Restoring critical habitat on Penguin Island

Kate Brown[1], Aurelie Labbé[2] and Grazyna Paczkowska[1], [1]Department of Parks and Wildlife, [2]Murdoch University

Introduction

Historically, the dynamic processes involved in shaping the vegetation on Penguin Island have included trampling and disturbance by seabirds. Dense colonies of nesting cormorants deposited guano and trampled woody shrubs that over time would be replaced by native succulent shrubs such as *Rhagodia baccata* and *Nitraria billarderi* and succulent creepers including *Tetragona implexicoma*, *Enchylaena tomentosa* and *Carpobrotus virescens*. Once the cormorants moved on woody shrubs would eventually re-establish cover until the birds returned to nest and the cycle would start over (Gilham 1961). Sometime after 1961 a large colony of silver gulls (*Larus novaehollandiae*) became established on Penguin Island. Currently large numbers nest on the island each year over the winter months causing extensive trampling, guano deposition and disturbance. In addition the birds are effective carriers of weed seed which are ejected from their crops in a viable form (Gilham 1956, Calvino-Cancela 2011). In large areas where gulls nest, a cover of nitrogen loving exotic grasses and annuals has replaced native shrublands. The transition from native shrubs and succulents to a cover of introduced annual grasses following establishment of large colonies of gulls has been reported for floras of small islands across the world (Hogg and Morton 1983, Ellis 2005, Otero et al. 2015).

The vegetation in north east section of Penguin Island has historically been important nesting habitat for bridled terns (*Onychoprion anaethetus)*. The birds return from Japan and Borneo in spring each year to nest and breed. Under bilateral migratory bird agreements with Japan (JAMBA), the Australian Government has undertaken to provide for the protection and conservation of migratory birds, including bridled terns, and their important habitats. In recent years silver gulls have moved into the area and the cover of native shrubs that was important nesting habitat for bridled terns has largely been replaced by a cover of weedy annual grasses in winter/spring and bare ground through summer. Native cover adjacent to the site is largely made up of only two species *Rhagodia baccata* and *Tetragona implexicoma.*

Figure 1: Location of study site.

Trials in 2014 revealed that silver gulls consistently pulled out tube stock across planted sites. By December 2014, of the 490 plants that went into the ground in June, only three survived. The results indicated that to re-establish vegetation cover at the site tubestock required protection from silver gulls until well established. Subsequently, in 2015, we established trials to investigate techniques to protect tube stock in the early stages of establishment. In addition we investigated brushing and direct seeding with *Rhagodia baccata* as methods of establishing native vegetation cover. We also investigated the capacity of soil stored seed to return native vegetation cover if sites were weeded and protected from silver gulls. The objective of all treatments was to replace dense stands of annual weeds with a resilient native vegetation cover that provided bridled tern habitat.

Methods

In June 2015 five replicates of four different treatments were placed across the study site (Table 1). All treatments were protected with weld mesh cages. The cages were constructed from 3m x 2.4m sheets of weld mesh in the Mandurah Workshop.

Table 1: Treatment plots

Treatment	**Date**	**Size**	**Weeded**	**No. replicates**
Brushed with branchlets of *Rhagodia baccata* covered in ripe fruit	March 2015	1m x 1m	Yes	5
Control	March 2015	1m x 1m	Yes	5
Direct seeding with *Rhagodia baccata* fruit	June 2015	1m x 1m	Yes	5
Planting, no weed matting	June 2015	2m x 1m	no	5
Planting, weed matting	June 2015	2m x 1m	no	5

Figure 2: 1m x 1m trial plot brushed with Rhagodia baccata.

Figure 3: Planting trials had paired weed matted (left) and unmatted plots under the same cage.

Brushed: Material for brush trials was collected off *Rhagodia* bushes with ripe fruit from across Penguin Island. The brush was collected and laid across plots on 19 March 2015 (Figure 2). Cover of *Rhagodia baccata* resulting from germination of seed was recorded monthly for 10 months until March 2016 then bi monthly until November 2016. Plots were hand weeded each month.

Control: Control sites were hand weeded, sites caged and cover of native vegetation resulting from germination of soil stored seed recorded monthly for 10 months until March 2016 then bi monthly until November 2016. Plots were hand weeded each month.

Planting: Five sites were planted in June with 40 tube stock, 20 in matted and 20 in unmatted, under a single cage. Sites were hand weeded before the matting went down and cover of planted natives and cover of weeds was recorded monthly for 10 months until March 2016 then bi monthly until November 2016 (Figure 3).

Direct seeding: Seed of *Rhagodia baccata* was collected from across Penguin Island

in March 2015 and cleaned and stored in the Threatened Flora Seed Centre. In June 2015, 2.4 grams (~250 seed) were sown in each plot following hand weeding and were caged. Cover of *Rhagodia* was recorded monthly for 10 months until March 2016 then bi monthly until November 2016. Plots were hand weeded each month. Preliminary trials direct seeding with *Enchylaena tomentosa* (ruby saltbush) were also established in 2016. Seed was collected and directly scattered across five 50cm x 50cm trial plots (~400 seed per plot) on June 10, 2016 (Figure 4). Plots were hand weeded each month. They were observed and photographed over the following six months but not scored.

Results and discussion

Germination in the brushed sites began in early winter 2015 and seed germination was prolific (Figure 4) with seedlings rapidly creating cover in the plots (Figures 5 & 6). By September 2015 average cover across the five plots was 73% and significantly higher than direct seeded, with 10.0% cover or control sites 3.5% cover (Figure 4). Cover dropped over summer 2015/16 but recovered the following winter. Germination of *Rhagodia* in direct seeded and control sites was comparatively slow in the first year but plants that established in 2015 expanded rapidly in 2016 and by November 2016 there was no significant difference in cover of *Rhagodia* between brushed, control or direct seeded sites.

Germination in the control sites indicated viable seed present in the soil seed bank across the restoration site. Observations of preliminary trials direct seeding with *Enchylaena tomentosa* indicate it will be possible to create a dense cover of the species within 12 months using this method (Figures 9,10 & 11) *Enchylaena tomentosa* also germinated in two control plots in 2015.

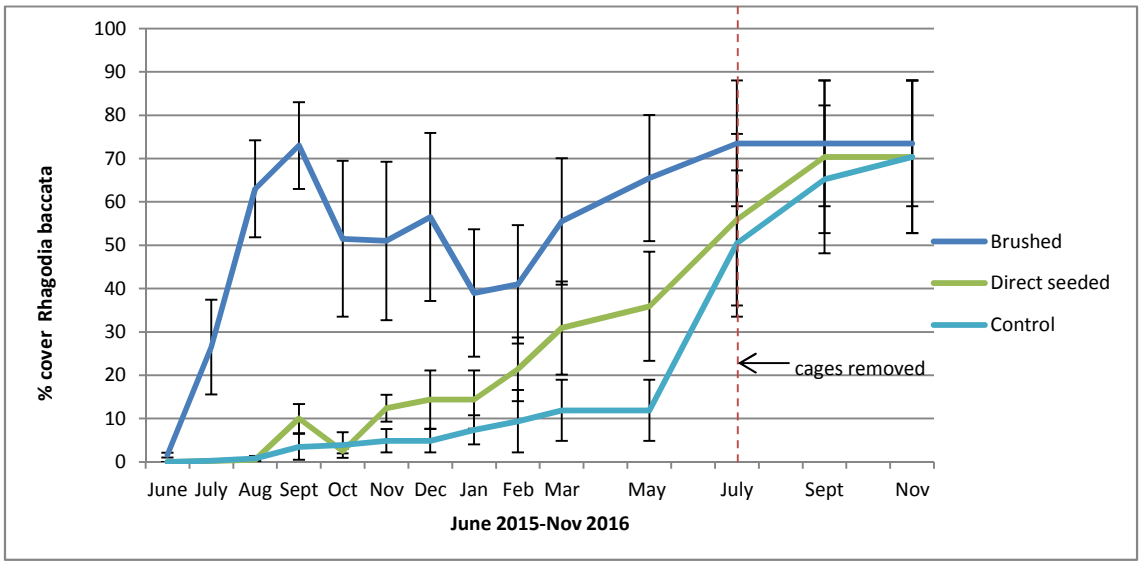

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Figure 4: Average % cover Rhagodia baccata *June2015 to November 2016 in treatment plots n=5.*

Figure 5: Rhagodia baccata *seedlings, brushed plot June.*

Figure 6: Rhagodia baccata *cover, brushed plot September.2015*

Figure 7: Rhagodia baccata *cover, direct seeded plot October 2015*

Figure 8 Rhagodia baccata *cover, direct seeded plot July 2016*

Figure 9: Direct seeding Enchylaena tomentosa*, June 2016*

Figure 10 Direct seeded Enchylaena tomentosa*, germinating July 2016*

Sites planted with *Rhagodia baccata* and T*etragona implexicoma* in June 2015 had an average cover of 83% natives by September 2015. Average weed cover was also high by September 2015, particularly in the sites with no weed matting, 88% (Figure 12). The high cover of weeds in unmatted sites appears to have led to a decline in average native cover to less than 48% by December 2015. In matted sites, where weed cover was much lower, natives maintained over 80% cover though to December 2015 (Figure 11). Weed cover however was significantly reduced across both matted and unmatted the following winter as cover of natives across both treatments recovered. Our results indicate although weed matting reduces weed cover in the first year, by the second growing season, the established perennial native vegetation effectively displaces annual weeds under both treatments.

Figure 11 Direct seeded Enchylaena tomentosa *(right of removed cage) creating dense cover Jan 2017*

Following removal of cages protecting sites from silver gulls in July 2016, cover of native vegetation across all treatments remained stable or continued to increase (Figure 4, Figure 11). The indications are that we can effectively and rapidly restore /revegetate *Rhagodia* shrublands on Penguin Island if we manage weeds and provide protection from silver gulls in the initial 12 months of establishment.

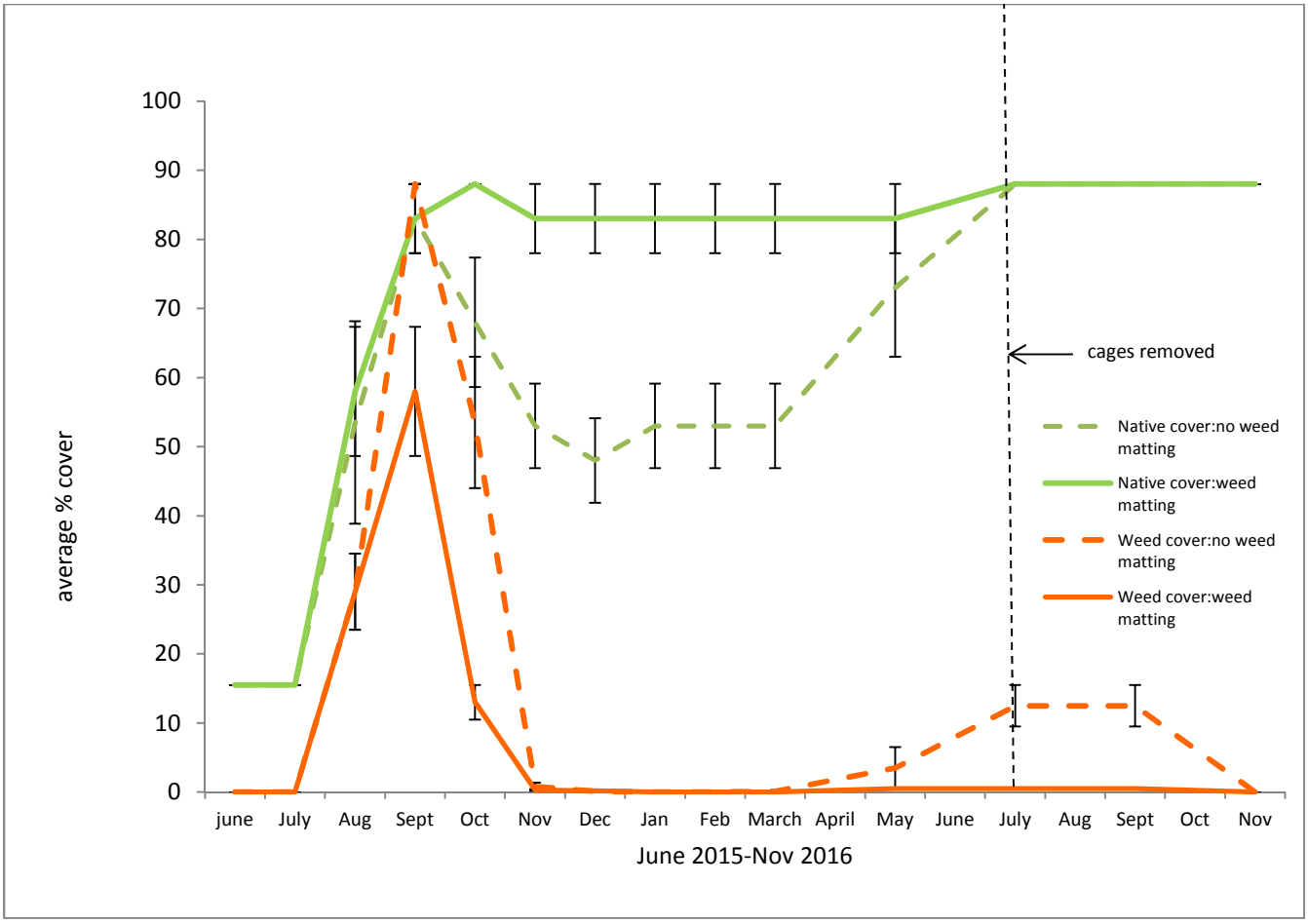

Figure 12 Average % cover of natives and weeds in matted and unmated plots June 2015 to December 2016.

Conclusions and recommendations

- Brushing using *Rhagodia baccata*, with no cost for plant material, is a cost effective rapid method of creating native cover within 6 months. Indications are that direct seeding with fresh fruits of *Enchylaena tomentosa* in June is also a cost effective and rapid method of creating native cover.
- Direct seeding with *Rhagodia baccata*, while creating cover after 18 months requires significantly more resources than bushing (seed collection, preparation and storage) and is not a recommended option.
- Native seedling germination in control sites indicates that there is a native soil seedbank present at the restoration site. Simply hand removing annual weeds early in the season and placing weld mesh cages over weeded sites to protect germinating seedling from silver gulls is cost effective method of restoring native shrublands. Indications are it will be that establishment of cover is slow in the first12 months but rapidly increases in the second growing season. Follow up weeding will be required at least over the first 2 years until a cover is established. A great project for volunteers.
- Although weed matting reduced weed cover in the first year, by the second growing season, the established perennial native vegetation effectively displaced annual weeds in both matted and unmatted treatments.Planting allowed establishment of *Tetragona implexicoma*. Plants of this species were grown from cuttings. We have not been able to grow them from seed. The species creates a significant cover on Penguin Island and is important habitat for nesting seabirds including little penguins (*Eudyptula minor*). When funding is available planting tubestock and caging is a very effective method of establishing native cover.

- We can effectively and rapidly restore /revegetate native shrublands on Penguin Island if we manage weeds and provide protection from silver gulls in the initial 12 months of establishment.

Acknowledgements

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Re-introducing the Australian Hollyhock, (*Malva preissiana*) to Penguin Island

Kate Brown[1], Aurelie Labbé[2], Grazyna Paczkowska[1] and Leonie Monks[1], [1]Department of Parks and Wildlife, [2]Murdoch University

Introduction

Malva preissiana or Australian hollyhock only occurs on offshore islands around the western and southern coasts of Australia. Its life cycle is linked to that of nesting seabirds and it grows specifically in their guano deposits. The habitat is nutrient rich, continually disturbed by seabird trampling and highly susceptible to weed invasion.

Figure 1: Malva preissiana *on Carnac Island.*

Competition from weeds including the introduced **Malva dendromorpha*, **M. pseudolavatera,* annual grasses including **Lolium* spp., **Bromus* spp. and from ice plant **Mesembryanthemum crystallinum,* has had a major impact on populations on islands along Perth's coast including the Shoalwater Islands. Over the last 20 years *M. preissiana* has gone extinct on Rottnest, Green, Bird, Seal, and Penguin islands. Carnac and Shag islands now support the only population of *M. preissiana* in the region (Figure 1). Over the last five years seed has been collected from the Carnac Island population and stored at the Department of Parks and Wildlife Threatened Flora Seed Centre.

The type collection (the first collection of the species and the specimen for which the species is named) was from Penguin Island on 11th of November 1839 by German naturalist Ludwig Preiss. Unfortunately *M. preissiana* disappeared from Penguin Island sometime in the 1970s. There were many factors that may have led to the decline of the Penguin Island populations including increasing numbers of silver gulls (*Larus novaehollandiae*) and associated weed invasion, direct competition from the introduced **Malva dendromorpha*, establishment of large pelican (*Pelecanus conspicillatus)* rockeries and guano mining in the southern parts of the island.

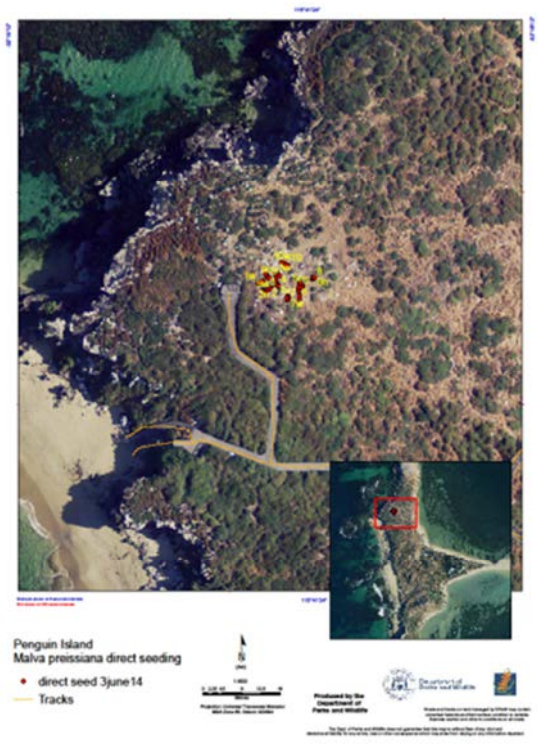

Figure 2: Location of trial sites.

Our project aimed to evaluate establishment techniques for the reintroduction of *M. preissiana* to Penguin Island. As well as being the type location, it is the most accessible of the Shoalwater Islands allowing for consistent monitoring and management of trial sites. Once techniques have been established through small scale trials, the aim is to investigate the feasibility of establishing self-sustaining populations on Penguin Island. The Australian hollyhock once formed an important component of the island's vegetation and this reintroduction is part of a larger restoration program for the island.

Methods

Figure 3: Direct sewing Malva preissiana *seed.*

In June 2014 10 pairs of 50 x 50cm trial plots were established in old pelican nesting sites at the northern end of the island (Figure 3Figure). All weeds were hand removed from one plot in each pair, in the other plot weeds were left in place. All plots were then direct seeded with *M. preissiana* from the Carnac Island collections. Each of the plots was sown with 48 seed.

Half of these seed (24) had been pre-treated by nicking the seed coat using a scalpel prior to planting (this was done under laboratory conditions the week before planting and then the nicked seed was transported to the island in paper envelopes). The remaining seeds (24) were not nicked. Seed were sown by hand 3–4mm below the surface. Seedling germination and survival were monitored each month through to December 2015. Follow up weeding (in the weed treatments) was also carried out as each plot was monitored.

Results and discussion

Nicking and weeding had an initial germination rate of only around 6% (average of 2.8 seedlings) and no treatment, (not nicked, not weeded) a little over 2% or just over one seedling per plot (Figure 4). Plots were trampled by gulls and pelicans in the month after sowing and this impacted on germinating seedlings. Some plots were more disturbed than others and there was high variation in survival rates across replicates. By December 2014 an average of less than one plant per plot survived in the nicked and weeded plots and none in the untreated plot.

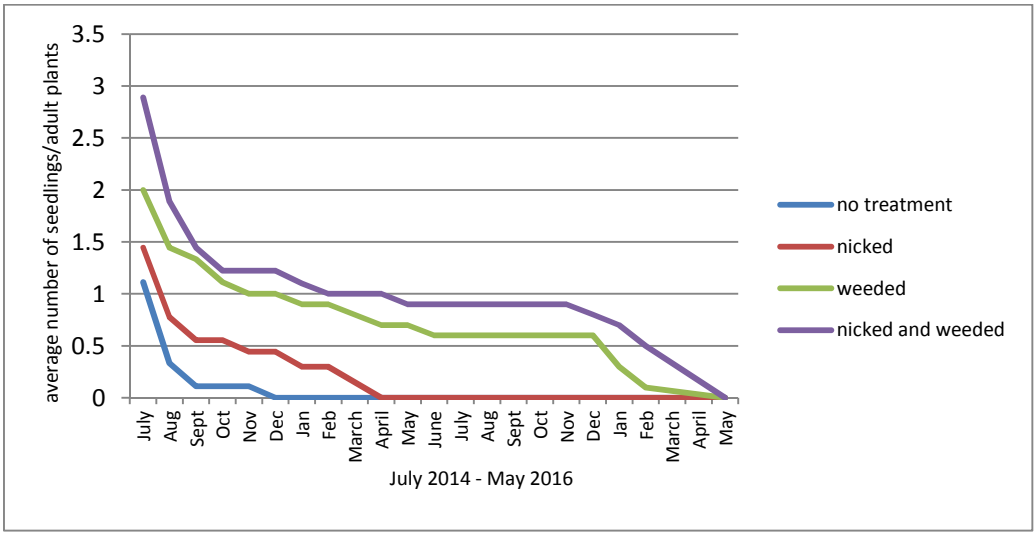

Figure 4: Average number of Malva preissiana *seedlings in 50cm x 50cm treatment plots (n=10) on Penguin Island over July 2014 to May 2016*

While germination and establishment rates were not high, the trials provided information on survival rates of seed and establishment rates of reproductive individuals under natural conditions including trampling and disturbance by gulls and pelicans.

In addition, 60% of weeded plots and only 20% of unweeded plots contained flowering and fruiting individuals by December 2014. Removal of competition from weeds does appear to be important

for establishment of populations (Figure 5). Of the plants that did survive most went onto flower and produce fruit. In addition a number of 50cm x 50cm plots were filled by a single individual (Figure 5). The decreasing number of plants per plot over time may partly be explained by competition from adjacent *M. preissiana* seedlings (self-thinning). Most plants that survived the 2014/15 summer and made it through to spring 2015 flowered and seeded prolifically (Figure 6).

All fruit examined on plants in 2014 appeared to be heavily predated and on the December 2014 monitoring trip invertebrate samples were collected. They were identified as seed bug, *Oxycarenus arctatus*, also commonly known as the coon bug, a ladybird beetle in the genus *Telsimia*, most likely an undescribed species, and a beetle larvae. Heavy seed predation has been

Figure 5: Weeded (left) and unweeded plots (centre) and an individual in a 50cm x 50cm plot flowering in October 2014.

observed on populations of *M. preissiana* in most seasons. Some years though, for example 2014 on Carnac and 2015 on Penguin Island, little predation was evident.

Figure 6: Pelicans moved onto the site over winter/spring 2016 nesting and depositing guano.

Figure 7: Seedling M. preissiana *Jan 2017. Established from soil stored seed over winter/spring 2016*

Malva preissiana is a short lived perennial and by May 2016 all plants germinated in the June 2014 trials had completed their life cycle, flowered, set seed, and died (Figure 4). Pelicans moved back onto the site in June 2016 nesting there over the winter and and depositing guano. We were not able to access sites until they moved off in January 2017. Survey of the area at this time found two *M. preissiana* seedlings that had established the previous winter from soil stored seed. This second generation of plants indicates it is feasible to establish self-sustaining populations of the *M. preissiana* on Penguin Island.

Management implications

- The results indicate direct seeding combined with weed control is a useful technique for reintroducing *M. preissiana* to Penguin Island. Plants can go on to flower and set seed in the first year and produce a second generation from soil stored seed in the third year..
- Based on the results of these trials if 5000 seed are directly sewn across a 20m by 20m area where weeds are controlled, around 100 plants should become established, a figure close to the natural densities on Carnac Island. Weed control should start early in the season and be consistent on a monthly basis for the first 12 months.
- While nicking seed appeared to result in higher germination rates seed germinated without nicking. Nicking is an expensive pre-treatment. Sowing higher numbers of seed rather than nicking could be an option. If seed is limited other pre-treatments such as hot water could be investigated.
- Disturbance by trampling birds impacted on successful establishment. We did attempt to discourage seagulls using fishing line strung across the plots. This was unsuccessful. One option is to cage the sites. However given there was survival without caging and trampling is a part of the system and habitat, it is not a preferred option.

Conclusion

These trials have provided a management framework for the reintroduction *M. preissiana* to Penguin Island, an important part of the larger restoration plan for the island. The next phase of the project will involve acquiring resources to scale up the trials and through an adaptive management process, establish self-sustaining populations on the island.

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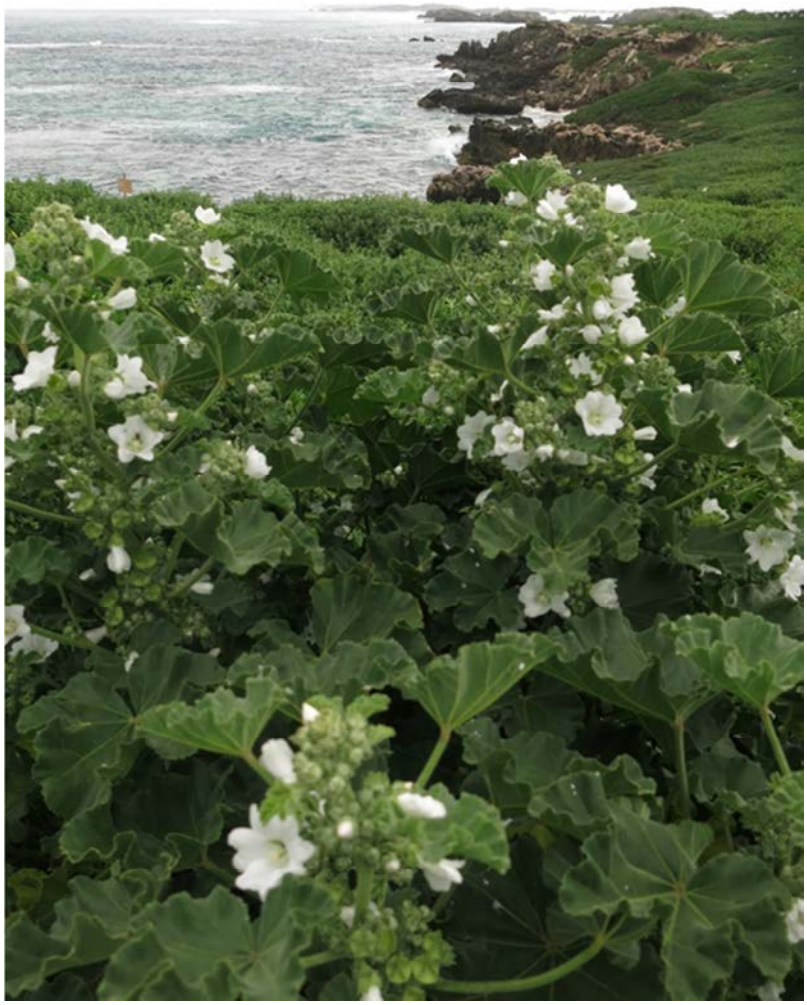

Figure 6: Individual of Malva preissiana *flowering and setting seed 17 months after germination, October 2015 Penguin Island.*