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THE DISTRIBUTION AND SPREAD OF ALIEN VASCULAR PLANTS ON PRINCE EDWARD ISLAND

P. G. RYAN, V. R. SMITH† and N. J. M. GREMMEN‡*

Surveys of alien plants at subantarctic Prince Edward Island in 2001 show that the ranges of all three introduced species have increased since the last survey in 1998. *Poa annua*, the longest-established species, increased its range substantially after 1987, prior to which it was confined to a single site for more than 20 years. It remains largely restricted to sites characterized by intense disturbance by seals and seabirds. *Sagina procumbens*, the most recently discovered alien plant, has spread even more rapidly (up to 800 m $year^{-1}$) and has colonized the west coast of the island (a leap of at least 3 km). Unlike *Poa annua*, it is not restricted to animal-disturbed areas, although its seeds probably are dispersed by both birds and fur seals. *Cerastium fontanum* also continues to spread at the island, but remains confined to the western coastal plain, where it occurs mostly on dry feldmark slopes or erosion scars. All three species have expanded their ranges faster than at Marion Island, possibly because of a warmer recent climate and higher densities of seabirds and seals at Prince Edward Island. The ranges of alien plants are likely to continue to expand, with *S. procumbens* causing considerable changes in the island's terrestrial ecology.

Key words: *Cerastium fontanum*, invasive plants, Prince Edward Island, *Poa annua*, *Sagina procumbens*, Subantarctic

Introduced organisms pose the most significant threat to the conservation status of oceanic islands (e.g. Williamson 1996). Subantarctic Prince Edward Island, the smaller of the two islands in the Prince Edward Island group, has few introduced organisms; it is currently known to support only three introduced animals (all invertebrates; Chown *et al.* 1998) and three introduced vascular plants (Gremmen and Smith 1999). By comparison, nearby Marion Island has supported naturalized populations of two introduced mammals, one fish, 16 invertebrates and at least 12 vascular plant species (Watkins and Cooper 1986, Chown *et al.* 1998, Gremmen and Smith 1999). The paucity of introduced species at Prince Edward Island is the main factor determining the island's high conservation ranking among subantarctic islands (Chown *et al.* 2001).

The near-pristine status of Prince Edward Island has been degraded by the recent arrival of two new alien plants. Prior to the 1980s, the almost ubiquitous weed *Poa annua* was the only introduced vascular plant at the island (Huntley 1971, Gremmen 1975). In 1987, a well-established population of *Cerastium fontanum* was discovered growing on the northern slope of Kent Crater (Bergstrom and Smith 1990) and in 1997 *Sagina procumbens* was found at two sites on the east coast (Gremmen and Smith 1999). All three species are widespread at Marion Island, where they produce small, easily dispersed seeds that form a persistent seedbank (Gremmen 1997). With the exception of *Cerastium*, they also become locally dominant, displacing native species (Gremmen 1997). The occurrence of *Sagina* is especially worrying, because of its marked impact on a wide range of terrestrial communities (Gremmen 1997, Gremmen and Smith 1999). It is also an extremely difficult alien plant to eradicate, because it produces exceptionally large numbers of long-lived seeds; up to 200 000 *Sagina* seeds m^{-2} were recorded in infested areas at Gough Island (NJMG unpubl. data).

This study reports the current distribution of alien plants on Prince Edward Island, based on surveys made in 2001, updating the last survey of alien plants made in 1998 (Gremmen and Smith 1999). Its aim is partly to document the rates of spread of alien species, but it also provides information for making informed decisions about possible attempts to eradicate one or more of the introduced species, as called for in terms of the Prince Edward Islands Management Plan (Prince Edward Islands Management Plan Working Group 1996). Of particular interest is the feasibility of controlling *S. procumbens* on Prince Edward Island, given the rapid habitat transformation it has caused on Marion Island (Gremmen 1997, Gremmen and Smith 1999).

* Percy FitzPatrick Institute, University of Cape Town, Rondebosch 7701, South Africa. E-mail: pryan@botzoo.uct.ac.za
† Department of Botany, University of Stellenbosch, Matieland 7602, South Africa
‡ Data Analyse Ecologie, Hesselsstraat 11, 7981 CD Diever, The Netherlands

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Table I: *Poa annua* populations on Prince Edward Island in 2001 and 2003. The locations of numbered sites are shown in Figure 1

Site	Status and habitat
1	Widespread, but with few dense stands in an area dominated by fur seals and southern elephant seals *Mirounga leonina*. First recorded at this site in the 1990s[1]
2	Penguin Beach: very abundant in the elephant seal wallows and adjacent areas affected by fur seals and king penguins *Aptenodytes patagonicus*. Some dense stands of up to 100 m^2. First recorded in the 1990s[1]
3	Fairly abundant in a localized area dominated by fur seals. First recorded in the 1990s[1]
4	Cave Bay: very abundant in the areas dominated by fur seals both north and south of the main landing beach. Also occurs along the edge of the rockhopper penguin *Eudyptes chrysocome* colony and along the lower reaches of the stream. NJMG recorded a few plants in *Acaena-Azorella* vegetation between the two Golden Gate outcrops in 1994. It does not extend inland to above Golden Gate, despite the presence of fur-seals and gentoo penguins *Pygoscelis papua* breeding there. The affected area has increased considerably since first recorded here in 1965[2]
5*	Abundant with some dense stands on a fur seal-dominated area, with scattered plants extending up an erosion slip to the south and around the inland fringe of a rockhopper penguin colony to the north
6*	Scattered plants around white-chinned petrel burrows on a denuded area of *Blechnum penna-marina* slope between two mire areas
7*	Locally abundant in a fur-seal-dominated area immediately south of Boggel Beach, with scattered plants at white-chinned petrel burrows at the top of the coastal cliffs
8*	As Site 7, but north of Boggel Beach, and extending north along the coast to the end of the area occupied by fur seals (the extent of coastal lowlands); sparse above the small, boulder beach midway through this area
9*	A few plants were found along the stream in the upper reaches of Albatross Valley in 2003
10*	Albatross Valley: abundant along the lower stream course and on adjacent slopes dominated by fur seals. Scattered plants extend up some of the stream beds and widely through the grey-headed *Thalassarche chrysostoma* and yellow-nosed albatross *T. [chlororhynchos] carteri* colonies
11*	A few plants on a small stream course among dense *Acaena* vegetation
12*	Fairly common, but mostly scattered plants in a fur-seal-dominated area, with small numbers of plants extending patchily inland along a small stream through mire vegetation
13*	Hope Stream: locally abundant in seal-dominated areas, with scattered plants extending c. 300 m inland along all four tributaries
14	Apparently restricted to the bottom of two small ponds; first recorded in 1990s[1]
15*	A few plants recorded in vegetation quadrats in an area of jumbled black lava where there is a high density of grey petrels *Procellaria cinerea*

[1] Gremmen and Smith (1999)
[2] Huntley (1971)
* New sites

STUDY AREA AND METHODS

The Prince Edward Islands lie in the Indian Ocean sector of the Southern Ocean. They have depauperate native floras, because of their relatively recent volcanic origin, isolation from other land masses, and possibly their cold, wet and extremely windy climate (Gremmen 1981). The recent origin and depauperate nature of the native flora renders it susceptible to introductions of non-native species by human visitors.

Prince Edward Island (44 km^2; 46°38′S, 37°57′E) was visited from 17 to 22 December 2001. During this period, PGR conducted surveys of surface-nesting seabirds at the island and also made notes on all alien plants encountered. Coverage included all readily accessible coastlines, as well as much of the adjacent interior of the island (see Fig. 1 of Ryan *et al.* 2003). In view of the association between most alien plants and seabird and seal colonies, coverage is thought to have been reasonably comprehensive, especially given the localized ranges of most species. However, some aliens may have been missed in areas where access was impossible owing to high densities of fur seal *Arctocephalus* spp. bulls defending harems. December is the period of peak territory defense by fur seal bulls.

Additional observations were made by VRS during a nine-day visit to Prince Edward Island in April 2001 and by NJMG and VRS during a five-day visit in April 2003. The whole island was inspected for alien plants in 2001; only the eastern part was visited in 2003. GPS fixes were made for most sites, and distributions were plotted on a revised map of the island. The mapped distributions are only approximate, and are intended to show the extent of affected areas. A revised map with names of localities is given in Figure 1 of Ryan *et al.* (2003).

RESULTS

No new alien vascular plants were found during the surveys of Prince Edward Island in 2001, but the ranges of all three alien species known at the island were substantially larger than the ranges observed in 1998 (Gremmen and Smith 1999). All three species were flowering during December, but it was too early to ascertain the proportion of flowers setting seed.

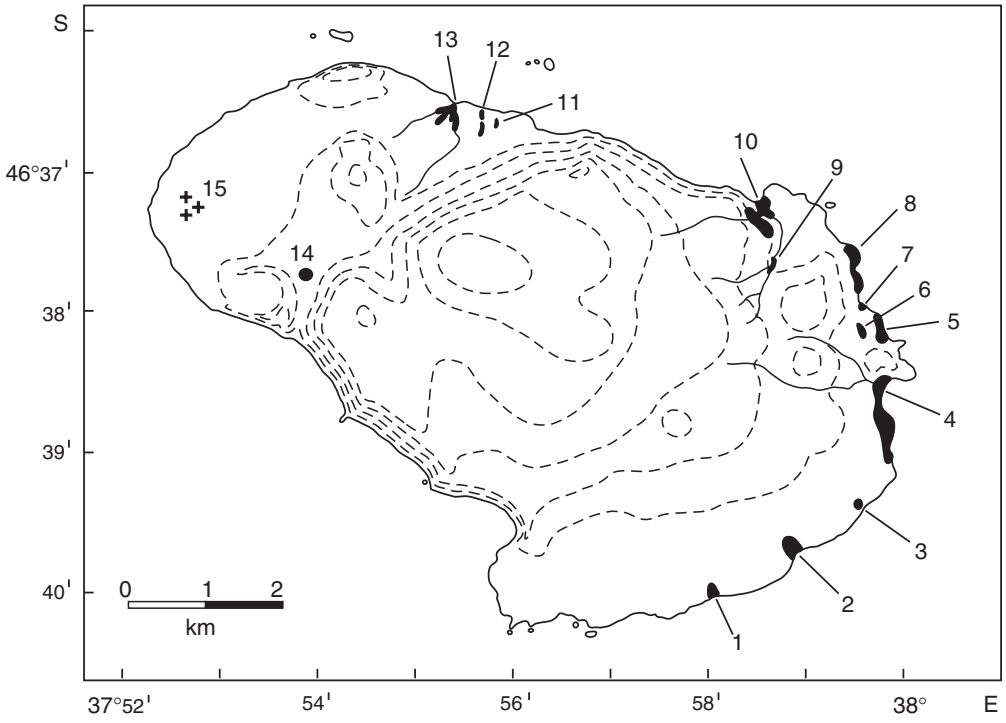

Fig. 1: Distribution of *Poa annua* on Prince Edward Island in 2001 and 2003. The symbol + denotes scattered plants (see Table I)

Poa annua

This species was found at 15 sites, 10 of which are new records (Table I). It is widely distributed along the east, north and west coasts (Fig. 1) and is the most abundant alien plant on the island. Most sites where it occurs are characterized by trampling and manuring by seals or, to a lesser extent, penguins and other seabirds (Table I). At most seal-affected sites it forms dense stands, especially in old wallows, entirely dominating the vegetation for areas of up to 100 m^2. It tends to be more scattered when associated with seabird colonies, typically occurring singly or in small clumps in disturbed areas (e.g. around albatross *Thalassarche* nests or petrel burrows), or forming a narrow fringe around the edge of *Eudyptes* penguin colonies. It is possible that the species is even more widespread than shown in Figure 1, because single plants are easily overlooked (e.g. Site 15). It is probably also more widespread in the albatross colonies that extend westwards along the cliffs from Site 10 (these steep cliffs were not visited during 2001).

P. annua was first reported from the island in 1965, when it was found at Cave Bay (Site 4 in Fig. 1; Huntley 1971). It may have been on the island for some time prior to this (possibly even dating back to early visits by sealers), but Cave Bay was the only known site for the species through at least 1987 (Bergstrom and Smith 1990). In the 1990s, it was discovered at three sites frequented by fur seals south of Cave Bay on the east coast (Sites 1–3 in Fig. 1) as well as in ponds north of Kent Crater, the first record from the west coast (Site 13; Gremmen and Smith 1999). Its initial spread from Cave Bay has averaged approximately 280 m $year^{-1}$ on the east coast, with larger movements involved in the colonization of the west coast. Once established in a suitable site, it seems to spread rapidly. The stands at Penguin Beach (Site 2) are at least as extensive as those at Cave Bay, and fairly large, dense stands have already formed at several seal-dominated sites where the species was not found in 1998 (e.g. Sites 5, 8, 10 and 13).

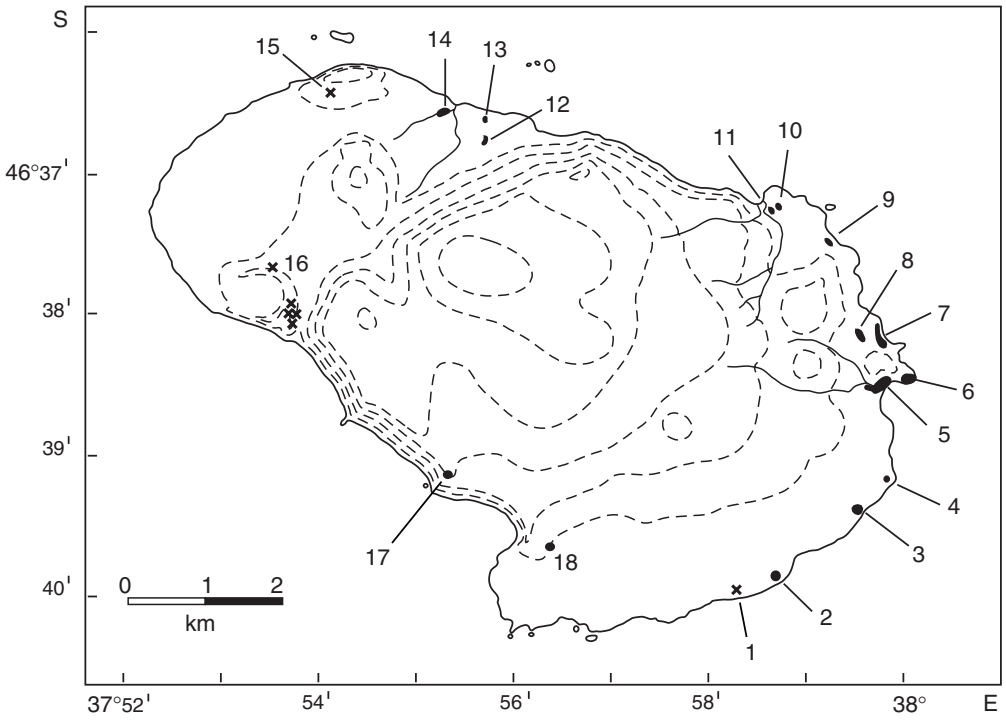

Fig. 2: Distribution of *Sagina procumbens* on Prince Edward Island in 2001 and 2003. The symbol x denotes small plants removed in April 2001 (see Table II)

Sagina procumbens

This species was first recorded at Prince Edward Island in 1997 at two east coast localities (Sites 2 and 5 in Table II and Fig. 2), and then at two further localities in 1998 (Sites 3 and 4; Gremmen and Smith 1999). In 2001 it was found at another seven localities on the eastern side of the island, suggesting an average spread of c. 800 m year^{-1}. It was recorded for the first time on the west side of the island in April 2001, but some of the localities discovered there in December 2001 (e.g. Site 14, Hope Stream, Table II) were heavily infested with some very large plants (cushions in excess of 1 m^2), suggesting that they were colonized several years previously. VRS did not visit Hope Stream in April 2001, but it was inspected in 1998 (by NJMG and D. C. Nel, Percy FitzPatrick Institute, University of Cape Town) and it is unlikely that the species was overlooked there then. VRS removed all *S. procumbens* plants he found on the west coast in April 2001 (Sites 15 and 16 in Fig. 2). None was recorded at these sites in December 2001, but had PGR been aware of the April findings the two sites would have been inspected more closely.

In 2001, *S. procumbens* was less abundant than *P. annua* at Prince Edward Island, but it was equally widely dispersed (Figs 1, 2). It co-occurred with *P. annua* at seven of 18 sites and tended to be more abundant at these sites. Most sites with *S. procumbens* were influenced by seabirds or seals, but it was also at sites with little or no animal influence, e.g. *Crassula* and *Cotula* salt-spray communities along cliff tops on the east coast (Sites 1 and 2), inland mires (sites 12 and 18), and dry feldmark slopes on Kent Crater, Vaalkop and above McNish Bay (sites 15–17).

Cerastium fontanum

This species is locally abundant, but remains the most restricted of the three alien plants found on Prince Edward Island, only occurring on the west coast (Fig. 3).

Table II: *Sagina procumbens* populations on Prince Edward Island in 2001 and 2003. The locations of numbered sites are shown in Figure 2

Site	Status and habitat
1*	A single, small plant removed in April 2001 from *Crassula* cliff-top vegetation; none seen in December 2001
2	Fairly common in *Crassula* cliff-top vegetation; seven large plants found in May 1997[1]. Possibly spreading farther inland in 2001
3	Extensive mats >200 m^2, concentrated in an area where fur seals haul out. Large cushions (total extent >100 m^2) were already present in May 1998[1]
4	Near East Cape: scattered, fairly small plants in a coastal area of *Cotula* and *Crassula* with moderate seabird activity, but no seals. This is in the same area where well-established plants were present in May 1998[1], but no large plants were found in 2001
5	Cave Bay: quite common on the fur-seal-dominated slope area north of the beach, with a concentration in the disturbed area where the old hut was situated. Two plants were found here in May 1997[1]. A few plants occur high up the slope along the route to the interior, but none was found above the level of the inland cliffs (Golden Gate)
6*	RSA Point: abundant on the southern part of the point, with total cover >50% in some areas, becoming less frequent closer to the macaroni penguin *Eudyptes chrysolophus* colony (where *Poa cookii* predominates)
7*	A few plants on the slope south of the fur seal-dominated area, but many more forming large cushions on the north slope, with scattered plants extending north along the inner edge of a rockhopper penguin colony
8*	Scattered plants around white-chinned petrel burrows on a denuded area of *Blechnum penna-marina* slope between two mire areas
9*	Scattered plants around white-chinned petrel burrows on the cliff top
10*	Albatross Valley: a few small plants on mire vegetation, at the edge of the areas influenced by fur seals and wandering albatrosses *Diomedea exulans*
11*	As Site 10; the two sites are separated by a deep stream valley
12*	A few small plants at the edge of a small pool (stream) in a area of level mire, inland of the area where most fur seals penetrate
13*	Several small and medium-sized plants on a stream bank used as a commuting route by fur seals
14*	Western tributary of Hope Stream: quite common in the fur-seal-dominated area; some large cushions >1 m^2, with the total affected area >10 m^2
15*	Vaalkop: seven small plants removed in April 2001 from c. 20 m diameter area on southern slope; none seen in December 2001
16*	Kent Crater: scattered small plants (<6 cm diameter) on dry feldmark along 80 m crest of eastern crater rim (288 plants), plus a single plant on north side. All plants found in April 2001 were removed; none seen in December 2001
17*	Small plants (<10-cm diameter) in open, high-altitude feldmark in 2003
18*	Large, coalescing cushions in mire vegetation around a small lake found in 2003, possibly overlooked in 2001

[1] Gremmen and Smith (1999)
* New sites

In 2001 it was found at five sites, two of which are new records (Table III). It colonizes open areas on dry feldmark and scoria slopes, as well as erosion slips and slumps. The average rate of spread since 1998 has been approximately 370 m $year^{-1}$, with a leap of at least 1 km to reach Vaalkop (Site 4). Its current range is consistent with gradual spread from its initial colonization site at Kent Crater.

DISCUSSION

All three alien plants found at Prince Edward Island are widespread, naturalized species at adjacent Marion Island (Gremmen 1975, Bergstrom and Smith 1990, Gremmen and Smith 1999). Two of the three alien plants have arrived at the island during the past 20 years, despite strict controls on human visits to the island (Prince Edward Islands Management Plan Working Group 1996). It is not known whether the two recent arrivals colonized Prince Edward Island naturally from Marion Island (i.e. seeds carried by seabirds or the wind), or were carried there by people (Bergstrom and Smith 1990, Gremmen and Smith 1999). The distributional data presented here, coupled with the virtual lack of human traffic on the island, argues strongly that dispersal around Prince Edward Island is primarily by natural means. For example, the presence of *Sagina* and *P. annua* at remote, isolated petrel colonies suggests that propagules are dispersed either by birds or the wind. Ryan *et al*. (2003) show the first definite movements of birds from Marion to Prince Edward Island, with three southern giant petrels *Macronectes giganteus* banded as chicks at Marion being found breeding on Prince Edward during the December 2001 survey.

In general, the dispersal rates estimated for the alien species at Prince Edward Island are 2–3 times higher than those calculated for the same species at Marion Island (Gremmen and Smith 1999). The more rapid dispersal on Prince Edward Island has taken place despite the virtual absence of humans there. One plausible explanation for the faster spread is the much higher densities of seabirds and, to a lesser extent, fur seals at Prince Edward Island, which appear to be

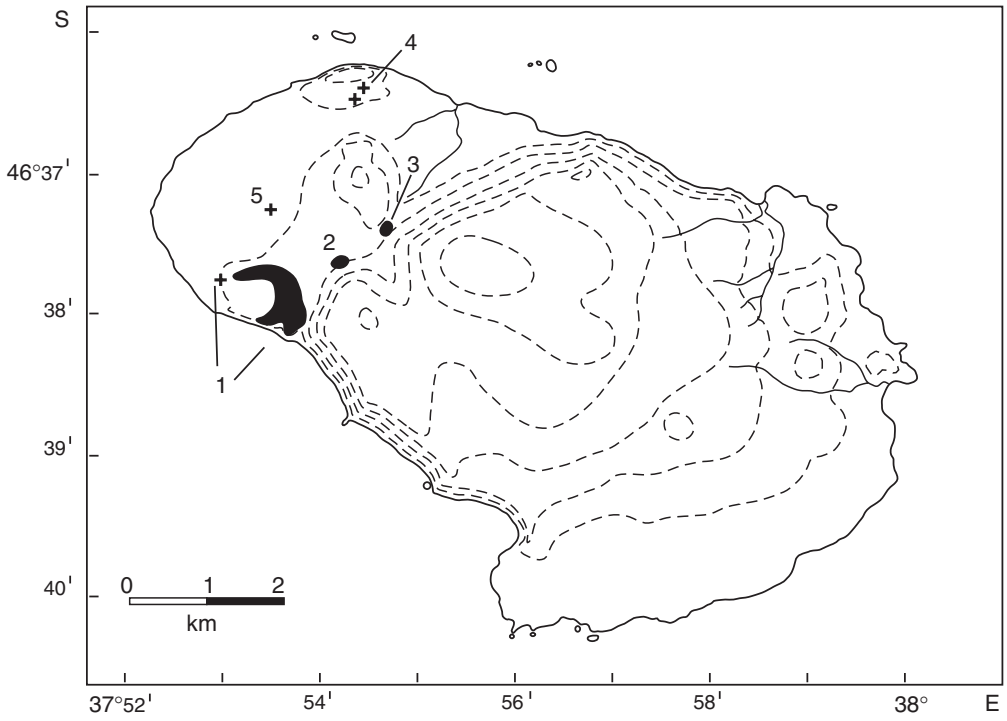

Fig. 3: Distribution of *Cerastium fontanum* on Prince Edward Island in 2001. The symbol + denotes single or small groups of plants (see Table III)

important vectors in spreading propagules. The rapid increase in numbers of fur seals (Bester *et al*. 2003) may have aided the recent spread of *P. annua* by creating more suitable habitat for it. Climate amelioration or a succession of warm summers, resulting in the production of more viable seeds, might also have aided the spread of alien plants during the last few years (Smith 2002). Climate change is predicted to facilitate

Table III: *Cerastium fontanum* populations on Prince Edward Island in 2001. The locations of numbered sites are shown in Figure 3

Site	Status and habitat
1	Kent Crater: abundant on dry feldmark slopes (mostly outer slope and crest, but also on the inner slopes). A few plants occur off the crater walls, mostly in the exposed margins around the lake shores at the crater entrance. Its range has increased considerably since it was first found in 1987[1], but appears to be little changed since 1994[2]
2	Foot of the western scarp: locally common on a slump area, where individual plants grew much larger and more luxuriantly than at more exposed sites on Kent Crater. First reported from this area in 1998[2]
3	Neck between Moeder-en-Kind and the western scarp: only one large plant was found on loose scoria; it was reported to be numerous in this area in 1998[2], but it may have been overlooked because observers walked farther from the foot of the western scarp
4*	Vaalkop: several groups of plants on the southern and eastern slopes, each containing 5–10 individuals
5*	Black lava flow east of West Point: one medium-sized plant on flat expanse of lava in April 2001

[1] Bergstrom and Smith (1990)
[2] Gremmen and Smith (1999)
* New sites

the establishment and spread of alien species in the Antarctic (Kennedy 1995).

Gremmen and Smith (1999) suggested that the rapid spread of *Sagina* on Marion Island during the 1990s could be linked to the exponential increase of the plant around the base area (Gremmen 1997), resulting in a massive increase in the production of seeds. This mechanism does not appear to account for the fast spread of the plant on Prince Edward Island, where it has dispersed before building up a significant population around the initial sites of infestation. However, given that colonization of Prince Edward Island by this species may well have been "natural", it is possible that the widespread, small populations on Prince Edward Island are the result of multiple invasions from Marion Island. Many of the long-distance dispersal events of *Sagina* at Marion appear to be linked to human activities, with focal infestations at huts around the island (Gremmen and Smith 1999). This is unlikely to account for its spread at Prince Edward Island, where the greater densities of seabirds are a more plausible vector (cf, its occurrence at colonies of white-chinned petrels *Procellaria aequinoctialis*).

Gremmen and Smith (1999) argued that alien plants have a negligible impact on the terrestrial ecosystems at Prince Edward Island, although they did suggest that *S. procumbens* has the potential for a significant impact. The situation on Marion Island, where alien plants (especially *S. procumbens* and *Agrostis stolonifera*) are influencing the island's biota and ecosystem severely (Gremmen *et al.* 1998), suggests that Prince Edward Island will be similarly susceptible to invasive exotic plant species. Our surveys show that the abundance and distribution of *Sagina* has increased much faster than on Marion Island. Control was deemed "very difficult" based on the species' range in 1998 (Gremmen and Smith 1999), and it is now probably too late to instigate control measures. In any case, given the huge source of *Sagina* on Marion Island, and the likelihood that it arrived (possibly several times) "naturally" at Prince Edward Island, control measures are likely to be futile. Judging from what we know about the ecological preferences of *Sagina* on Marion Island, areas offering ideal habitats for the species are numerous, large and widespread on Prince Edward Island. It is inevitable, therefore, that *Sagina* is going to markedly influence the island's biota and ecology.

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A view over the camp at Cave Bay that was used for the 2001 survey of seabirds and seals at Prince Edward Island (photo R. J. M. Crawford)