DESCRIPTION: Decumbent, sprawling, lightly branched, succulent, leafy, monoecious, annual herb, forming circular mats or low mounds within sand, to 2 or 3 m diam. Branches 20–150 mm long, succulent, cream or yellow, rooting at nodes; exposed surfaces coated with deciduous, watery, spherical, glistening papillae. Cotyledons (5–)10–12 × (3–)5(–7) mm, succulent, pale yellow, margins entire; these followed by 2–3 pairs of ± sinuate, or lobed juvenile leaves. Adult leaves (5–)10(–20) × (2–)5(–7) mm, oblong-obovate, ovate, elliptic, or lanceolate, green to glaucous-green, succulent. Petioles short, 0.5–1 mm. Leaf surface glabrous, sparsely to densely covered in deciduous watery, spherical, glistening papillae; apex and base obtuse; margin entire, very rarely with one or two lobes. Male flowers axillary, in clusters of 3–4, rarely

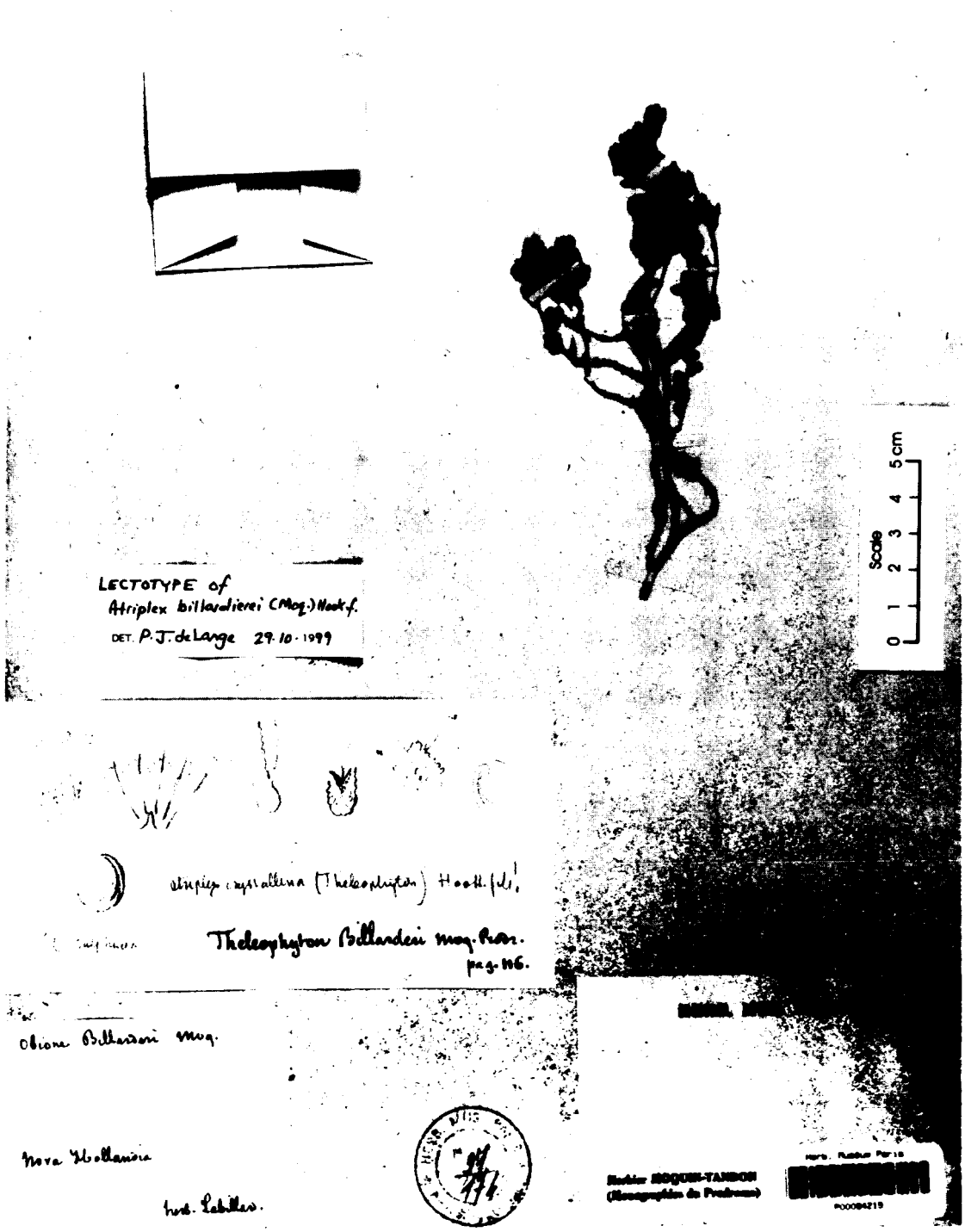

Fig. 3 Lectotype of *Atriplex billardierei* (*J. J. H. de Labillardière*, P 94219).

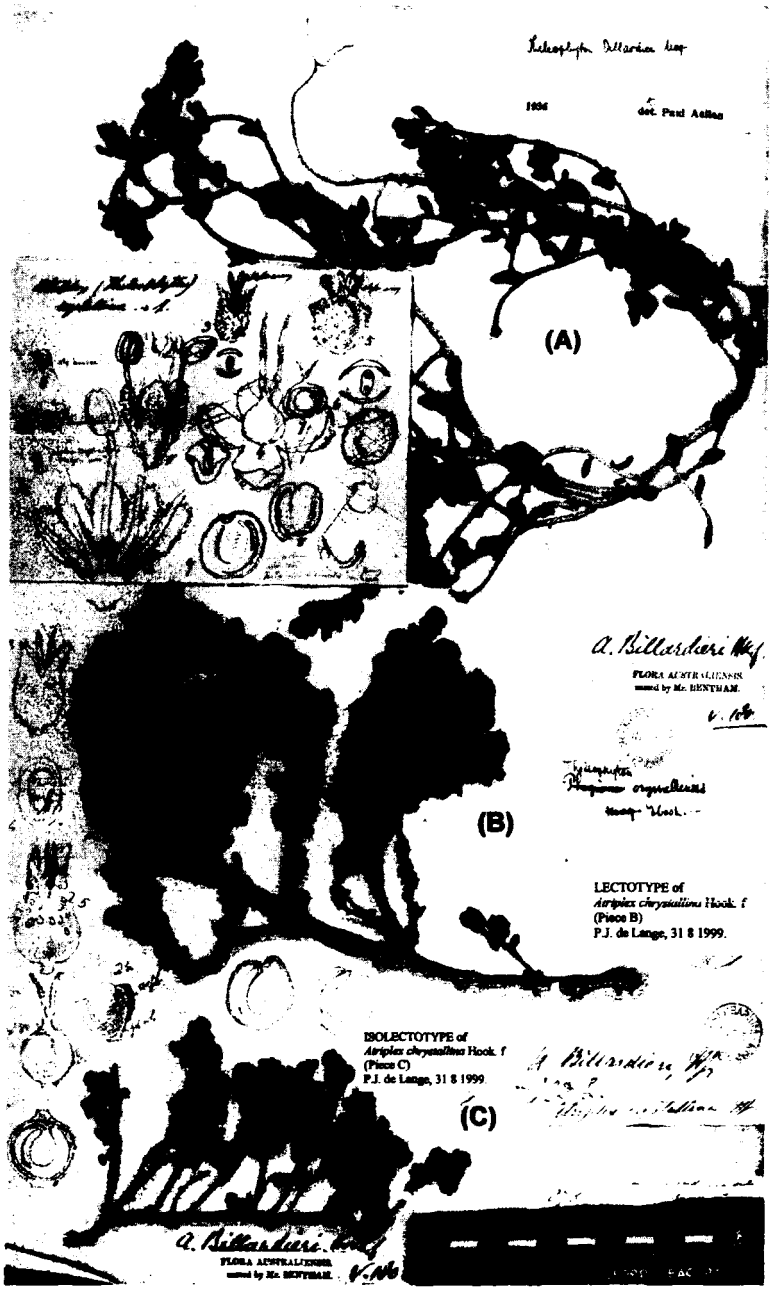

Fig. 4 Lectotype of *Atriplex chrystallina* (*R. C. Gunn 875*, K).

single; occasionally with rudimentary stigma; perianth lobes 5, green or pale cream, 1.2 mm long, elliptic-oblong, apex inflexed, cucullate, margins laciniate-crenate, abaxial surface covered in watery papillae; stamens 5, filaments 0.6 mm long, white, anthers 0.2 mm long, oblong, basifixed, pollen sulphur yellow. Female flowers minute, (1–)1.5(–2) mm, shortly stipitate, borne in leaf axils, either solitary, or in pairs, usually accompanied by a short shoot with one pair of reduced leaves. Peduncles minute, 0.25 mm long. Perianth absent; bracteoles fused for ¾ of their length, lips entire; external bracteole surfaces entirely covered in watery, spherical, glistening, papillae 0.2–0.3 mm diam.;

style connate, stigmas 2, 1–1.3 mm, white, half exserted, tapering-terete, 0.1–0.2 mm diam., exserted portion with antrorse papillae. Ovary flattened at right angles to lips, 0.5 mm diam., sessile or almost so. Fruiting bracteoles (3.3–)5(–9.5) × (2.2–)3.7(–6) mm, light brown or tan, subsessile or shortly stipitate; urceolate, valves rigidly fused for ¾ of their length, swollen toward base, corky, otherwise coriaceous with an entire margin, apex usually entire, rarely finely crenate, or fimbriate; surface densely coated in watery papillae 0.2–0.3 mm diam. Seed circular in outline, convex, (1.8–)2(–4) mm diam., testa chestnut-brown, maturing to purple-brown, fading to black in herbarium specimens, surface matt, ± smooth, or finely rugose; radicle lateral, erect. FL Oct–Apr; FT Nov–May.

REPRESENTATIVE SPECIMENS: AUSTRALIA: VICTORIA: Between Warrnambool and Port Fairy, *F. von Mueller*, n.d., PERTH 2374668; Port Fairy, *H. B. Williamson*, 3 Feb 1906, MEL 607476, NSW 338582; Portland, Discovery Bay, *A. C. Beaglehole*, 14 Jan 1950, PERTH 2374684; Lower Bridgewater (near Portland), *K. J. Kittson*, 7 Jan 1950, MEL 92438; Philip Island, *F. von Mueller*, Feb 1863, MEL 607467, NSW 338580, P; Aire River, *F. von Mueller*, 1874, MEL 607466; Victoria, *F. von Mueller*, P; Darby River mouth, Wilsons Promontory, *J. W. C. Audas & P. R. H. St John*, 9 Nov 1908, MEL 690858. TASMANIA: South West Coast, n.c., 1850, NSW 338585; East Coast, *C. Walter*, Oct 1872, NSW 338587; Cape Barren Island, Furneaux Group, *J. S. Whinray*, 3 Jan 1977, MEL 609588; ?Adventure Bay, *G. Caley*, 1805, BM; Surprise Bay, King Island, *D. I. Morris 7909*, 3 Jan 1979, HO 29270; Mt Cameron West, *T. E. Burns*, 5 Mar 1960, HO 8987; Mt William National Park, *P. Collier*, 18 Mar 1986, HO 99586; Giblin River mouth, *A. M. Buchanan 7716*, 9 Jan 1986, HO 121487; Policemans Point, Anson Bay, *F. Coates*, 19 Jan 1989; HO 114135; Turua Beach, Deadmans Bay, *A. Moscal 14227*, 21 Jan 1987, HO 103707; Modder River mouth, *A. M. Buchanan 2784*, 26 Jan 1984, HO 83964; Recherche Bay, Cockle Creek, *P. J. de Lange TAS76*, 15 Apr 2000, AK 246821.

NEW ZEALAND: SOUTH ISLAND: OTAGO: near Dunedin, *W. A. Thomson*, n.d., CHR 331685. SOUTHLAND: Fortrose, *D. Petrie*, 4 Jan 1913, WELT 51799; Shades Beach, *P. N. Johnson*, 6 Feb 1982, CHR 364567. STEWART (RAKIURA) ISLAND: The Old Neck, *T. Kirk*, 31 Jan 1887, WELT 51797a; The Neck, *D. Petrie*, Jan 1877, WELT 51798. CHATHAM (REKOHU) ISLAND: *H. H. Travers*, WELT 50828a-c; Wharekauri, *E. Madden*, 18 Feb 1954, CHR 91950; Maunganui Beach, 1.5 km west of Takehanga Stream, *D. R. Given 14001*, 1 Mar 1985, CHR 417631; West Waitangi Beach, *G. A. S. Taylor*, 3 Feb 1992, CHR 477363; Long Beach, near Henga, *W. R. Sykes 456/93*, 4 Dec 1993, CHR 496830; Kaingaroa Beach, *P. J. de Lange CH52 & G. M. Crowcroft*, 22 Feb 1996, AK 227267; Petre Bay, Waitangi Beach, *P. J. de Lange CH54 & G. M. Crowcroft*, 21 Feb 1996, AK 229590.

CHROMOSOME NUMBER: $n = 9$, AK 227267–9 (de Lange et al. 1997a).

DISTRIBUTION: Formerly present along the south coast of Victoria, Australia, and the South and Stewart Islands of New Zealand, *Atriplex billardierei* is still extant in Tasmania and Chatham (Rekohu) Island (de Lange et al. 1997a) (Fig. 2). The species has also been reported from Pitt Island, in the Chathams group (D. R. Given pers. comm.) but we have not seen herbarium specimens.

ETYMOLOGY: The epithet "*billardierei*" honours J. J. H. de Labillardière (1755–1834).

ILLUSTRATIONS: Mueller (1889, Pl. t. 2) as *A. crystallinum*; Wilson & Given (1989, p. 88, 89) as *Theleophyton billardierei*; Dopson et al. (1999, p. 169).

REMARKS: The status of *Atriplex chrystallina* remains uncertain. At present authentic specimens of this taxon are limited to the type material, a further two Gunn collections (NSW 338588 & NSW 338590) all gathered before 1850, and one collection made in 1966 (*B. G. Briggs 4733*, NSW 338589). In some respects, e.g., their compact, heavily branched habit and greater preponderance of lobed adult leaves, these specimens approach *A. hollowayi*. However, with regard to the length and coriaceous texture of the bracteoles and the seed size these specimens fall within the range of *A. billardierei* sens. str. Although herbarium and field evidence (B. G. Briggs pers. comm.) suggests that *A. chrystallina* may represent a sporadically occurring, aberrant form of *A. billardierei*, only through cultivation of these plants can their exact status be resolved. Until such time we follow current treatments in relegating *A. chrystallina* into synonymy with *A. billardierei*.

RECOGNITION

Plants of *Atriplex hollowayi* differ consistently from those of *A. billardierei* by their smaller stature, sturdy, erect, heavily branched habit (Fig. 5, 6),

Fig. 5 Habit of *Atriplex hollowayi* at the type locality. Specimen 1.2 m across.

Fig. 6 Habit of *Atriplex billardierei*, Kaingaroa Beach, Chatham (Rekohu) Island. Specimen 2.5 m across.

distinctly irregular sinuate-dentate leaves, weakly fused, chartaceous fruiting bracteoles, and smaller seeds (Fig. 7, 8; Tables 1 and 2).

These characters are retained in cultivation, and remained stable in six generations of plants grown from seed produced from the original cultivated plant material obtained from Waikuku Beach in October 1990. A difference in the flowers of the two species is evident from observations on good flowering material. The female flowers of *A. hollowayi* lack a connate style, while the male flowers of this species possess apicifixed anthers. In *A. billardierei* sens. str. the female flowers possess a connate style and the males have basifixed anthers (R. O. Gardner unpubl.

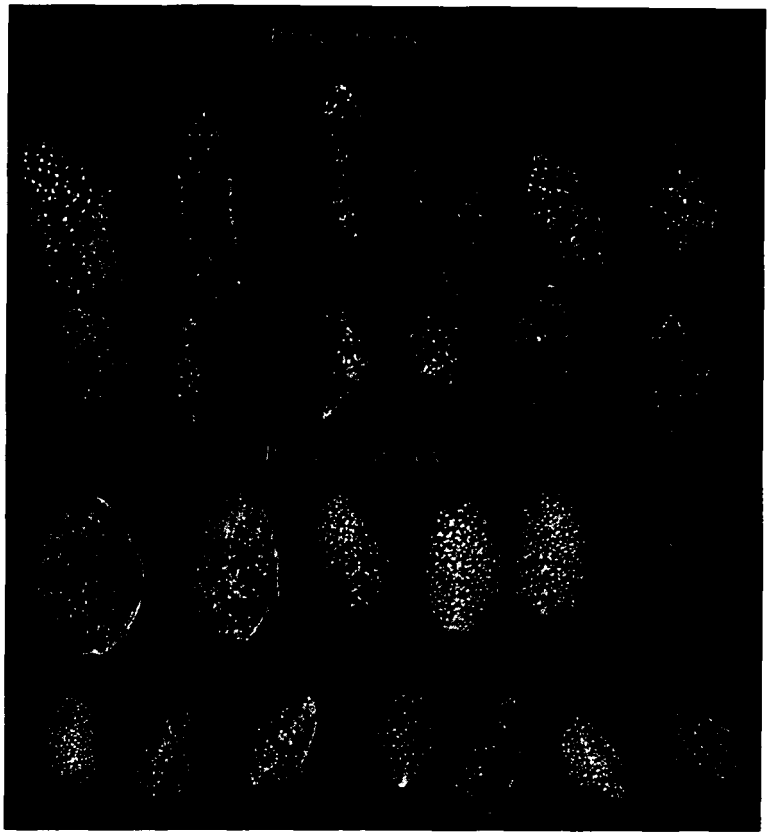

Fig. 7 Leaf outlines of cultivated specimens of *Atriplex hollowayi* and *A. billardierei*.

Fig. 8 Bracteole and seeds of *Atriplex billardierei* (West Waitangi Beach, Chatham Island) and *A. hollowayi* (Waikuku Beach, North Island, New Zealand).

data). However, because of the poor condition or immature state of the majority of dried or preserved flowering material of this species a thorough comparison could not be made.

Although the irregular sinuate-dentate leaves of *A. hollowayi* readily distinguish it from *A. billardierei*, there are a few specimens of *A. billardierei* from Chatham Island (e.g., WELT

50828A, WELT 50828B) and Tasmania (e.g., NSW 338589) that possess an occasional lobed adult leaf. Such examples, along with those extremes described as *A. chrystallina* (Hooker 1847), we believe represent a partial continuance of the normally weakly toothed leaves of juvenile plants. It may have been from plants such as these that *A. hollowayi* evolved through the persistence in isolation of this neotenic stage to the onset of sexual maturity (cf. Sykes 1971; Macmillan 1989).

ECOLOGY

Both these species of *Atriplex* are strand plants, i.e., plants which are found near high tide level at the top elevation of coastal beaches forward of dunes or beach ridges. In New Zealand *A. billardierei* and *A. hollowayi* are virtually restricted to widely shelving sandy beaches, as was also the case for *A. billardierei* on mainland Australia. In Tasmania, *A. billardierei*, although frequenting the same sandy beach habitat, has also occasionally been collected from pebble beaches. Within the sandy beach habitat favoured by both species, plants show a distinct preference for those beaches partially or fully sheltered from storms, usually occurring near freshwater streams or seepages in places where beach sand accumulates (i.e., in the direction of long-shore drift). This preference for stability can be readily seen on Chatham Island where *A. billardierei* is most common on beaches protected by submerged near-shore reefs (D. R. Given pers. comm.).

In these beach habitats, both species are rarely associated with other vegetation. Indeed, throughout the extant ranges of both species, the most frequently encountered associates are the naturalised *Cakile maritima* and *C. edentula* (Brassicaceae), both strand plants. However, other occasional associates in New Zealand include *Desmoschoenus spiralis* (Cyperaceae), *Austrofestuca littoralis* (Poaceae), *Atriplex prostrata* (Chenopodiaceae), and *Salsola kali* (Chenopodiaceae) for *A. hollowayi*; and for *A. billardierei* on the Chatham Islands, *Desmoschoenus spiralis*, *Poa chathamica* (Poaceae), and *Embergeria grandifolia* (Asteraceae). Although in Tasmania *A. billardierei* usually grows by itself, it has been found in association with *Cakile maritima*, *Atriplex*

Table 1 Distinguishing features of *Atriplex hollowayi* and *A. billardierei*.

	A. hollowayi	*A. billardierei*
Growth habit	Erect to decumbent, densely branched annual, forming circular mounds 0.8–1.2 m diameter	Decumbent, sprawling, sparsely branched annual, forming circular mats or low mounds 2–3 m in diameter
Adult leaves	2–12 × 1–6 mm, distinctly and irregularly sinuate-dentate	5–20 × 2–7 mm, entire, very occasionally weakly lobed
Bracteoles	2.8–4 × 1.5–2.3 mm, straw-yellow, chartaceous, frequently torn or frayed so as to partially expose seed	3.3–9.5 × 2.2–6 mm, light brown or tan, coriaceous, basal portion distinctly corky
Seeds	0.9–2 mm diameter	1.8–4 mm diameter

Table 2 Summary statistics for leaf, bracteole, and seed measurements (all in mm except for ratios) from herbarium specimens of *Atriplex billardierei* and *A. hollowayi*.

	A. billardierei		*A. hollowayi*		ANOVA	
	n	mean ± s.e.	*n*	mean ± s.e.	*F* value	*P* > *F*
Leaf length	61	9.7 ± 0.22	42	6.1 ± 0.29	96.34	<0.001
Leaf width	61	4.9 ± 0.21	42	3.2 ± 0.18	33.31	<0.001
Leaf length/width ratio	61	2.1 ± 0.07	42	2.0 ± 0.08	0.893	0.352
Bracteole length	14	5.1 ± 0.40	15	3.6 ± 0.19	11.98	0.002
Bracteole width	12	3.7 ± 0.14	4	2.3 ± 0.08	31.39	<0.001
Bracteole length/width ratio	12	1.5 ± 0.05	4	1.3 ± 0.10	3.86	0.070
Seed diameter	28	3.1 ± 0.16	24	1.5 ± 0.09	66.66	<0.001

prostrata, and, at Cockle Creek, adjacent to or occasionally intermixed with *Austrofestuca littoralis*, *Acaena pallida* (Rosaceae), *Acacia sophorae* (Fabaceae), and *Leucopogon parviflorus* (Epacridaceae) on the most seaward margin of terrestrial vegetation. Although no information is available of the plant associations it once formed on mainland Australia, examination of several historic *A. billardierei* sites at Philip Island, Warrnambool, and Port Fairy suggests it once grew there with a similar range of associates.

Atriplex billardierei and *A. hollowayi* seeds germinated readily, at least in some treatments, with germination starting after 8 days and reaching 80% in the best treatments (Fig. 9). There was no significance difference in seed germination between *Atriplex billardierei* and *A. hollowayi* ($F = 0.41$, $P = 0.530$). However, there was a significantly higher rate of germination when the seed of both species had been soaked in sea water than when it had been stored in damp sand ($F = 26.18$, $P < 0.001$). There was also a significant light effect in germination ($F = 16.63$, $P < 0.001$), with germination in the dark significantly lower than germination in 50% or 100% light which were not significantly different from each other. There was no germination of seeds that were sown in sea water. Seed longevity was not assessed for New Zealand plants, but Tasmanian seed of *Atriplex billardierei* has shown considerable longevity. Of 100 seeds sown in 1994 in a glasshouse seed tray, 4 germinated 1 year after sowing, 2 germinated after 2 years, 12 after 3 years, and 1 after 4 years. The monitored population of *Atriplex hollowayi* at Waikuku and Whareana Beaches has varied dramatically in number over the 10 years studied from a low of no plants present in 1992/93 to in excess of 200 plants in 1991/92 and 1995/96 (Fig. 10).

These results fit well with what is known of the ecology of *Atriplex billardierei* and *A. hollowayi*. These plants occur in small, often isolated, populations along beaches that present a very dynamic environment for plant growth. The high year-to-year variability in plant numbers (Fig. 10) reflects the effects that storms have in altering the suitability of conditions for plant establishment and growth, while storms can also be important agents in the burial and exposure of seed. That seed remained viable for four years suggests that seed can tolerate periods of burial beneath sand, and the very low germination in the dark suggests that seeds are well adapted to respond to re-exposure after burial. Long-distance dispersal can also play an important role in

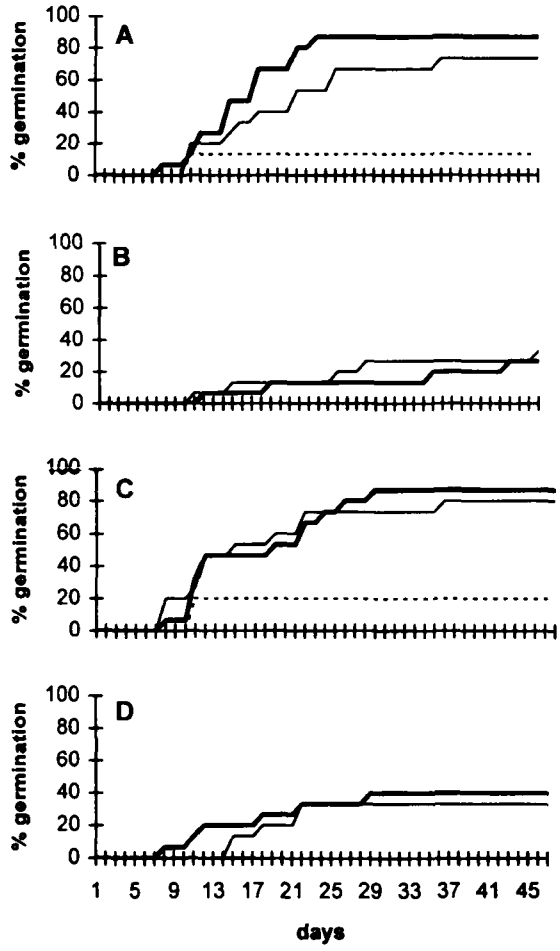

Fig. 9 Cumulative germination of seeds of *Atriplex hollowayi* soaked in sea water (**A**) or stored in damp sand (**B**), and *A. billardierei* soaked in sea water (**C**) or stored in damp sand (**D**) after different storage treatments and at different light levels. Dotted lines 0% light, narrow lines 50% light, and thick lines 100% light treatments.

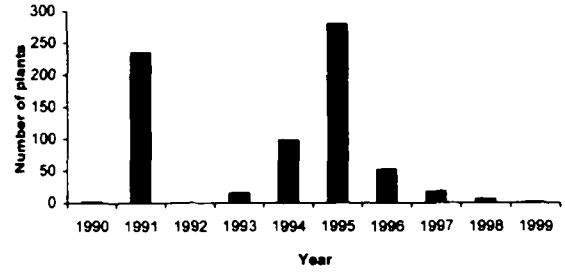

Fig. 10 Population fluctuations of *Atriplex hollowayi* at the type locality over a 10-year period. Dates refer to year in which summer commences.

the re-establishment of localised populations after storms, and the better seed germination after 3 month's immersion in salt water suggests that, as with *Atriplex cinerea* (de Lange et al. 1997b), these species are well adapted to oceanic dispersal. However, the requirement of fresh water for successful germination provides an important environmental cue indicating that the seed has reached a suitable site for germination.

CONSERVATION

In this paper we have shown that the North Island form of *Atriplex billardierei* is a new, apparently endemic species, *A. hollowayi*. With this recognition comes the necessity to reappraise the conservation status of *A. billardierei* and *A. hollowayi*.

Atriplex hollowayi

Atriplex hollowayi was once locally distributed on easterly North Island sandy beaches (Fig. 2). By the 1920s the distribution of *A. hollowayi* had contracted significantly, such that it was only known from the remote sand beaches of Great Exhibition Bay and Te Paki. By 1990 *A. hollowayi* had become confined to Waikuku and Whareana Beaches near North Cape, where the total number of plants has rarely exceeded 200 over the last 10 monitored growing seasons (Fig. 10). However, unconfirmed reports of *A. hollowayi* continue to be made from East Beach, south of Houhoura Harbour (V. Hensley pers. comm.), a location close to where the species was last collected in 1971.

Although the exact cause of decline is uncertain, we suggest that over-collecting by botanists, competition from introduced strand plants, and browsing and/or mechanical damage from animals have been significant factors. Herbarium evidence suggests that *Atriplex hollowayi* seems to have been particularly susceptible to over-collecting during the mid to late 19th century. During this time botanists tended to gather whole specimens (comprising all facets of the species life cycle) from the same locations in numbers which would be considered excessive by today's standards (cf. Norton et al. 1994). For example, in one day per location cited, pioneer New Zealand botanist Thomas Kirk collected a total of 25 plants (10 herbarium sheets; AK, BM, CHR, NSW, WELT) from Great Omaha, near Warkworth and 10 plants (7 herbarium sheets; BM, WELT) from Whangapoua, Great Barrier Island. Another botanist, Harry Carse, gathered an entire plant of *A. hollowayi* from Ranganu Harbour, near Kaitaia remarking "only plant seen". It is perhaps significant that *Atriplex hollowayi* has not been seen in any of these localities since these collections were made. For an annual species such as *A. hollowayi*, with populations naturally prone to large yearly fluctuations, collecting of plants at these levels would represent a significant drain on the species potential seed bank.

Aside from over-collecting, competition from naturalised strand plants has also been suggested as a cause of decline in both *A. hollowayi* and *A. billardierei* (P. N. Johnson pers. comm.). The New Zealand indigenous flora is notable for its lack of beach strand plants; of those known few are common, and even these are rarely found growing together (P. J. de Lange unpubl. data). In contrast to this, the naturalised flora of New Zealand contains several strand species, of which *Atriplex prostrata*, *Cakile edentule*, and *Salsola kali* are now widespread and common species on New Zealand's sandy beaches. Notably, these strand plants occupy exactly the same habitat as *Atriplex hollowayi* (Fig. 11) and *A. billardierei* (P. J. de Lange unpubl. data). Although further experimental study is needed to ascertain whether these species adversely affect *A. hollowayi* or *A. billardierei* populations, it is our impression and that of other field workers (Walls 2000; A. Rozefelds, A. Buchanan, D. R. Given, & P. N. Johnson pers. comms) that this may be the case.

In addition to over-collecting and competition, many of the former beach habitats of *A. hollowayi*, e.g., Whangaruru, Omaha, Mt Maunganui, have now been seriously modified for residential and recreational use, and improved beach access has increased vehicle and human pedestrian traffic. Because *Atriplex hollowayi* and *A. billardierei* have very brittle branches, plants are easily damaged or killed by trampling (P. J. de Lange unpubl. data) and neither species is likely to persist in urban or recreational beach environments. Improved beach access has also facilitated the further spread of browsing animals such as rabbits (*Oryctolagus cuniculus*) and hares (*Lepus europaeus*), while unfenced beach margins in farmed areas have also allowed cattle (*Bos taurus*) and horses (*Equus caballus*) access to some Northland beaches, e.g., Kowhai Beach, East Beach. All of these animals, whether by browsing or trampling, have helped hasten the decline of the species to its current remote beach habitat. The remaining populations of *A. hollowayi* are now mainly threatened by cyclonic storms, which typically strike the coastline during January/Feburary when the

Fig. 11 *Atriplex hollowayi* being smothered by a dense growth of *Salsola kali*, Waikuku Beach, North Island, New Zealand.

plants have only just started setting seed. Although this disturbance impact is natural, the small number of plants found at these sites increases their vulnerability to such stochastic events. Data obtained over 10 years of monitoring (Fig. 10) suggest that these small populations are now limited by storm cycles, the intensity of which has increased in the last decade as a result of severe El Niño/La Niña weather cycles. As a result of these factors we believe that there is a high probability that *A. hollowayi* will become extinct in the short term. Accordingly, we propose a conservation listing of Critically Endangered for *A. hollowayi*, an assessment which has been taken up by the New Zealand Threatened Plants Committee (de Lange et al. 1999) where the species was treated as *Atriplex* aff. *billardierei* (AK 225956; North Island).

Atriplex billardierei

Available evidence suggests that *A. billardierei* is close to being extinct, if not already so, in mainland Australia (de Lange et al. 1997a). This is of interest because the species has not yet been listed by ROTAP (Briggs & Leigh 1988, 1995) despite the fact that it has not been collected over the last 50 years in Victoria (Walsh 1996) and is now rated in that state as "Vulnerable" (Ross 2000). Even in Tasmania where *A. billardierei* has been considered locally common (A. Buchanan pers. comm.), conservation agencies are now considering the formal listing of the species as "Rare" in recognition that it has declined from some parts of its former state range (N. Lawrence pers. comm.).

In New Zealand, *A. billardierei* sens. str. was last collected from the South Island in 1982 at Shades Beach on the South East Otago Coast (*P. N. Johnson* CHR 364567!). Repeated searches of this locality have not rediscovered it there (J. Barkla and B. Rance pers. comm.). However, in a situation somewhat similar to that reported from Tasmania (A. Buchanan pers. comm.), the species remains abundant on the remote beaches of Chatham Island.

As with *Atriplex hollowayi* the exact cause of decline is not known, though it would seem that in both countries competition from *Cakile* spp. and other introduced strand plants could be a factor. Certainly at Warrnambol and Port Fairy, Victoria, where the species had previously been collected, *A. billardierei* habitat is now dominated by *C. maritima* (Fig. 12) and resident botanists have wondered whether this species may have been a factor in the apparent decline of *A. billardierei* (N. G. Walsh pers. comm.). Even in Tasmania, botanists have observed that *C. maritima* and *Atriplex prostrata* have increased their range at the possible expense of *A. billardierei* (A. Rozefelds & D. Morris pers. comm.). Further research into competition is needed to determine whether the spread of these naturalised strand plants has indeed facilitated the loss of *A. billardierei* from parts of its Australian range.

Unlike *A. hollowayi* which seems to have suffered from over-collecting by botanists, the decline of *A. billardierei* from mainland Australia and the South Island of New Zealand cannot easily be linked to this particular threat. Nevertheless, as with *A. hollowayi*, it would seem that coastal resort development, sand mining, and the actions of browsing trampling animals such as rabbits, hares, cattle, and horses are factors which may have helped hasten the decline of

Fig. 12 *Cakile maritima* dominating former *Atriplex billardierei* habitat at Port Fairy, Victoria, Australia. *Atriplex billardierei* was last collected from this site in 1906.

an annual species already vulnerable to the natural perturbations of its sandy beach habitat.

These factors of decline have effectively eliminated the species from the main part of its former range and these same threats occur in varying levels of intensity in the current strongholds of Chatham Island and Tasmania. In some respects this situation is paralleled by such species as *Sicyos* aff. *australis* (Cucurbitaceae), a formerly widespread northern New Zealand endemic that is now virtually confined to the Kermadec Islands and several smaller offshore island groups bordering the North Island of New Zealand. Although the species remains abundant on these islands, its susceptibility to the readily transmitted and widespread cucumber mosaic virus (Thomson 1999) means that even on these island strongholds its long-term survival is uncertain. Accordingly, this species, and indeed many others which remain numerically common, e.g., *Gnaphalium luteo-album* var. *compactum* (Asteraceae), *Peraxilla colensoi* (Loranthaceae), *P. tetrapetala* (Loranthaceae), but which occupy very vulnerable habitats, had until recently received high IUCN listings by the New Zealand Threatened Plant Committee (Cameron et al. 1995). Recently, de Lange & Norton (1998) have argued for a different series of threat categories, citing (amongst other issues) the problem of dealing with declining populations of numerically abundant taxa. In their assessment, such taxa merit classification as "Declining". As *Atriplex billardierei* is still very common on the Chatham Islands and in parts of Tasmania, we believe such a high listing as Endangered is inappropriate. However, on present evidence, the long-term survival of this species in its current strongholds does not seem assured. Accordingly, we proposed that the species should be listing as Declining, an assessment which has been adopted by the New Zealand Threatened Plant Committee (de Lange et al. 1999).

ACKNOWLEDGMENTS

For comments on the ecology, conservation, and occurrences of *Atriplex billardierei* and field assistance in New Zealand we thank Shannel Courtney, Amanda Baird, John Barkla, Brian Rance, and David Given, and in Australia we thank Alex Buchanan, Andrew Rozefelds, Naomi Lawrence, Dennis Morris, Neville Walsh, Peter Roberts, Trish Roberts, and Barbara Briggs. For comments, observations, and field assistance regarding *Atriplex hollowayi* we thank Lisa Forester, Francis Fitzpatrick, Denis McKay, Miriam Ritchie, Trevor Bullock, Nicky Syddall, Bruce Waddell, Mike Avis, and Hugh Wilson. For nomenclatural advice we thank Brian Molloy, Elizabeth Edgar, Patrick Brownsey, and Phil Garnock-Jones. Rhys Gardner provided the Latin diagnosis and Chris Edkins Fig. 1. We thank Hamish Cochrane for assistance with some figures. Alex Buchanan and Andrew Rozefelds (HO, Tasmania) provided seed and fresh material of *Atriplex billardierei*. Suzanne Clegg, Lisa Forester, and Bruce Waddell helped provide samples of *A. hollowayi*. Steve Benham (Auckland Regional Council Botanic Gardens), Tony Silbery, and Vicki Wilton took care of cultivated plants of both species of *Atriplex* at various times between 1990 and 1999. For comments on the manuscript we thank Mike Bayly, Patrick Brownsey, Alex Buchanan, Lisa Forester, Rhys Gardner, Peter Heenan, Peter Johnson, Brian Molloy, Andrew Rozefelds, Neville Walsh, Bec Stanley, Colin Webb, and Paul Wilson. We thank the curators of AD, AK, AKU, BM, CANU, CHR,

CNB, FI, HO, K, M, MEL, NSW, NZFRI, P, PERTH, W, WAIK, WELT, and WELTU for assistance and the loan of specimens. In particular we thank Phillipe Morat, Director (P), Mauro Raffaeli, Curator (FI), and Fiona Willis (K) for assistance with the type material of *A. billardierei* and *A. chrystallina*.

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