Polar Biol (2005)
DOI 10.1007/s00300-005-0035-z

ORIGINAL PAPER

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Probable long distance dispersal of *Leptinella plumosa* Hook.f. to Heard Island: habitat, status and discussion of its arrival

Received: 5 January 2005 / Revised: 30 May 2005 / Accepted: 3 June 2005

Abstract During the 2003–2004 austral summer the number of vascular plant species recorded from Heard Island rose from 11 to 12 with the discovery of one small plant of *Leptinella plumosa* Hook.f. (Asteraceae), an indigenous subantarctic species. It is described and its habitat, likely status and possible means of arrival on the island are discussed. We conclude that the species probably arrived by natural means with a seabird as its most likely dispersal vector. The life history and biology of *L. plumosa* indicates its likely persistence on Heard Island.

Introduction

The establishment of indigenous species on subantarctic islands has been considered an infrequent event because the large distances between islands impose significant geographical barriers to immigration and successful colonisation (Smith 1987). Heard Island (53°05′S, 73°30′E) lies immediately south of the Antarctic Polar Front and is substantially ice-covered, with small areas of ice-free land occurring mainly around the coast (Fig. 1). The island has an area of 367 km^2 and rises to a height of 2,745 m. The closest landmass, other than the McDonald Islands 40 km to the west, is the Iles Kerguelen group approximately 500 km to the northwest. Only 11 vascular plant species had been recorded in the Heard and McDonald Islands up to 2003–2004, an indication of the small area of land available for plant growth and the harsh environmental conditions (Scott 1989) (Table 1). Heard Island's vascular flora has its greatest affinity with Iles Kerguelen, its nearest major neighbour (Scott and Bergstrom, in press).

Significant glacial retreat has occurred on Heard Island over the past few decades. It has been predicted by Bergstrom and Chown (1999) and Scott and Bergstrom (in press) that the expansion of ice-free areas together with ameliorating climate will result in the arrival and establishment of additional plant species. On January 24, 2004 during the 2003–2004 Australian Antarctic Program (AAP) expedition to Heard Island, a single small plant of *Leptinella plumosa* Hook.f. [= *Cotula plumosa* (Hook.f.) Hook.f. (Lloyd 1972; Lloyd and Webb 1987)] was discovered at Paddick Valley on the south coast of Heard Island (Fig. 1). A detailed description of the single known plant is provided, along with information on the habitat, possible provenance and mode of dispersal to the island.

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Description of *Leptinella plumosa* specimen

Leptinella plumosa Hook.f., *Fl Antarctica* 1:26, Tab.19 (1844). Heard Island, dry streambed in braided channels of glacial moraine, Paddick Valley, *K.Kiefer s.n.*, February 2004 (ADT7356). Herb, stems creeping, to 3 mm diameter, with short, stout, green to purple lateral branches bearing terminal rosettes of leaves, glabrous or with a few scattered villous hairs and minute glands. Leaves oblanceolate in outline, 2–4.5 cm long, 1–1.5 cm wide (petiole comprising one-third to one-half the length), silvery green, densely villous when young, tripinnate, primary pinnae seven to ten sub-opposite pairs.

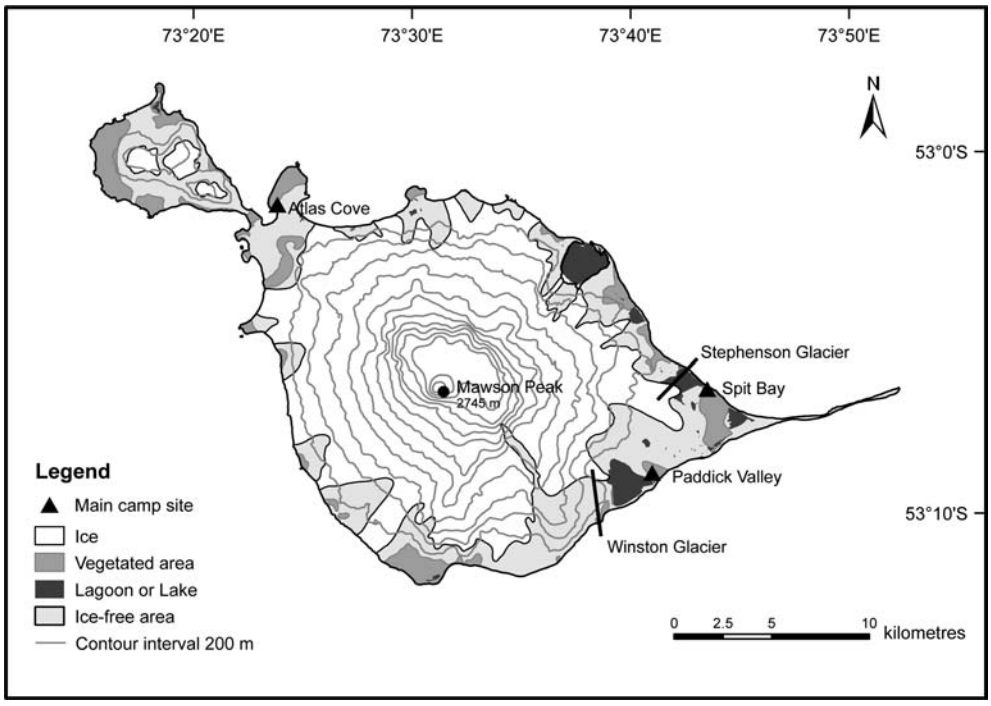

Fig. 1 Heard Island showing the location of Paddick Valley where *L. plumosa* was found. Ice-free areas and place names are indicated

Table 1 Vascular plants recorded from Heard Island. Ticks and years (in brackets) indicate specific locations of species and when they were added to the flora, respectively

Family	Species	Heard Island	Eastern end of Heard Island only	McDonald Island	Southern Indian Ocean Islands only
Apiaceae	*Azorella selago* Hook.f.	√		√	
Asteraceae	*Leptinella plumosa* Hook.f.	√	√ (2005)		
Brassicaceae	*Pringlea antiscorbutica* R.Br.ex Hook.f.	√		√	√
Caryophyllaceae	*Colobanthus kerguelensis* Hook.f.	√		√	√
Callitrichaceae	*Callitriche antarctica* Engelm. ex Hegelm.	√		√	
Poaceae	*Deschampsia antarctica* Desv.	√	√		
	Poa annua L.	√	√ (1989)		
	Poa cookii Hook.f.	√		√	
	Poa kerguelensis Steud.	√			√
Portulacaceae	*Montia fontana* L.	√	(1989)		
Ranunculaceae	*Ranunculus crassipes* Hook.f.	√	√ (1989)		
Rosaceae	*Acaena magellanica* (Lam.) Vahl	√	√		

Sources: Lloyd and Webb (1987); Scott (1989); Flora of Australia (1993); Jenkin (1997)

Scape slender, to 2 cm long, shorter than leaves, densely villous distally. Capitulum ca. 0.5 mm diameter, involucral bracts broadly ovate to triangular, green with a wide brown irregular scarious margin; pistillate florets yellow, ca. 40–60 in two to three rows; ca. 3.0 mm long, corolla joined to the ovary, ovary 1.2–1.5 mm long, staminate florets; fewer than the pistillate florets, yellow, ca. 3.0 mm long, stamens exserted when mature. Achenes, cylindrical, obscurely four-angled (when mature), 1.8–2 mm long, glabrous or sparsely glandular papillose, golden brown.

Lectotype: Auckland Islands, J.D.Hooker 1448, K n.v. (Allan 1961). Observed flowering period: January–February (five capitula observed and two collected). *Habit*: The species shows the typical mat-forming habit for this species (Flora of Australia 1993). When first recorded the plant measured 10×15 cm, and 4 cm in height (Fig. 2). *Habitat*: The plant was growing on a slightly raised section of stream terrace in mineral soil, at the edge of a small half-buried boulder and a loosely formed *Azorella selago* cushion Hook.f., with small clumps of *Colobanthus kerguelensis* Hook.f., *Poa kerguelensis* (Hook.f.) Steud., *Montia fontana* L. subsp. *fontana* and *Poa cookii* (Hook.f.) (Fig. 2). The roots of the *Leptinella* plant extended down into the *Azorella* cushion. *Remarks*: The description of the plant is based upon photographs and the specimen, and was undertaken several months after its discovery. Although having smaller leaves and capitula than in material from some other subantarctic islands, it differs in no significant way from other specimens of *L. plumosa*. The species is highly variable in size and this is thought to be

Fig. 2 *L. plumosa* plant in situ between small boulder and *Azorella selago* cushion. Other species are *Colobanthus kerguelensis* (lower edge of boulder), *Poa cookii* (lower left corner of boulder), *Montia fontana* and *Poa kerguelensis* (lower right corner of boulder). Pencil length = 15 cm. Photo: J.J. Scott

largely due to differences in microhabitat, as plants growing in sheltered positions are larger and more luxuriant, while those in exposed conditions are dwarfed (Chastain 1958; Huntley 1971; Gremmen 1981; Flora of Australia 1993; Smith and Steenkamp 2001). The indumentum is variable between plants and somewhat variable between different islands but no consistent differences have been identified.

Leaf samples of this plant's DNA have been included in a phylogenetic study of the relationships of the *Leptinella–Cotula* group of daisies being undertaken by C. Oberprieler and I. Breitwieser (personal communication). Analysis of ITS and ETS DNA sequences is likely to provide data on higher level relationships within these genera, and therefore is unlikely to yield information on infraspecific and biogeographical relationships within *L. plumosa*.

Additional material examined: Macquarie Island: Handspike Point, 54°30′S, 158°53′E, altitude 5 m, *R.D.Seppelt 12462* (HO66808); North Head, 54°29′S, 158°56′E, altitude 80 m, *R.D.Seppelt 11775* (HO66820); The Isthmus, 54°30′S, 158°56′E, *N.R.Laird s.n.* (HO86653). Campbell Island: De La Vire Point, *D.R.Given 99084* (HO131385). Iles Kerguelen: Ile Australia, *D.Bergstrom* s.n., 49°28′S, 69°53′E (K3648).

Leptinella plumosa on Heard Island and description of its habitat

Paddick Valley is a vegetated ice-free area, approximately 1 km wide extending several kilometres inland, wedged between the extensive lateral moraines of the Stephenson and Winston Glaciers (Fig. 1). The single plant of *L. plumosa* is located approximately 150 m inland on a wide, mostly dry streambed (Figs. 3, 4). This streambed is a flat expanse of gravel and rock 150–200 m wide with many braided channels, indicating numerous changes in course taken by the glacial stream over time. The area surrounding the *Leptinella* plant was field-checked by a series of transects spaced 5–10 m apart over the ice-free vegetated area extending from the coast to approximately 700 m inland. No additional *Leptinella* plants were found. The plant was photographed, measured and its location recorded by differential GPS.

The *Leptinella* plant is situated on a slightly raised section of terrace, about 1 m above the surrounding terraces, which was formerly a lens-shaped island surrounded by braided streams. This island is visible in the aerial imagery of Paddick Valley from 1987 (Fig. 5, 1987 diagram), and in the 2003 satellite imagery (Fig. 5, 2003 diagram). The satellite imagery of 2003 indicates that the stream also changed course sometime between 1987 and 2003 to its present orientation along the western side of the valley (Fig. 5).

Figure 5 also shows the change in the vegetation on the stream terrace from 1987 to 2003. In 1987 the stream terrace was sparsely vegetated with fellfield vegetation (Scott and Ryan 2004) consisting of scattered small forbs, grasses and bryophytes. Fellfield is the predominant vegetation community of the stream terrace further inland, and the vegetation on older moraines appears relatively stable. The main change in vegetation is a considerable expansion of maritime tussock grassland and tussock with cushionfield (Scott and Ryan 2004) within 300 m from the coast.

Vegetation on the *L. plumosa* site is currently mapped as 'tussock with cushionfield' by Scott and Ryan (2004), and consists of open *A. selago* cushionfield, with maritime tussock grassland. This vegetation type is characteristically found on recently exposed moraines with developing vegetation and on coastal terraces influenced by nutrient input and trampling from seals and seabirds.

Fig. 3 Photograph of the environment surrounding *L. plumosa* looking inland. Pencil = 15 cm. Photo: J.J. Scott

Fig. 4 Photograph of the environment surrounding *L. plumosa* looking towards the coast. Pencil in foreground gives scale; pencil = 15 cm. Photo: J.J. Scott

Near the coast (Fig. 4), the streambeds and terraces in the valley are utilised by elephant seals, fur seals and gentoo penguins.

Discussion

Occurrence of *Leptinella plumosa* on Southern Ocean islands

L. plumosa is a circumantarctic species occurring on the Antipodes, Auckland, Campbell, Crozet, Heard, Kerguelen, Macquarie, Marion and Prince Edward Islands (Lloyd 1972; Flora of Australia 1993). Patterns of *L. plumosa* occurrence are recorded for Marion Island (Huntley 1971; Gremmen 1981; Smith and Steenkamp 2001), Iles Kerguelen (Hooker 1844; Cour 1959; Aubert de la Rüe 1964; Delarue 1988), Iles Crozet (Hooker 1844; Werth 1911), Macquarie Island (Cheeseman 1919; Taylor 1955; Gillham 1961; Copson 1984; Selkirk et al. 1990) and Campbell Island (Oliver and Sorensen 1951; Meurck et al. 1994). On these islands *Leptinella* grows optimally in well-drained soils, and is usually restricted to coastal lowlands including areas affected by salt-spray, and/or sites where animals provide nutrient enrichment to the soil. It has also been found above 100 m altitude and more than 1 km inland on sites either exposed to salt-laden winds or in seal and seabird areas, on eroded peat and as a primary coloniser on beaches.

Leptinella displays different growth forms in each habitat. In saline habitats on Marion Island it typically grows in small rosettes up to several centimetres high and is densely covered with long white hairs, and in coastal wind-exposed areas with little peat or soil moisture it is replaced by *C. kerguelensis* and *A. selago* (Gremmen 1981). This 'coastal fellfield habitat' on

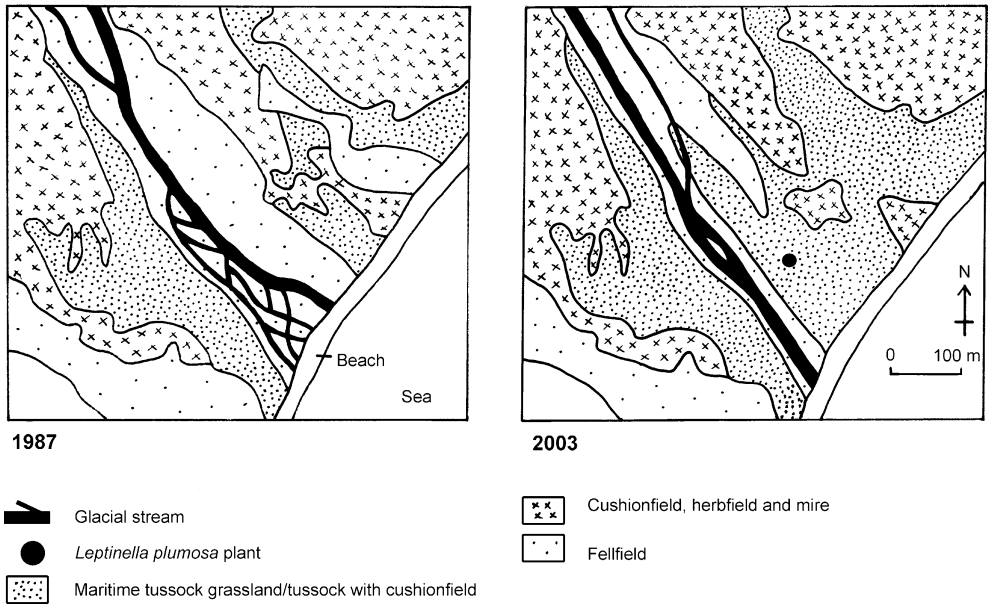

Fig. 5 Changes in the vegetation and stream courses at Paddick Valley between 1987 and 2003 in the stream terrace environment surrounding *L. plumosa*. The key refers to both diagrams

Marion Island (Smith and Steenkamp 2001) most closely resembles the current habitat of *Leptinella* on Heard Island. In nutrient-enriched areas *Leptinella* plants are bright green and luxuriant, reaching 10–25 cm high with long ascending leaves (Gremmen 1981).

Potential dispersal mechanisms

The Asteraceae are among the largest and most widespread flowering plant families, with high species diversity and particular dominance in arid and alpine ecosystems (Flora of Australia 1993). Species of the Asteraceae exhibit a number of characters, including large numbers of propagules and wind-dispersed seeds, which enable successful invasion into new environments and consequently the Asteraceae are considered to be one of the world's most invasive families (Pyšek 1997, 1998). After the Poaceae, the Asteraceae are the second largest family of alien species in the subantarctic (Frenot et al. 2005). The Poaceae and Asteraceae had the greatest diversity of propagules collected from clothing and equipment of AAP expeditioners during recent experiments involving voyages to both Heard and Macquarie Islands (Whinam et al. 2005). *L. plumosa* is perennial and monoecious, and therefore has the capacity to start reproduction through only a single individual. It has a sticky seed coat (Webb and Simpson 2001) and a persistent calyx (Selkirk et al. 1990). It is probable that the sticky seed surface assists dispersal through attachment to the feathers or feet of a bird. Given these traits, the arrival of this species on Heard Island is not unexpected. Transport by humans appears unlikely but not beyond possibility. Transport through attachment to marine mammals is even less likely, but we have no information on whether the seeds can survive prolonged seawater immersion.

Human vs natural dispersal

The possibility of a *L. plumosa* propagule being transported to Heard Island accidentally by humans in the last couple of years and being discarded at Paddick Valley seems extremely unlikely; but then, so does the chance arrival of a viable seed in the recent past via natural means such as a seabird.

Human-mediated dispersal is a possibility because Heard Island is visited by researchers, fishing patrols and tourists. Between 1980 and 2002 there were 33 visits to Heard Island by the Australian National Research Expeditions and AAP and 20–25 visits by fishery patrols and tourism-related expeditions (Chown 2003). A tightening of quarantine regulations for visitors to the island, including inspection and cleaning of clothing and equipment, commenced prior to the 2000–2001 AAP expedition. Regulations were further reinforced and strengthened for the 2003–2004 AAP expedition through application of the recommendations of an independent quarantine risk assessment (Chown 2003) commissioned by the Australian Antarctic Division in 2003. The new management plan being prepared for Heard and McDonald Islands has comprehensive quarantine measures applying to all visitors and provisions for investigating and responding to new species recorded (E. McIvor personal communication).

The reason why human-mediated transport is considered less likely than natural dispersal is that the *Leptinella* plant was discovered at Paddick Valley where relatively few people visit. Most visitors use areas at Atlas Cove or Spit Bay (Fig. 1). The plant is also not located on any track, route or within a scientific study area. Most of the plants introduced by humans to the other subantarctic islands have been around research stations or other sites of habitation (Walton and Smith 1973; Walton 1975; Frenot et al. 2005).

However, Paddick Valley has had some visitors, mainly researchers, working in the area. Expeditioners on the 2000–2001 expedition visited the refuge hut located 750 m further inland than the *Leptinella* plant, and may have traversed the site. This expedition included scientific researchers who had worked on Marion Island, Macquarie Island, Iles Kerguelen and possibly additional subantarctic islands in recent decades, also possibly using the same field clothing and equipment. The likelihood of humans facilitating the arrival of introduced plant species to Heard Island from another subantarctic island is of great concern and the new management plan includes measures to reduce the possibility of this happening in the future.

The most likely although unproven 'natural' dispersal mechanism for vascular plant seeds across the Southern Ocean is accidental carriage by migratory seabirds, on feet or in feathers, and especially during periods of strong winds and storms (Taylor 1955; Smith 1984; Smith et al. 1989; Scott 1989, 1990; Selkirk et al. 1990; Muñoz et al. 2004). Storms may accelerate bird transportation, and lessen the likelihood of touching down at sea. This may increase the chance of seeds remaining attached for the duration of travel (Taylor 1955).

L. plumosa is a circumantarctic species which has successfully dispersed across wide expanses of the Southern Ocean. While we are unable to prove that the occurrence of *L. plumosa* on Heard Island is due to bird-seed transport we consider this as the most probable explanation for its arrival. The sticky nature of *L. plumosa* seeds, and the wildlife inhabited sites in which *L. plumosa* occurs, are conducive to bird-seed transport (Taylor 1955; Bergstrom 1986; Selkirk et al. 1990). The most likely seabird species assisting transport to Heard Island are skuas, giant petrels, kelp gulls and albatrosses.

Evidence of seabirds travelling between Heard and other Southern Ocean locations is scarce, not surprisingly considering the few opportunities to record band resights. Heard Island band resights from the Australian National Antarctic Research Expeditions (ANARE) expeditions between 1985 and 1988 included a Great Skua banded at Marion Island, a South Polar Skua and a Cape Petrel banded at the Antarctic continent, a Black-browed Albatross banded at Iles Kerguelen and a Wandering Albatross banded at Macquarie Island (Woehler 1989).

The establishment of indigenous taxa on the subantarctic islands has been considered an infrequent process, because the large distances between islands impose significant barriers to immigration (Smith 1987). Heard Island's vascular flora has its greatest affinity with Iles Kerguelen, its nearest major neighbour, and also with other southern Indian Ocean islands (Scott and Bergstrom in press). With the exception of *Poa annua*, all vascular plants of Heard Island are considered indigenous, originating in the Southern Hemisphere. Of these, *Montia fontana* also occurs in the Northern Hemisphere (Flora of Australia 1993). *P. annua* originates in the Northern Hemisphere and is now almost cosmopolitan (Flora of Australia 1993). It is classified as an alien species on Heard Island (Frenot et al. 2005) under the definition that follows. Most of Heard Island's vascular plants are either circumpolar or cosmopolitan in origin, apart from three plants (*Pringlea antiscorbutica*, *Colobanthus kerguelensis* and *Poa kerguelensis*), which are found only on the southern Indian Ocean islands of Heard, Kerguelen, Crozets, Marion and Prince Edward, with *P. kerguelensis* restricted to Heard Island and Iles Kerguelen (Table 1) (Greene and Walton 1975; Smith et al. 1989; Scott and Bergstrom in press). The most likely source of the Heard Island *Leptinella* is one of the southern Indian Ocean islands, namely Iles Kerguelen, Iles Crozet or Marion and Prince Edward Islands, located approximately 500, 1,700 and 2,700 km to the northwest and west of Heard Island, respectively.

Indigenous vs alien "introductions"

Knowledge of indigenous vascular floras for most of the subantarctic islands was substantially complete by the early twentieth century apart from a few under-explored islands such as the Heard and McDonald group and Prince Edward Island (Greene and Walton 1975; Smith 1984). Recently, new indigenous vascular species have been recorded in the subantarctic islands, for example on Macquarie Island: *Hymenophyllum falklandicum* Baker (= *H. peltatum*, of Hnatiuk 1972), *Nematoceras dienema* (D.L.Jones) D.L.Jones, M.A.Clem. & Molloy (= *Corybas macranthus*, of Brown et al. 1978) and *Galium antarcticum* Hook.f. (Seppelt et al. 1984) and Iles Kerguelen, *Elaphoglossum randii* Alston & Schelpe (Massé et al. 1982). This increase in vascular flora is probably due to an increased presence of botanical researchers discovering cryptic species, and/or further exploration of islands rarely visited by botanists [addition of six species to the flora of Marion and Prince Edward Islands in 1965–1966 (Huntley 1971) and three species to the Heard Island flora in 1987 (Scott 1989), see Table 1]. Sometimes misidentification or taxonomic revision has resulted in the discovery of new indigenous species, for example on Macquarie Island, *Uncinia divaricata* Booth in Hook.f. (= *meridensis*, of Seppelt et al. 1984), *Poa litorosa* Cheeseman [of Seppelt et al. 1984, but probably first recorded as *Festuca contracta* Kirk of Handspike Point, Macquarie Island by Taylor (1955), D.M. Bergstrom et al., unpublished data] and *Azorella macquariensis* Orchard (Orchard 1989).

Long-distance dispersal and establishment of indigenous vascular plants around the Southern Ocean is doubtlessly still continuing (Selkirk et al. 1990), but without always being noticed by researchers. Presumably over the past 10,000 years or so in the environment of a relatively stable regional climate (Smith 1984; Selkirk et al. 1990), all the indigenous species likely to establish on an island have already arrived. This situation may change as climatic conditions continue to

ameliorate in the region, although there has been a lack of evidence so far (Frenot et al. 2005). The arrival of *L. plumosa* on Heard Island could be a chance dispersal event or circumstantial evidence of changing climate.

On Heard Island, with its unique combination of a very depauperate flora and substantial recent environmental changes favouring plant colonisation, it has been possible to record the approximate arrival and establishment time of a new indigenous plant species. The three conditions for invasion success are dispersal, establishment and subsequent persistence (Hobbs 1989). Here we interpret "persistence" to include reproductive success. *Leptinella* on Heard Island would be in the early establishment phase, and successful survival and reproduction appears likely. It is possible that additional indigenous species (as well as other *Leptinella* plants) have already established undetected on the island, and may have arrived, established and disappeared on Heard Island without being noticed by researchers. Relatively few botanical researchers have surveyed even the most accessible ice-free areas (Scott and Bergstrom, in press) while the island's rugged terrain means that some ice-free areas remain virtually inaccessible to researchers.

It is an unusual situation for researchers to record the recent arrival of an indigenous plant species on a subantarctic island rather than an alien species. We adopt the definition of 'alien' species used by Frenot et al. (2005), that is, species 'introduced to an ecosystem as a result of human activity (including species that arrive by natural means to a specific ecosystem but are alien to that biogeographical zone)'. Most publications discussing plant species introductions to the subantarctic and southern temperate islands refer to aliens as being probably introduced knowingly or accidentally by humans (e.g., Walton and Smith 1973; Walton 1975; Wace 1986; Meurck 1977; Gremmen 1997; Gremmen et al. 1998; Gremmen and Smith 1999; Frenot et al. 2001, 2005).

The documented dispersal pattern through time of alien vascular species in the subantarctic differs from that of indigenous species. Frenot et al. (2001) noted that relatively few alien vascular species were recorded on the French subantarctic islands early in subantarctic history (i.e., approximately 200 years in the past). A large number of alien species were recorded after subantarctic research stations were established in and around the 1950's, and since then there has been a continual increase in numbers. Fortunately only a few of these recent introductions have expanded their range beyond the vicinity of human settlements (Frenot et al. 2001, 2005). Similarly, in South Georgia very few alien plant species have become established beyond the immediate surrounds of abandoned whaling stations and the Government station at King Edward Point (Walton and Smith 1973).

In the 1970s Walton predicted that a major amelioration in climate would probably be necessary for most of the subantarctic alien flora to become 'weedy' and to compete actively within undisturbed indigenous vegetation (Walton 1975; see also Meurck 1977). Several aliens in the past decade have been reported to be aggressively spreading and invading native vegetation communities on Marion Island and Ile de la Possession in the Iles Crozet group (Gremmen et al. 1998; Gremmen and Smith 1999; Frenot et al. 2001, 2005), while the rate of climatic warming in the subantarctic region has been increasing since the 1970's (Bergstrom and Chown 1999; Walther et al. 2002; Thost and Allison in press; Frenot et al. 2005). Although evidence exists for recent expansion of alien species at a local level on some islands, Frenot et al. (2005) caution that there is no clear evidence so far to link climatic change with long-distance inter-island colonisation by new species. This is, however, expected to occur (Walther et al. 2002; Chown 2003).

The danger of additional alien vascular plants, especially invasive species, arriving and establishing on Heard Island is very real (Chown 2003; Scott and Bergstrom in press; Frenot et al. 2005). The likelihood of alien introductions has been found to increase with rising numbers of human visitors (Chown et al. 1998), whether they are researchers or non-researchers, and the likelihood of alien species establishing and spreading will also increase for the same reasons as outlined earlier (continued climatic warming and expansion of ice-free land).

Probable behaviour of *Leptinella plumosa* on Heard Island and recommendations for future management

L. plumosa is known to be an efficient coloniser on other subantarctic islands of salt-affected coastal and manured sites (subject to only moderate trampling), and disturbed sites. Colonisation is facilitated via a perennial life span and stoloniferous growth. Trampling, resulting in breakage of a creeping stem, will not necessarily negate growth. Instead, due to stoloniferous growth, plant persistence and expansion is more likely. If wildlife trampling does not eliminate the single plant recorded on Heard Island, it is likely to spread as there are substantial areas of suitable habitat in the vicinity. Additional plants of *L. plumosa* may also establish as a result of long-distance or local dispersal.

Current habitat conditions on Heard Island are similar to those of subantarctic islands already discussed. Salt-laden winds are frequent, areas of wind-blown sand are common, and there is also potential for abandoned elephant seal wallows, gentoo penguin areas and lee slopes enriched by nutrients from burrowing petrels to become colonised by *Leptinella*.

On subantarctic islands where *Leptinella* is well established it usually plays an important role in vegetation succession on areas disturbed by coastal wildlife, along with *P. annua* (Gremmen 1981). The latter species, a persistent alien (Frenot et al. 2005), has been recently established on Heard Island and is expanding its distribution, with its most vigorous expression in nutrient-

enriched near-coastal sites (Scott 1989; Scott and Kirkpatrick in press).

The ice-free portion of Heard Island consists of a number of small 'islands' between the glaciers (Fig. 1), each with their own combinations of habitats and plant species (Scott and Bergstrom in press). For plant species to spread around the island, intra-island dispersal events must occur. It is also possible that separate long-distance (inter-island) dispersal events may be responsible for colonising other ice-free areas of the island. Of the 12 vascular plant species now known on Heard Island, five have been recorded only on the eastern side of the island (Table 1). The spread of three of these restricted species; *P. annua*, *Ranunculus crassipes* (Hook.f.) and *Acaena magellanica* (Lam. Vahl.) is currently being monitored on the island (Scott and Kirkpatrick in press; D.M. Bergstrom et al. unpublished data).

The new management plan for Heard and McDonald Islands will reduce the risk of alien introductions occurring through human visitation but will not alter the possibility of introductions by natural long-distance dispersal. *P. annua*, the only alien vascular species recorded on Heard Island is thought to have arrived by natural means (Scott 1989; Scott and Bergstrom in press), although there is no certainty of its origin. This species was one of the few aliens recorded early in subantarctic history (discussed previously), which may reflect its unusually successful survival strategies and possibly include its ability, seemingly rare among aliens, to transfer between Southern Ocean islands without human assistance. With continuing ameliorating conditions in the subantarctic region, however, the possibility of natural long-distance dispersal and establishment of additional alien vascular species on Heard Island cannot be discounted.

In the absence of any clear evidence concerning the means of arrival of *L. plumosa* on Heard Island, we recommend monitoring of the known plant during subsequent AAP Heard Island expeditions. A careful search for additional plants should be undertaken and if found, their progress and status should also be monitored. As environmental conditions for plant growth continue to improve, *L. plumosa* could legitimately be expected to arrive and establish on Heard Island from neighbouring subantarctic islands. If its presence is the result of a natural long-distance dispersal event, then it is one which researchers have been fortunate enough to record in the early stages of establishment. It is extremely difficult to identify long-distance dispersal events. Dispersal events are, in general, still a mystery (Williamson 1996). The occurrence of *L. plumosa* on Heard Island raises interesting ethical and management issues for the ongoing management of subantarctic islands.

Acknowledgements This research was made possible through AAS programs 1181 and 1015 and fieldwork was facilitated by AAP/ANARE expeditions. We thank Alex Buchanan, Rod Seppelt, Ewan McIvor, Dana Bergstrom and Justine Shaw for stimulating discussion and/or reviewing the manuscript, the Australian Antarctic Data Centre for Fig. 1, and C. Oberprieler and I. Breitwieser for providing molecular advice regarding the status of *Leptinella* and *Cotula*. Comments received by three anonymous referees improved the manuscript.

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