Flax planting trials to assess flax weevil damage to plants of different provenances, and plants growing in different microhabitats

Mana Island, July 2017

Background

Eighty adult flax weevils (*Anagotus fairburni*) sourced from Maud Island, Marlborough Sounds, were translocated to Mana Island on 12 May 2004, followed by a further 70 animals on 15 June 2006 (Miskelly 2010). The translocation was undertaken to implement a recommendation made in the *Mana Island ecological restoration plan* (Miskelly 1999). Flax weevils feed only on native flaxes (both harakeke *Phormium tenax* and wharariki *P. cookianum*), with adults eating foliage at night, and larvae feeding on the roots.

The 150 adult weevils were introduced to a dense sward of flax (believed to be hybrid plants *Phormium tenax* X *P. cookianum*) in the south-west of Mana Island, about 40 m south-east of the 'FW01' label in Figure 1. They rapidly established, and by late 2009 it was "easy to find ten or more weevils in as many minutes at the release site" on calm nights (Miskelly 2010, p.29).

Figure 1. The five sites where flaxes were planted in June and July 2017. 'FW01' is near where flax weevils from Maud Island were released in 2004 & 2006; FW26 is just beyond their current distribution. A mix of Maud Island and Mana Island sourced flaxes were planted at these two sites in June. Additional Maud Island sourced flaxes were planted at sites FW51, FW71 and FW86 in July, to assess the effects of varying water-tables on flax weevil damage.

The weevils reached higher densities at the release site, and caused more damage to host plants, than had been recorded previously. Deaths of mature flaxes were noted by 2013 (Miskelly 2013). Adults caused obvious damage to the edge of leaves (Figure 2a), and prevented flowering of heavily infested plants by devouring unopened flower spikes (Figure 2b). However, the fact that large plants that still had numerous leaves collapsed and died (Figure 2c) points to the lethal damage occurring below ground level, where flax weevil larvae burrowed into the root stocks (Figure 2d).

a b
c d

Figure 2. Impacts of flax weevils on host plants on Mana Island: (a) feeding sign caused by adults, June 2017; (b) adult flax weevils feeding on unopened flower spikes, November 2013; (c) a dead mature flax plant, June 2017; (d) flax weevil larvae within the root stock of a dying plant, November 2013. All images: Colin Miskelly.

Two hypotheses for the super-abundance of flax weevils on Mana Island have been proposed:

1. That Mana Island flaxes were more susceptible to weevil browse than those on Maud Island, with browse resistance lost during cultivation (of the windbreak *P. tenax* planted during the MAF farming era in the 1970s) and/or through hybridisation between the two species.

2. That a natural bio-control agent that affects flax weevil larvae was left behind on Maud Island when the adult weevils were translocated, with the most likely candidate being an as-yet unsearched for pathogenic (and species-specific) strain of *Metarrhizium anisopliae* fungus.

In order to investigate the first hypothesis, seeds from *P. cookianum* were collected on Maud Island in early 2015, and propagated in the Mana Island nursery. Unfortunately no effort was made to collect locally-sourced seed on Mana Island at the same time, and so the first trial described here used transplanted juvenile flax plants sourced from near the planting sites, planted in equal numbers with Maud Island plants.

Field observations, June 2017

During 16-18 June 2017, flax weevil feeding sign was noted on every flax plant inspected in the south-west of Mana Island, in a radius approximately 500 m from the release site (including near the shore, halfway along the South Coast Track). There was also an infestation of flax weevils around the Lockwood, which has evidently resulted from deliberate or accidental translocation of these flightless weevils to the site, as there was about 400 m of unaffected plants separating the Lockwood infestation from the main weevil infestation.

Both *P. tenax* and *P. cookianum* were eaten, with the weevils showing a preference for the smaller and softer-leaved *P. cookianum* when the two species were growing in close proximity. However, fully mature plants of both species had been killed by the weevils, as well as several hectares of presumed hybrid plants around the release site. Flaxes growing in wet sites appeared to survive better than plants in dry sites. There are two possible (non-exclusive) explanations for this. Plants in wet sites may still be able to obtain sufficient water through a damaged root system, and so be better able to survive periods of drought stress, and a high water-table may kill or discourage weevil larvae from living among water-logged roots.

Planting trial methodology

1. Assessing the effect of plant provenance

Two sites with differing exposure to flax weevils were selected. The southern site was just inland of the junction between Southern Track and the petrel station track (Figure 1), close to where flax weevils were released. All 100 flaxes planted at this site were planted within 20 m of established flaxes showing weevil feeding sign. All 50 transplanted flaxes used at this site were gathered from within 200 m of the site, and all had weevil feeding sign (and so may have had weevil eggs or larvae among their roots and plant bases). The northern site was just north of the junction between Tirohanga Track and Central Track (Figure 1), on the eastern side of the small pond there. None of the adult flaxes around the pond had flax weevil feeding sign, but some sign was evident within 100 m to the south and north (the latter minor infestation is likely to have been assisted dispersal). None of the 50 transplanted flaxes used at this site had any weevil feeding sign on them. It is expected that flax weevils will reach this site within 1-2 years.

At each site, 25 waratah stakes were rammed into the ground at least 3 metres apart. All the stakes were individually tagged with yellow Allflex tags labelled 'WEEVIL S 2017' and numbered 1 to 25 (southern site; Figure 3) or 26 to 50 (northern site, Figure 4). The remaining tags (numbers 51 to 100; Figure 5) were used in the microhabitat trial (see below).

Figure 3. Spatial arrangement of marked plots at the southern study site.

Figure 4. Spatial arrangement of marked plots at the northern study site.

Figure 5. An example of one of the printed tags attached to a waratah stake, as used in the planting trials established in June and July 2017.

Four flaxes were planted in a cross centred on each stake (magnetic north, east, south and west), with each plant approximately 1 metre from the stake. Two Maud Island (nursery reared) and two Mana Island (transplanted) flaxes were planted around each stake, in a randomised pattern (Appendix 1). A c.30 cm long yellow Novacoil tube was partially buried around each plant to provide protection from pukeko and takahe (Figure 6), and all plants were watered (approx. 0.5 litre) on the day of planting.

Figure 6. An example of a flax planting plot, showing three of the four flaxes (in Novacoil tubes) planted one metre from a central, tagged waratah stake. Other tagged stakes can be seen in the background.

2. Assessing the effects of the microhabitats that flaxes are planted in

An additional 550+ Maud Island flaxes were planted at three sites (ten plots) in July 2017, with each cluster of three or four plots selected so that the plants would be subjected to a range of root saturation. One plot at each site was super-saturated, with the remaining plots on a gradient of better drainage and higher altitude (although all were very wet at the time of planting).

The locations of the three sites are shown in Figure 1, and the locations of the ten plots are shown in greater detail in Figures 7-9. The three sites were near the top of the valley leading down to Hole-in-Rock (stakes FW51 to 70; Figure 7), in the catchment that drains to Lance's gully (stakes FW71 to 85; Figure 8), and in upper Tauhinu Valley, one gully south of the macrocarpas (stakes FW86 to 100; Figure 9 [note that stake #91 has no tag]).

Figure 7. The locations of 20 tagged stakes (four plots of five stakes each) in Hole-in-Rock valley, below the takahe pen.

Five waratah stakes were rammed in and tagged at each plot, with four Maud Island flaxes planted in a cross, centred on each stake, at magnetic north, east, south and west compass points approximately 1 metre from each stake. This will allow the locations of 20 plants per plot to be checked over time, even if every plant in the plot dies. Fifteen to 60 additional 'unmapped' flaxes were planted at each plot as follows: FW51-55 = 60 additional flaxes, FW56-60 = c.20, FW61-65 = c.20, FW66-70 = c.20, FW71-75 = c.10, FW76-80 = c.15, FW81-85 = c.35, FW86-90 = 28, FW91-95 = 28, FW96-100 = 20. All plants were protected with a Novacoil tube, but no watering was required due to the very wet soil conditions in July.

There is a possibility that flax weevils were inadvertently introduced to some plots, as many of the nursery-reared plants had insect damage. It is unclear whether this was due to weevils (young flax leaves are less fibrous than adult leaves, and so the feeding sign is different). No weevil adults, larvae or eggs were noted during planting.

Figure 8. The locations of 15 tagged stakes (three plots of five stakes each) in Lance's gully, above the culvert pond.

Figure 9. The locations of 15 tagged stakes (three plots of five stakes each) in upper Tauhinu Valley, near the macrocarpas.

Recommendations for monitoring the flax plantings

FOMI members are requested to monitor the plantings during each working bee weekend, and to record the health of all 400 'mapped' plants in the trial. This is likely to take about 30-45 minutes for

1-2 people at each of the five sites. Each team will need a compass, or other means of assessing the orientation of the four plants around each post. Data forms are attached here as Appendices 2 & 3. Each plant should be scored as one of:

H/UnE	Healthy/Uneaten
H/E	Healthy/Eaten = weevil feeding sign apparent
UnH/UnE	Unhealthy/Uneaten
UnH/E	Unhealthy/Eaten
D/UnE	Dead/Uneaten
D/E	Dead/Eaten
Dead	(if it is not possible to determine whether the plant had been eaten or not)
Abs	Absent = no plant remains detectable

Acknowledgements

Many thanks to Frank Higgott and Sue Caldwell for gathering flax seed on Maud Island, FOMI and DOC for propagating the plants and caring for them for 2 years in the Mana Island nursery, and FOMI for purchasing the stakes used in the trial. Particular thanks to Jason Christensen and Linda Kerkmeester for sourcing equipment and supplies, and to Allflex for sponsoring the printed stock tags. Thanks also to Kate McAlpine for discussions on planting trial design. The plantings were completed during FOMI working bees on 17 June and 15-16 July 2016, with much support provided by DOC rangers Chris Bell and Otis Berard and their trusty Rhino. Many thanks to Adrian Jull, Allan Sheppard, Bruce Collett, Jacky Sargent, Jessica Richardson, Linda Kerkmeester, Miguel Braga, Mike Jacobson, Nancy Collis, Philippa Doig, Philippa Sargent and Richard Grasse for their assistance with transplanting and planting flaxes, and for the care that they took in setting up the planting trials.

Literature cited

Miskelly, C. 1999. *Mana Island ecological restoration plan*. Wellington, Department of Conservation. 149 pp.

Miskelly, C. 2010. *Mana Island ecological restoration plan review*. Wellington, Department of Conservation. 45 pp.

Miskelly, C. 2013. A plague of flax weevils – a conservation hyper-success story. Te Papa blog published 13 November 2013 (http://blog.tepapa.govt.nz/2013/11/13/a-plague-of-flax-weevils-a-conservation-hyper-success-story/)

Colin Miskelly
July 2017

Appendix 1. Configuration of flax plants around marked stakes FW01 (= WEEVIL S 2017 1) to FW50 (=WEEVIL S 50) at the two flax provenance study sites.

Southern study site				
Plot	North	East	South	West
FW01	Mana	Mana	Maud	Maud
FW02	Maud	Mana	Mana	Maud
FW03	Mana	Mana	Maud	Maud
FW04	Mana	Maud	Mana	Maud
FW05	Maud	Mana	Maud	Mana
FW06	Mana	Maud	Mana	Maud
FW07	Mana	Maud	Mana	Maud
FW08	Maud	Maud	Mana	Mana
FW09	Mana	Mana	Maud	Maud
FW10	Maud	Mana	Maud	Mana
FW11	Maud	Maud	Mana	Mana
FW12	Mana	Mana	Maud	Maud
FW13	Maud	Mana	Mana	Maud
FW14	Mana	Mana	Maud	Maud
FW15	Maud	Mana	Maud	Mana
FW16	Maud	Maud	Mana	Mana
FW17	Maud	Mana	Maud	Mana
FW18	Maud	Mana	Maud	Mana
FW19	Maud	Mana	Maud	Mana
FW20	Maud	Maud	Mana	Mana
FW21	Maud	Mana	Mana	Maud
FW22	Maud	Maud	Mana	Mana
FW23	Mana	Mana	Maud	Maud
FW24	Mana	Maud	Maud	Mana
FW25	Maud	Mana	Mana	Maud

Northern study site				
Plot	North	East	South	West
FW26	Maud	Mana	Maud	Mana
FW27	Mana	Mana	Maud	Maud
FW28	Mana	Mana	Maud	Maud
FW29	Maud	Maud	Mana	Mana
FW30	Mana	Maud	Mana	Maud
FW31	Mana	Mana	Maud	Maud
FW32	Mana	Maud	Maud	Mana
FW33	Mana	Mana	Maud	Maud
FW34	Mana	Mana	Maud	Maud
FW35	Mana	Maud	Mana	Maud
FW36	Maud	Maud	Mana	Mana
FW37	Mana	Maud	Maud	Mana
FW38	Maud	Mana	Maud	Mana
FW39	Mana	Maud	Mana	Maud
FW40	Mana	Maud	Mana	Maud
FW41	Mana	Maud	Maud	Mana
FW42	Maud	Mana	Mana	Maud
FW43	Maud	Mana	Mana	Maud
FW44	Maud	Mana	Maud	Mana
FW45	Maud	Maud	Mana	Mana
FW46	Maud	Mana	Maud	Mana
FW47	Maud	Maud	Mana	Mana
FW48	Maud	Mana	Mana	Maud
FW49	Maud	Mana	Mana	Maud
FW50	Mana	Mana	Maud	Maud

Appendix 2. Monitoring datasheet for flax plants at the flax provenance study plots.

Date: **Observer(s):**

Southern study site				
Plot	North	East	South	West
FW01				
FW02				
FW03				
FW04				
FW05				
FW06				
FW07				
FW08				
FW09				
FW10				
FW11				
FW12				
FW13				
FW14				
FW15				
FW16				
FW17				
FW18				
FW19				
FW20				
FW21				
FW22				
FW23				
FW24				
FW25				

Northern study site				
Plot	North	East	South	West
FW26				
FW27				
FW28				
FW29				
FW30				
FW31				
FW32				
FW33				
FW34				
FW35				
FW36				
FW37				
FW38				
FW39				
FW40				
FW41				
FW42				
FW43				
FW44				
FW45				
FW46				
FW47				
FW48				
FW49				
FW50				

Each plant should be scored as one of:

H/UnE Healthy/Uneaten
H/E Healthy/Eaten = weevil feeding sign apparent
UnH/UnE Unhealthy/Uneaten
UnH/E Unhealthy/Eaten
D/UnE Dead/Uneaten
D/E Dead/Eaten
Dead (if it is not possible to determine whether the plant had been eaten or not)
Abs Absent = no plant remains detectable

Please scan and email completed datasheets to colin.miskelly@tepapa.govt.nz

Appendix 3. Monitoring datasheet for flax plants at the microhabitat study plots.

Date: **Observer(s):**

Hole-in-Rock study plots (4)				
Stake	North	East	South	West
FW51				
FW52				
FW53				
FW54				
FW55				
FW56				
FW57				
FW58				
FW59				
FW60				
FW61				
FW62				
FW63				
FW64				
FW65				
FW66				
FW67				
FW68				
FW69				
FW70				
Lance's gully study plots (3)				
FW71				
FW72				
FW73				
FW74				
FW75				

Lance's gully study plots (continued)				
Stake	North	East	South	West
FW76				
FW77				
FW78				
FW79				
FW80				
FW81				
FW82				
FW83				
FW84				
FW85				
Tauhinu Valley study plots (3)				
FW86				
FW87				
FW88				
FW89				
FW90				
FW91*				
FW92				
FW93				
FW94				
FW95				
FW96				
FW97				
FW98				
FW49				
FW100				

*Tag missing

Each plant should be scored as one of:

H/UnE	Healthy/Uneaten
H/E	Healthy/Eaten = weevil feeding sign apparent
UnH/UnE	Unhealthy/Uneaten
UnH/E	Unhealthy/Eaten
D/UnE	Dead/Uneaten
D/E	Dead/Eaten
Dead	(if it is not possible to determine whether the plant had been eaten or not)
Abs	Absent = no plant remains detectable

Please scan and email completed datasheets to colin.miskelly@tepapa.govt.nz