Soil Disturbance at Puffin Burrows and Tree Mallow Seedling Numbers on Craigleith

Image Charlotte Tomlinson, Craigleith 2023

Report Prepared for the Scottish Seabird Centre

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Contents

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Summary

As invasive tree mallow spread across Craigleith, it blocked access to puffin burrows and caused a decline in breeding puffins from over 5000 pairs to a few hundred by 2006. Clearance of the plant from most of the island by volunteers participating in the SOS Puffin initiative, led by the Scottish Seabird Centre, successfully reduced tree mallow coverage from over 80% to less than 10% by 2010. This low level of tree mallow coverage has been maintained by SOS Puffin volunteers for over 15 years. However, due to the large seedbank of tree mallow seeds in the soil, germination and growth of new plants continues. This study has found that higher numbers of tree mallow seedlings occur around the entrances to puffin burrows compared to areas where burrows are absent. Soil disturbance by puffins digging and maintaining their burrows likely brings seeds closer to the soil surface, where favourable soil texture, moisture and nutrient levels provide ideal conditions for seed germination. Continued trampling during the nesting season kills most seedlings, with only seedlings that survive being those that germinate late in the year when puffins have left the burrows. Rabbit activity will act in the same manner as that of puffins, resulting in tree mallow seed germination, but rabbit herbivory will reduce the number of tree mallow seedlings that grow to maturity. Plants not grazed by rabbits will be cleared by SOS Puffin volunteers. Continued monitoring and clearance of tree mallow is recommended to ensure the plant is kept under control and puffins thrive on the island.

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Introduction

Invasive plant species pose a threat to our coastal areas by outcompeting native plant species and altering plant community dynamics (Manchester and Bullock, 2000). The cost of controlling the spread and dominance of these invasive species can be prohibitively expensive for landowners and rarely results in full eradication (Manchester and Bullock, 2000). To combat the problem, conservation groups often rely on volunteers to help with the control and/or eradication of these problem species (Pagès, Fischer and van der Wal, 2018).

Tree mallow (*Lavatera arborea*) is a biennial plant, native to coastal areas of the Mediterranean and the south-west coast of the UK (Van der Wal, 2006). When introduced beyond these native locations it can becomes an invasive species, causing significant changes to vegetation communities (Van der Wal, 2006). On Craigleith island in the Firth of Forth, tree mallow is believed to have spread from the Bass Rock, where it was introduced for medicinal purposes in the 17th century (Van der Wal, 2006). By 2006, invasive tree mallow covered over 80% of the island, blocking entrances to puffin (*Fratercula arctica*) burrows, with a resultant decline in the number of breeding puffins using the island (Van der Wal, 2006). A successful campaign of cutting and removing tree mallow from Craigleith (Scottish Seabird Centre's SOS Puffin initiative) has reduced the coverage of this invasive plant to less than 10% of the island (Anderson, 2024). A concurrent increase in the number of apparently occupied puffin burrows has occurred as tree mallow coverage has declined, indicating a successful outcome for the Scottish Seabird Centre's SOS Puffin initiative (Hunt and Goodship, 2024).

Mature tree mallow plants now only remain growing in areas of the island that are difficult for humans to access on the southern and eastern cliff faces (Anderson, 2024). However, tree mallow seedlings have been found growing across the island and previous studies have shown that, although the seedbank has reduced in size, the soil still provides a rich source of viable seeds (Anderson, 2021).

It is difficult for tree mallow seeds to germinate under dense swards of grasses, such as Yorkshire fog (Holcus lanatus) and red fescue (Festuca rubra), on the island (Rakotondratrimo, 2013). However, it has been thought that tree mallow seedling numbers were higher around the entrances to puffin burrows, particularly in patches of bare ground (pers. obs.). This led to the formulation of a theory that soil disturbance by puffins walking in and out of their burrows promotes the germination of tree mallow on Craigleith.

This study aims to determine if there is a significant relationship between soil disturbance by puffins and tree mallow seedling presence/absence on Craigleith. The study also considers if other factors (number of other plant species present, slope of the ground, amount of bare ground and aspect) influence the number of tree mallow seedlings present.

Part of this project was undertaken by an undergraduate student at SRUC, in fulfilment of their BSc (Hons) degree in Wildlife and Conservation Management. The work was completed as their final year dissertation project in the academic year 2023-2024. That dataset was analysed with additional data gathered in 2024 and is reported here.

Methods

The Site

Craigleith is a small (7.4 ha) island 1000 m north of North Berwick. Along with Fidra and the Lamb, it forms part of the Forth Islands SSSI and is also an SPA (Craigleith Management Group, 2023). It is home to breeding populations of many seabirds, including cormorants (*Phalacrocaorax carbo*), herring (*Larus argentatus*) and greater black-backed (*Larus marinus*) gulls and puffins (Craigleith Management Group, 2023). Tree mallow has been controlled on the island since 2007, with the slopes now dominated by grass swards of red fescue (*Festuca rubra*) and Yorkshire fog (*Holcus lanatus*) (Anderson, 2024). Common nettle (*Urtica dioica*), docken (*Rumex* spp.) and Yorkshire fog occupying large areas of the south side of the island (Anderson, 2024).

Sampling Protocol

Surveys of Craigleith were undertaken in the last weeks of August in 2023 and 2024. A puffin burrow density map (Lyons, 2017) was used in conjunction with trips to the island in July 2023 and 2024 for other research work to inform general locations of active puffin burrows. In-person visits during the breeding season were necessary as the puffin burrow density map from 2016 represented distributions of burrows from seven years prior to the initiation of this project.

A quadrat size of 0.6 x 0.6 m was used to select a plot area within which to sample. Sampling occurred in areas where puffin burrows were present and absent. Where puffin burrows were present, the quadrat was placed on the ground with the puffin burrow located in the centre of the plot. For the areas where puffin burrows were present, we surveyed locations from low to high densities of burrows. In areas where puffin burrows were absent, the quadrat was placed at random on the ground out of the sight of the person placing the quadrat.

Within each plot a number of variables were recorded: number of tree mallow seedlings, presence/absence of a puffin burrow, rabbit presence/absence (identified by the presence/absence of droppings and/or scrapings), slope in degrees (using an Invicta MK1 clinometer), bare ground (percentage cover of the quadrat), aspect (i.e., north, east, etc.) and other plant species present. The sum of the number of other plant species present in a plot was used to calculate the species richness of that plot. All results are quoted with standard error of the mean as ±. For details of the statistical analysis and results please see the Appendix.

Results

A total of 58 puffin burrow plots and 37 plots where burrows were absent were sampled. The mean number of tree mallow seedlings growing in plots at puffin burrows (4 ± 0.9) was significantly higher than in areas without burrows (1 ± 0.3; Fig. 1). The maximum number of tree mallow seedlings that were counted at a puffin burrow was 38.

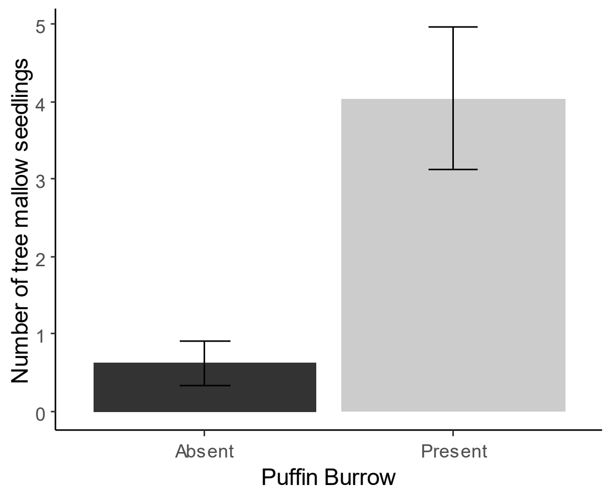

Figure 1 Mean number of tree mallow seedlings on Craigleith in the presence and absence of puffin burrows. Black bar indicate areas where puffin burrows were absent, grey bar where puffin burrows were present. Error bars show standard error of the mean.

There was a positive relationship between the number of plant species (other than tree mallow) present (species richness) and the number of tree mallow seedlings, i.e., when the number of tree mallow seedlings increased, the number of other plant species present also increased. This trend was similar for areas where puffin burrows were present and absent. However, there tended to be a greater species richness and number of tree mallow seedlings where puffin burrows were present (Fig. 2). Where puffin burrows were present, up six other plant species were also growing, although this number was more commonly four or five (Fig 2.). These species were usually Yorkshire fog, red fescue, chickweed (*Stellaria media*) and stinging nettle (*Urtica dioica*).

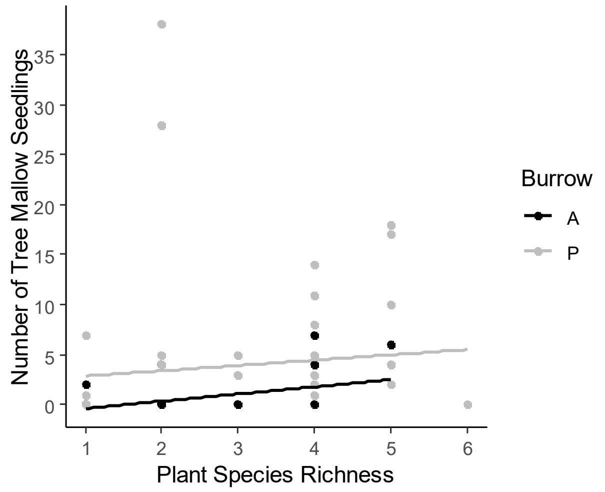

Figure 2 Number of tree mallow seedlings and plant species richness on Craigleith where puffin burrows were present and absent. Plant species richness was calculated as the sum of plant species other than tree mallow. Black symbols indicate locations where puffin burrows were absent, grey symbols where puffin burrows were present. Trend lines for the regression analysis are shown for the absence (black) and presence (grey) of puffin burrows.

Tree mallow seedlings occurred across the range of slopes surveyed for both locations with and without puffin burrows (from 0° to 45°). Although more tree mallow seedlings mostly occurred where slopes were shallower and where puffin burrows were present (Fig. 3a), this result was not statistically significant. Similarly, tree mallow seedlings grew across a range of extents of bare ground and although more seedlings tended to grow where puffin burrows were present (Fig 3b), this result was not statistically significant.

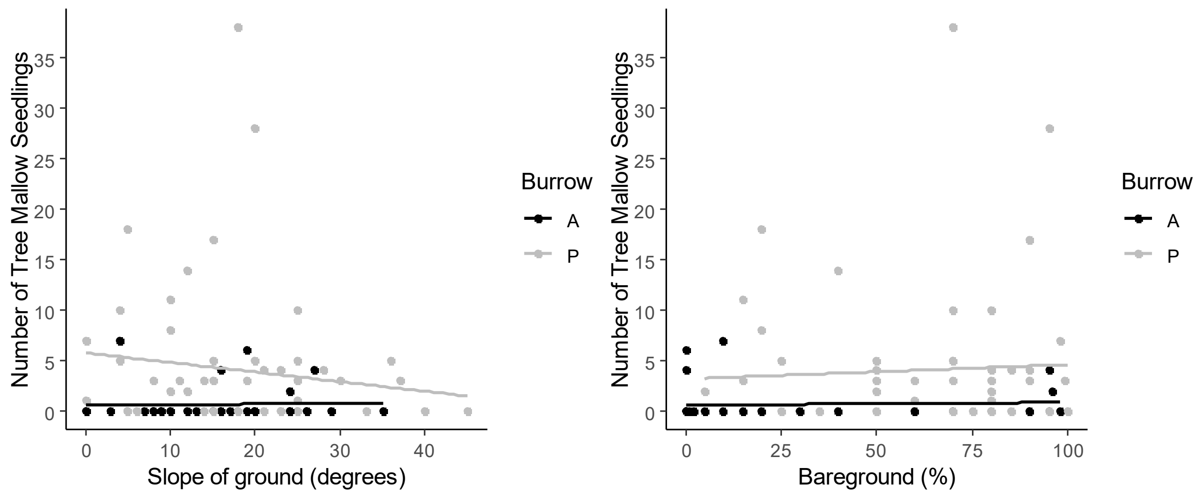

Figure 3 Number of tree mallow seedlings on Craigleith where puffin burrows were present and absent. (a) Number of tree mallow seedlings and slope of the ground. Slope was measured using an *Invicta MK1 clinometer* at the

location of where the tree mallow seedlings were found. (b) Number of tree mallow seedlings and percentage cover of bare ground. Black symbols indicate locations where puffin burrows were absent, grey symbols where puffin burrows were present. Trend lines for the regression analysis are shown for the absence (black) and presence (grey) of puffin burrows.

Tree mallow seedlings grew on ground facing every aspect on Craigleith. Although slightly more tree mallow seedlings grew on ground with a south-westerly facing aspect, again, this was not statistically significant.

Discussion

The SOS Puffin initiative, led by the Scottish Seabird Centre, has successfully reduced the extent of mature invasive tree mallow on Craigleith, decreasing its coverage from over 80% to less than 10% within a ten-year period (Anderson, 2024). Nevertheless, flowering tree mallow plants had already dispersed seeds widely across the island. This large accumulation of tree mallow seeds in the soil of Craigleith continues to germinate. Therefore, understanding the ecological mechanisms that promote tree mallow seed germination is important for informing future conservation strategies and ensuring effective control of tree mallow on Craigleith.

Puffin colonies are highly active places, with much movement of birds throughout the nesting season. New burrows are dug, existing burrows excavated and enlarged, and old burrows can collapse (Harris, 1984). During these processes, puffins naturally disturb the soil around the entrance to their burrows (Harris, 1984). This disturbance leads to plant seeds buried in the soil being brought closer to the ground surface, granting seeds improved access to water, nutrients and sunlight (Schutte *et al.*, 2014). These factors can promote seedling germination (Schutte *et al.*, 2014), resulting in the higher number of tree mallow and other plant species that were recorded around burrow entrances on Craigleith. Scarification (damage or softening of the seed coat) is necessary for plants with hard seed coats to germinate as it allows easier absorption of water by the seed (Krefting and Roe, 1949). Tree mallow seeds have a hard seed coat, therefore scarification by the claws on puffins' feet may also assist germination. It is likely that that the soil disturbances by puffins that help promote tree mallow seed germination, also assist germination of other plants, as observed in the increased species richness values around puffin burrows on the island. Thus, puffins naturally assist seed germination of all plants through their disturbance of the soil at and around their burrows. Additionally, the soft and friable soil texture and high fertility of the soil (from droppings) will provide an optimum growth medium for germination.

As well as disturbing the soil in the vicinity of their burrows which promotes seed germination, during the nesting season puffins also continually walk in and out of their burrows. These movements will trample newly germinated seedlings of tree mallow and other plants. Trampling has long been known to kill seedlings, with only grasses tending to survive due to their belowground rooting structure (Chappell *et al.*, 1971). Once the birds have left the island at the end of the nesting season and disturbance in and around the burrows has been removed, it is likely that any tree mallow seedlings present then have the potential to grow in a favourable environment mostly free of trampling. These tree mallow seedlings could then become mature plants. However, rabbits (*Oryctolagus cuniculus*) do eat young tree mallow seedlings (along with other plant species seedlings). The rabbit population on the island appears to have been effective so far in eating tree mallow seedlings that do germinate late in the nesting season (although we do not know what proportion of tree mallow seedlings they eat). Any tree mallow seedlings that persist and are not killed off by winter frosts will have been dealt with by any SOS Puffin volunteer parties that visit the island the control the plant. Since winter frosts are rare in the maritime climate of Craigleith, tree mallow seedling growth is likely controlled by a combination of herbivory by rabbits and on the ground conservation management actions by SOS Puffin.

Tree mallow seedlings were found growing across the range of different slope angles present on Craigleith, from entirely flat ground to slopes of 45°. This is in line with observations of young and mature plants by J Hunt, E Burton and the author. It is evident that tree mallow can grow on flat and sloping ground, particularly as plants continue to grow to maturity on the difficult to access steep slopes of Craigleith. Higher numbers of tree mallow seedlings growing on flat or very shallow slopes at puffin burrows were likely because the entrance passage of a puffin burrow is generally on a shallow slope, even if the surrounding ground is steeply sloped.

It was expected that greater numbers of tree mallow seedlings would be found growing on areas of bare ground, given that the immediate areas around puffin burrows and entrance passages often lack vegetation. Since tree mallow seedlings were found growing in areas that were bare right through to areas that had full vegetation cover, it appears that the presence of vegetation does not prohibit the germination of tree mallow seeds. However, it should be noted that all vegetation recorded was of small stature (less than approximately 20 cm tall). Hence, taller vegetation could block out light and slow germination of tree mallow seeds and growth of seedlings.

In this study we were unable to determine if soil disturbance had been caused by rabbit or puffin activity. Since both species disturb the soil in a similar manner and puffins do use burrows dug by rabbits (Ashcroft, 1979; Hornung, 1982), it is probable that soil disturbance by rabbits also promotes tree mallow seed germination. Studies focussed on burrow digging and use of burrows by both rabbits and puffins would be necessary to determine the ecological mechanisms of this relationship between these species.

Conclusions

Soil disturbance around puffin burrows on Craigleith brings tree mallow seeds closer to the ground surface. The soft, crumbly, fertile soils, along with suitable moisture levels at these locations likely provide an ideal environment for tree mallow seed germination. This also appears to be true for the seeds of other plants, such as Yorkshire fog, red fescue and chickweed. Trampling at active burrows generally kills off these small seedlings, with plants only surviving at burrows after the nesting season has finished. However, the presence of rabbits on the island adds another dimension to these ecological mechanisms. Since rabbits are found in the same areas as puffins, disturb the soil by burrowing and leave numerous droppings high in nutrients, it is currently impossible to deduce how much of a contribution to seed germination is attributable to puffins or rabbits. The combined activity of rabbits and puffins on Craigleith will lead to enhanced germination of tree mallow seeds. Later in the season, any tree mallow seedlings remaining will be grazed by rabbits or cleared by the actions of SOS Puffin volunteers. This highlights the need for ongoing active conservation efforts to maintain low coverage of invasive tree mallow on Craigleith.

Acknowledgements

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Appendix

Statistical Analysis

To determine which of the recorded variables outlined above had a significant effect on the number of tree mallow seedlings growing on Craigleith a generalized linear model with a negative binomial distribution was used. The model fit was improved by square root transforming the number of tree mallow seedlings, but all results quoted are on the response scale, i.e., original number of tree mallow seedlings recorded. Statistical analysis was carried out in RStudio (2024).

Statistical Results

Table 1 *Analysis of Deviance Table from generalized linear model with a negative binomial distribution and number of tree mallow seedlings as the response variable.*

Variable	t-value	p-value
Burrow presence/absence	1.14	0.003
Plant species richness	2.54	0.013
Slope	0.92	0.37
Bare ground	1.04	0.30
Aspect	1.53	0.29