Rakiura Dune Restoration Programme
Monitoring Report
August 2023

Mike Hilton & Teresa Konlechner, School of Geography

Weeds

Lupin

Marram

Darwin's Barberry

Dune System morphodynamics

Doughboy

Masons

Botany

Euphorbia glauca translocation

Gunnera hamiltonii (Masons / Doughboy)

Research

Jen – lupin / nitrogen / ecology

Campbell – seepage / wetland community dynamics (Masons)

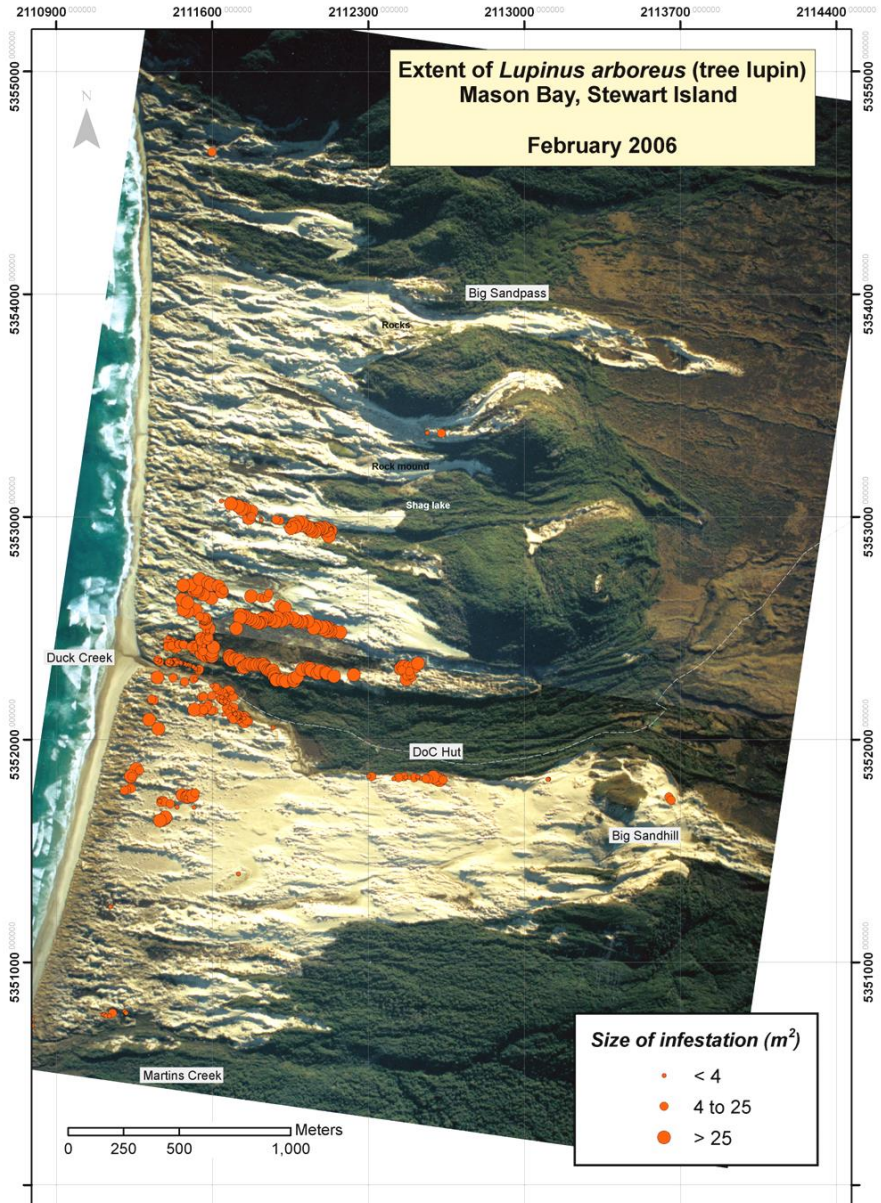
Maddie – dune system biogeomorphology (Doughboy)

Teresa / Mike – changing plant communities (Masons)

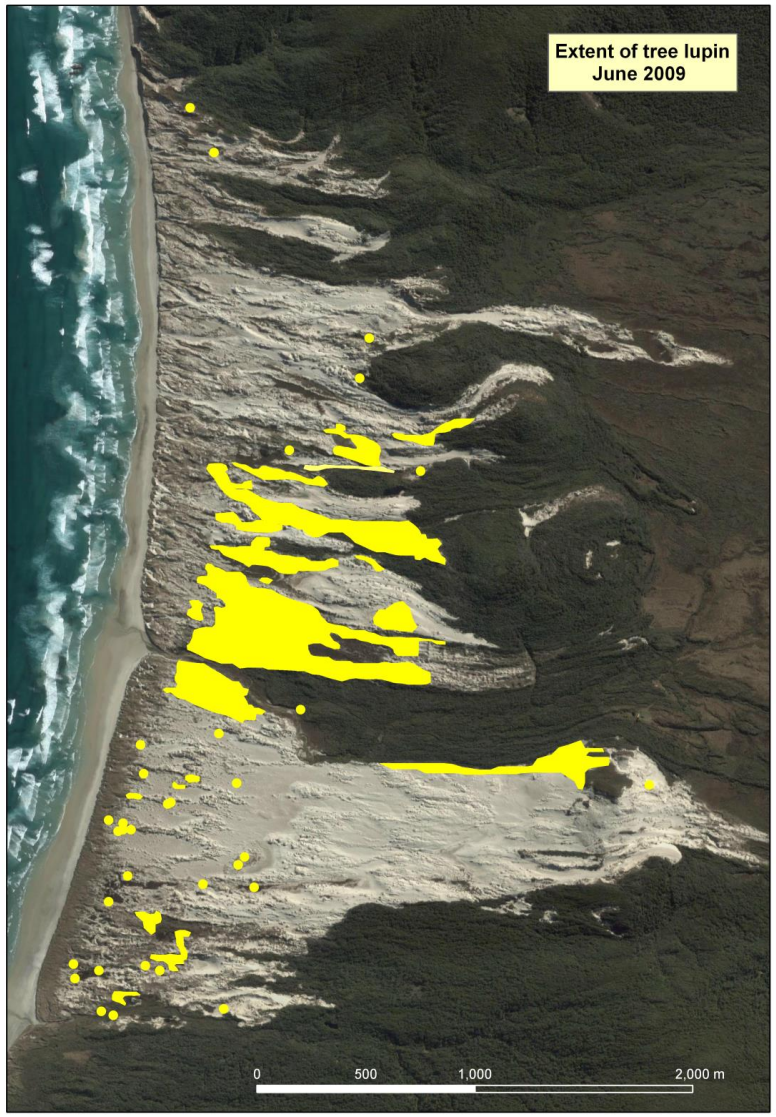
Other

Lupin records – Mason Bay 2006 – 2021 (2023 below)

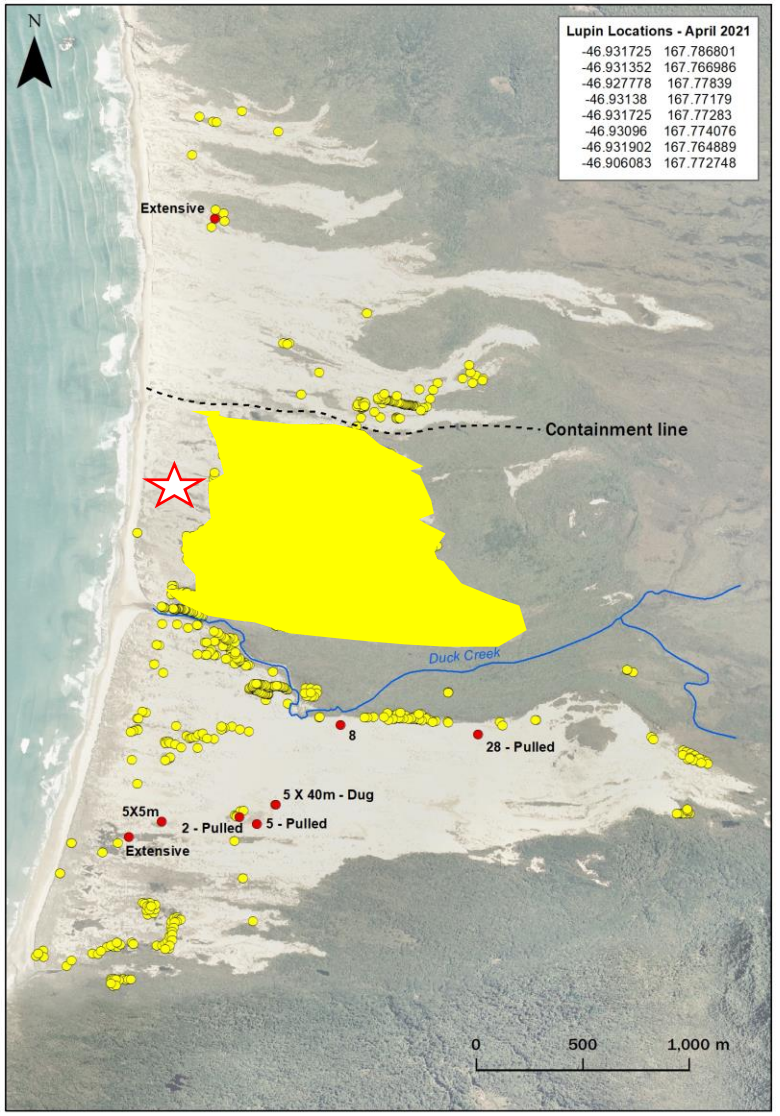
2006



2009



2021

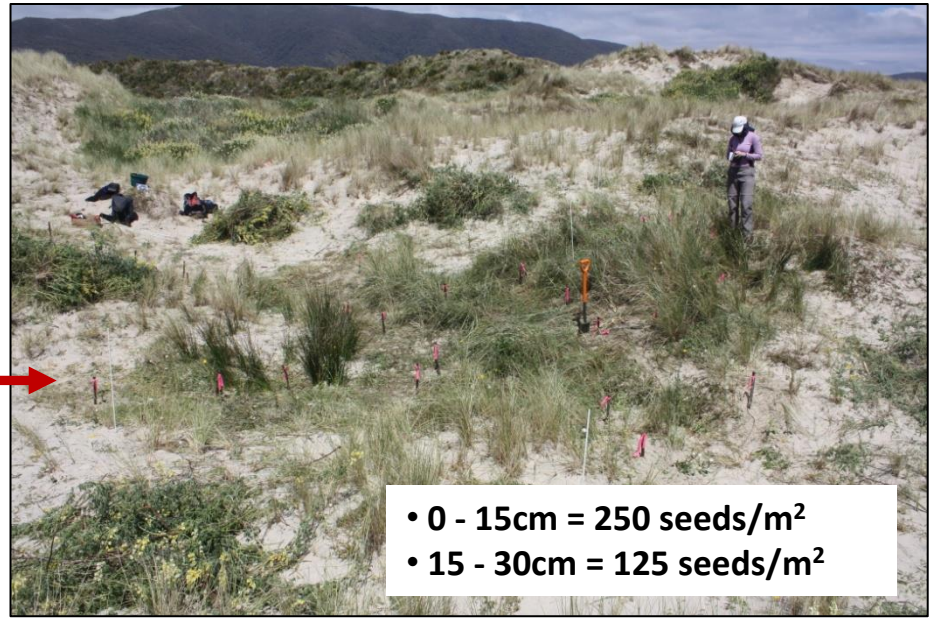


(to update … with 2023 data)

Lupin biology (DRAG 2013)

1. Seed dispersal – how is seed dispersed?
   - Deer, people, wind
2. How fast is tree lupin invading?
   - Fast, exponential expansion in area
3. Seed bank - how large is it?
   - Large - 000's/m^3
4. Seed bank – how long do seeds remain viable?
   - Decades
5. How much seed germinates after canopy removal?
   - Enough to ensure maintenance of canopy

0 - 15cm = 426 seeds/m^2
15 - 30cm = 50 seeds/m^2
30 - 45cm = 50 seeds/m^2



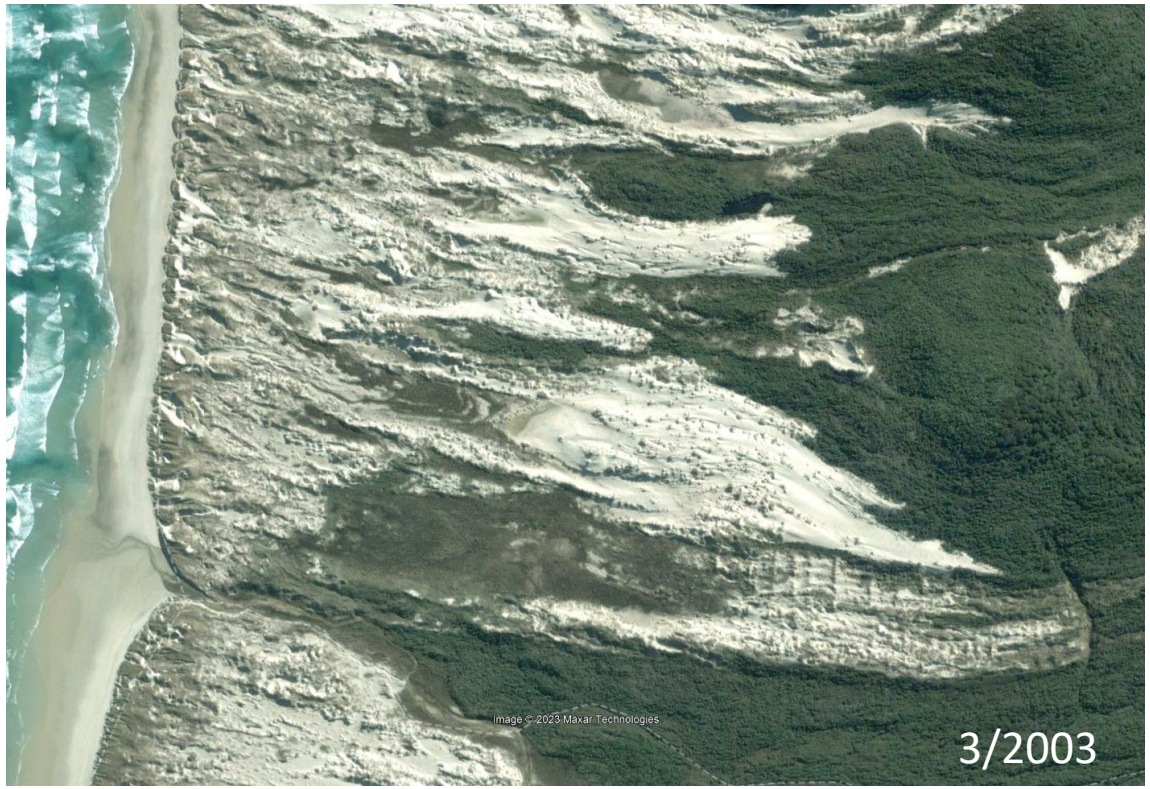
- **0 - 15cm = 250 seeds/m^2**
- **15 - 30cm = 125 seeds/m^2**

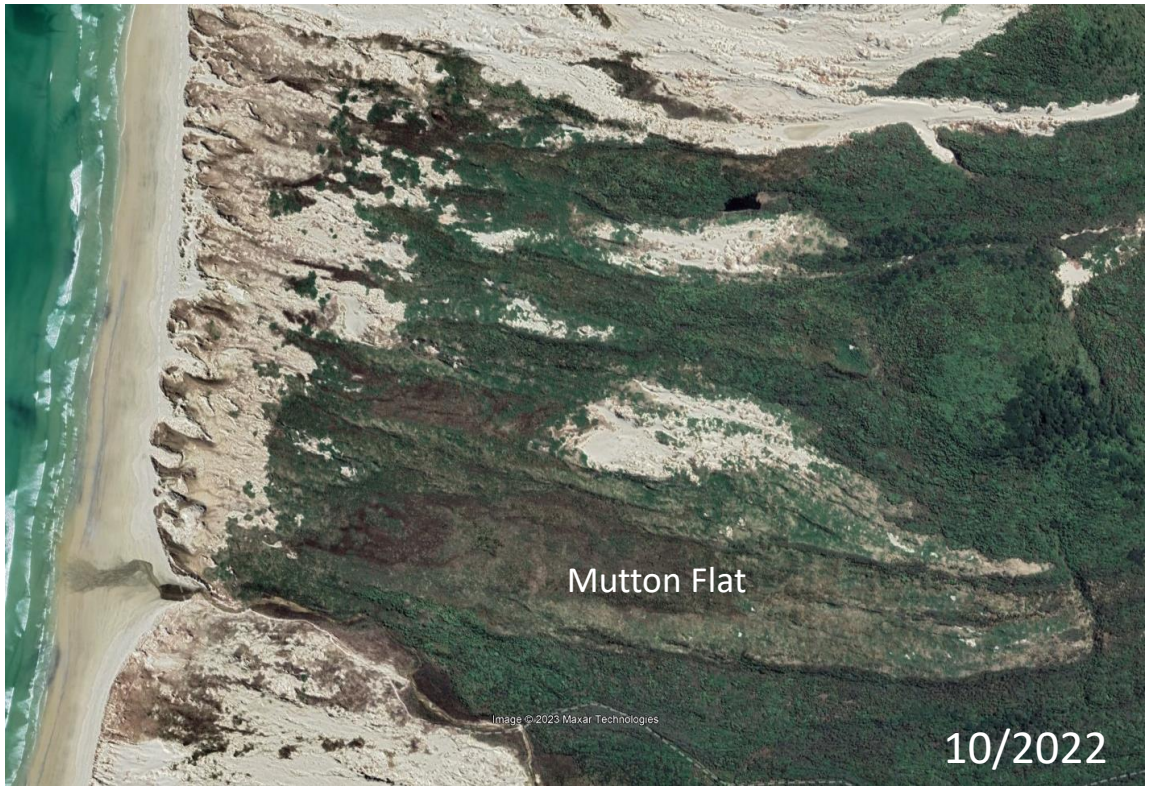
Seed production & dormancy (high & long)

- 1 plant (1m^2) carries 300 pods, (= 2,400 seeds) (Kaitorete, 2010) (10-15,000 seeds/plant/year (California)
- reaches maturity in second spring (18 months)
- 7-year life span = 60,000 – 90,000 seeds
- 90% viable after 3 years (Kaitorete, 2010)

Lupin – implications for management (DRAG 2013)

- a management program is likely to be long-term (decadal)
- regular and extensive surveillance is essential (<2 years)
- high likelihood of regeneration at control sites
- success will depend on ability to control regeneration from seed bank
  - plus, plant communities in some areas (e.g. Mutton Flat), might be permitted to convert to kanuka & eventually mutton bird scrub / forest cover (… but with implications for dispersal) (DRAG 2023)





Lupin – N1, N2 & N4

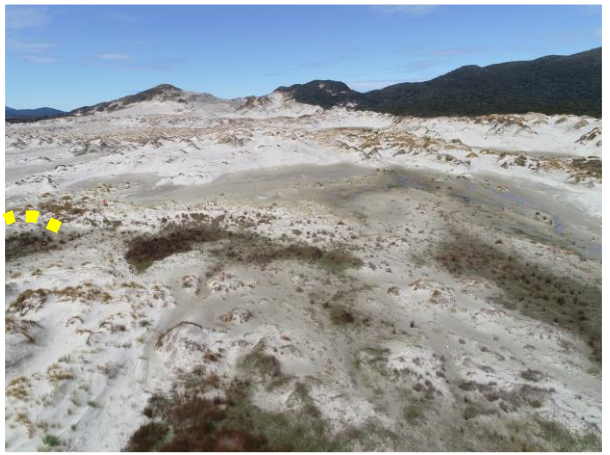
Treated (cut/gel) - August 2023

Lupin

Big Sandpass

June 2023

Special Place lupin patch



August 2023

- plants within an area of 397* m^2
- 8 person hours – cut / gel / dug (or pulled ☹)
- many plants half buried or small plants within *Isolepis*
- larger plants easier to cut and gel
- dense growth of exotic grasses across former stack
- submature plants, no seed pods

Note: Area of netball court = 465m^2

Lupin – Big Sandhill (east)

Pre- and post-heliops (December 2022)

3 Sept 2022

June 2023

Big Sandhill –
Lupin (June 2023)

June 2023

Fieldwork:

Doughboy Bay – November 2022 (4p, 10 days) – Mike, Maddie, Megan, Campbell
December 2022 (4p, 10 days) – Mike, Teresa, Pearl, Paulina

Mason Bay – June 2023 (3p, 5 days) – Mike, Campbell, Jen
August 2023 (5p, 11 days) – Mike, Jen, Callum, Lizzy, Rose

Masons, August 2023

Masons, June 2023

Aims and Objectives

How does tree lupin modify soil nutrients and does this facilitate growth / enhance vigour of other species. What are the implications for managing tree lupion at Mason Bay?

(1) Does soil nitrogen vary with the age of lupin stands?

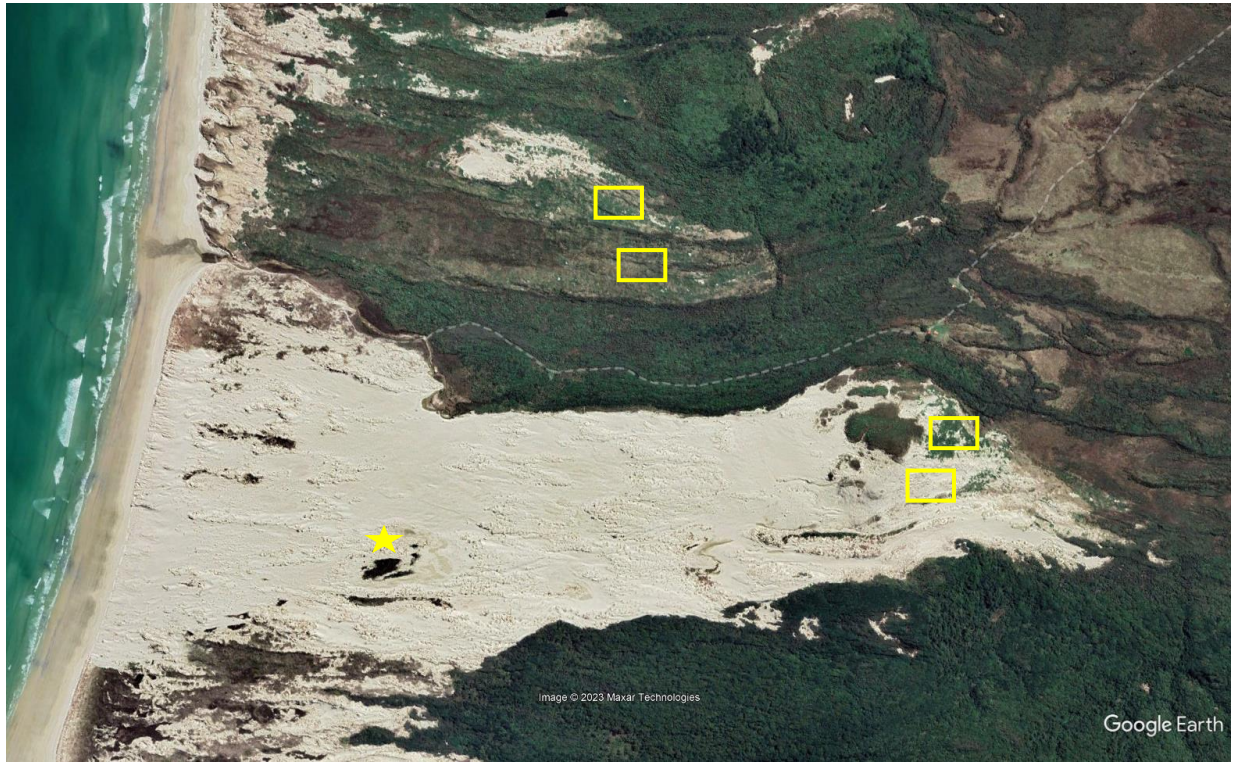
(2) What is the relative contribution of nitrogen from subsurface nodes/root system and above ground biomass?

(3) What are the ecological relationships between different lupin populations, deer browse, lupin dispersal and the establishment of other plant species?

(4) In what circumstances is lupin treatment necessary / unnecessary or can be delayed?

Field Work: August 2023 (after pilot study in June 2023)

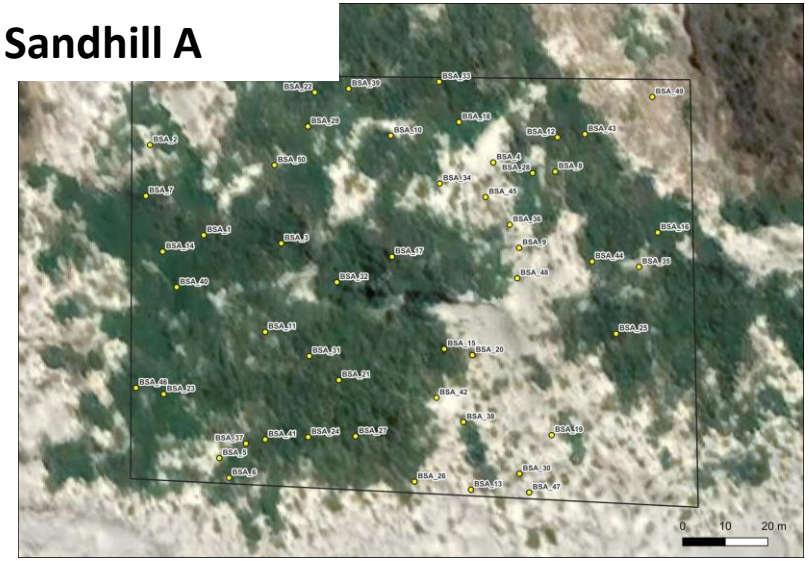
- **Four areas of interest (+ ‘Special Place’):**
  - sampling at 20 sites in each area occurred in a systematic, randomised manner.
  - additional samples in Special Place
- **Soil samples:**
  - 120 ml sample obtained from 2-3 cm and 10 cm depths.
- **Organic Matter:**
  - sample taken of organic matter on the surface (decomposing skeletal lupin/above ground biomass).
- **Vegetation surveys:**
  - 0.5 m^2 quadrant used to infer number and percentage cover of different species.
  - grazed exotic grass and deer scat counted.



Vegetation (cover, species) & soil sampling (240 samples, N., organic matter)

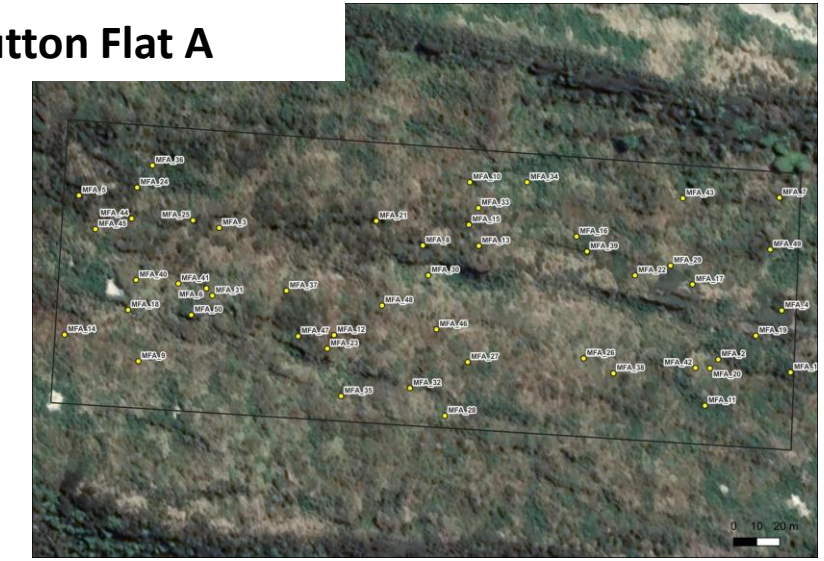
Big Sandhill A

3-4 year population (>2018). Treatment in Dec 2022



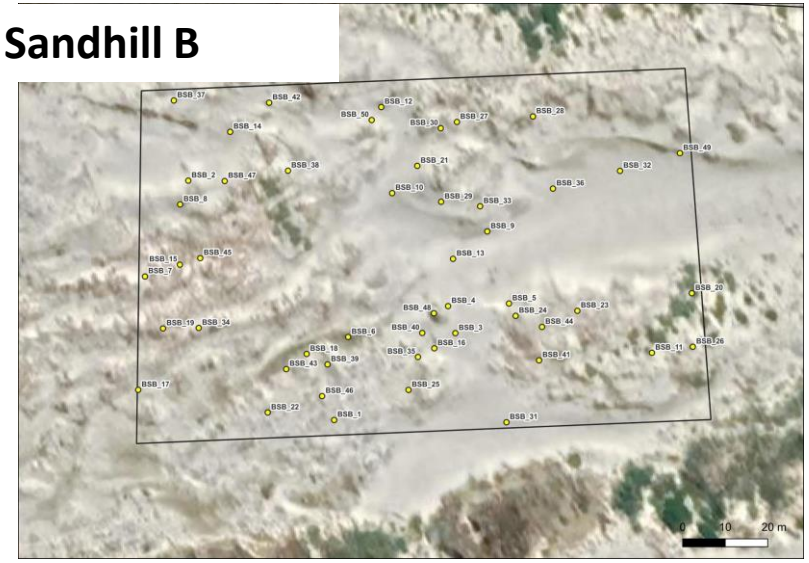
Mutton Flat A

Established population (1980s-)



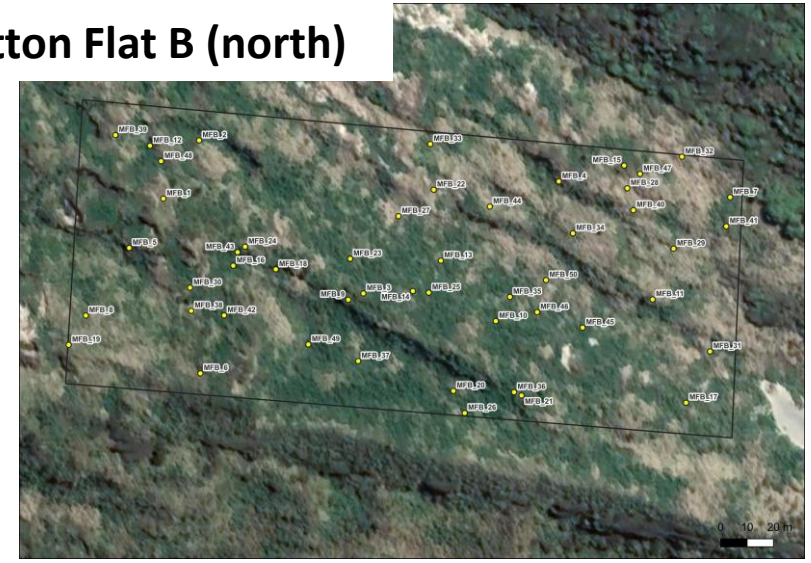
Big Sandhill B

"Control" site – no history of lupin

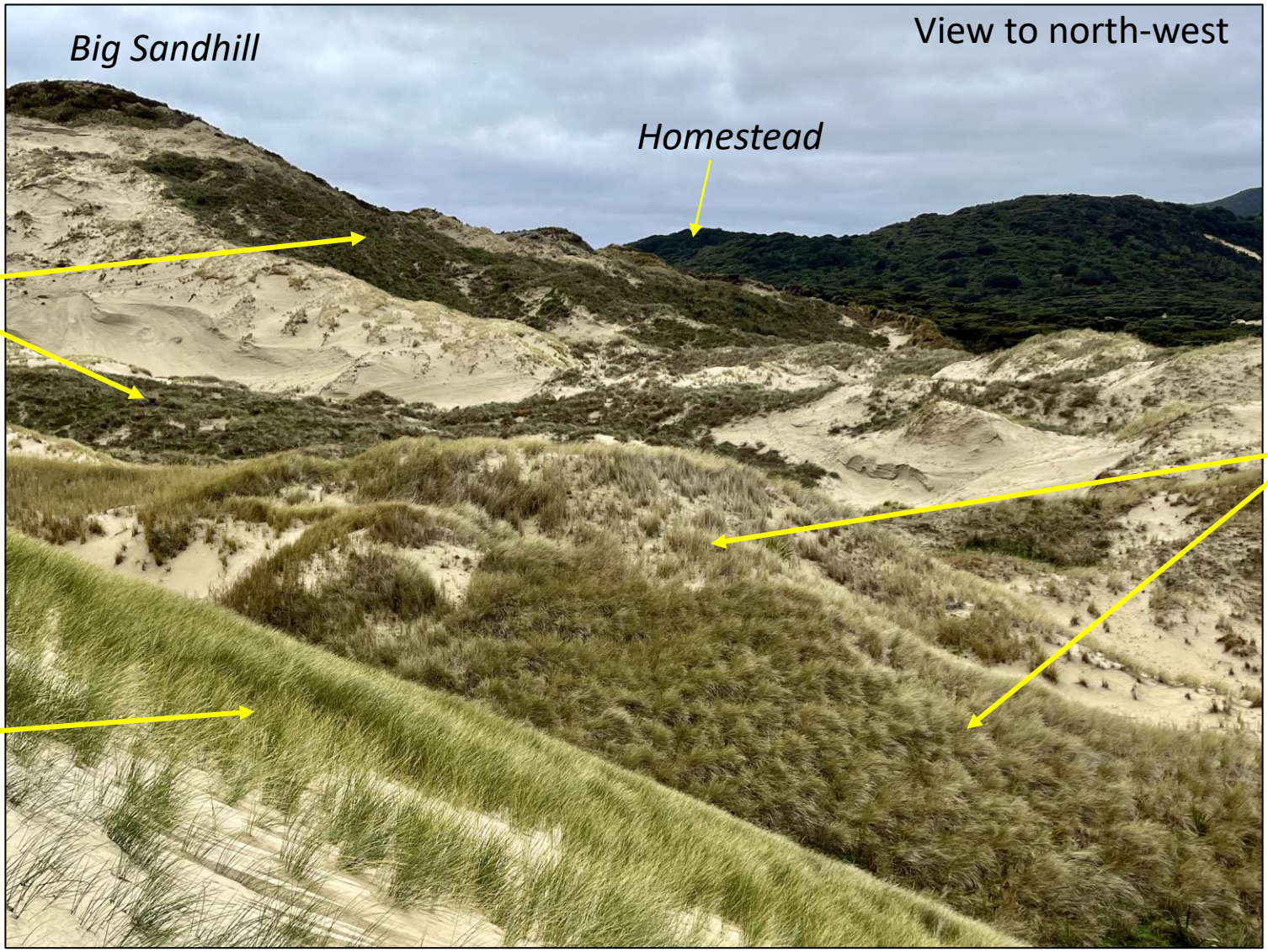


Mutton Flat B (north)

Established after 2015



Big Sandhill: *Ammophila arenaria vigor related to lupin / nitrogen enhancement*



'Super charged' marram associated with lupin decomposition

Dense and older (non-thrifty) stands of marram (no lupin)

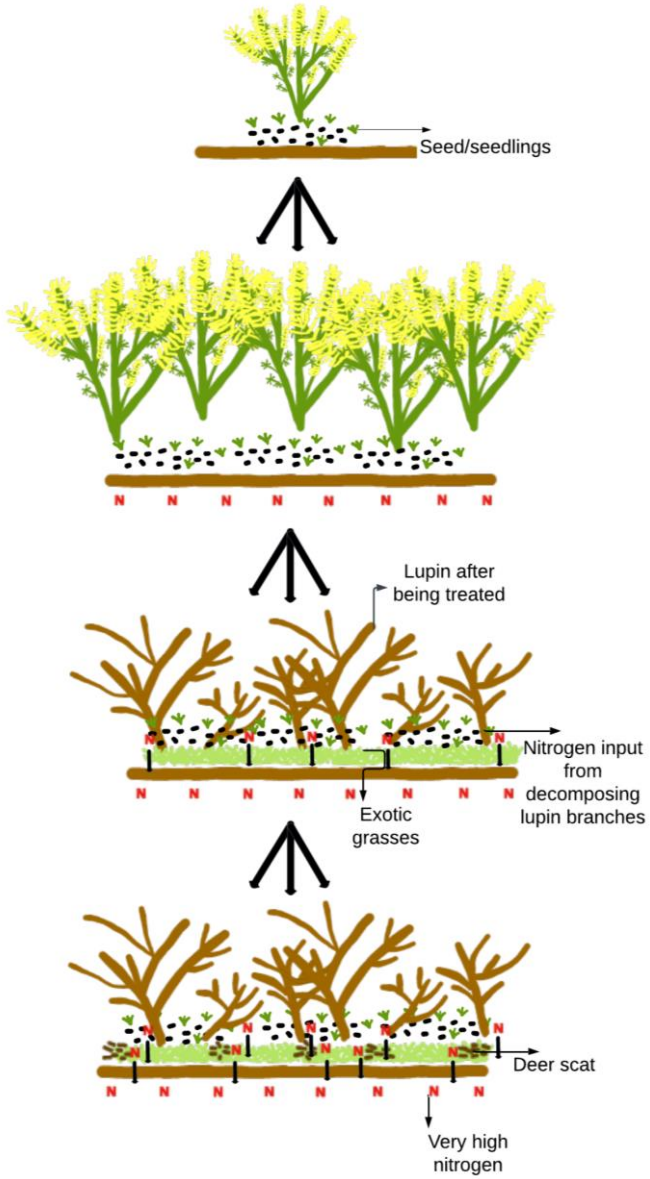
Thrifty marram related to ongoing sand / nutrient inputs unrelated to lupin

Special Place lupin

Rapid growth of exotic grasses under lupin stacked in April 2021, which suggests enhanced soil N results from decomposition of the above-ground lupin biomass.

Two nitrogen / plant community pathways (DRAFT – early thoughts)

Treated mature lupin (e.g. Big Sandhill)



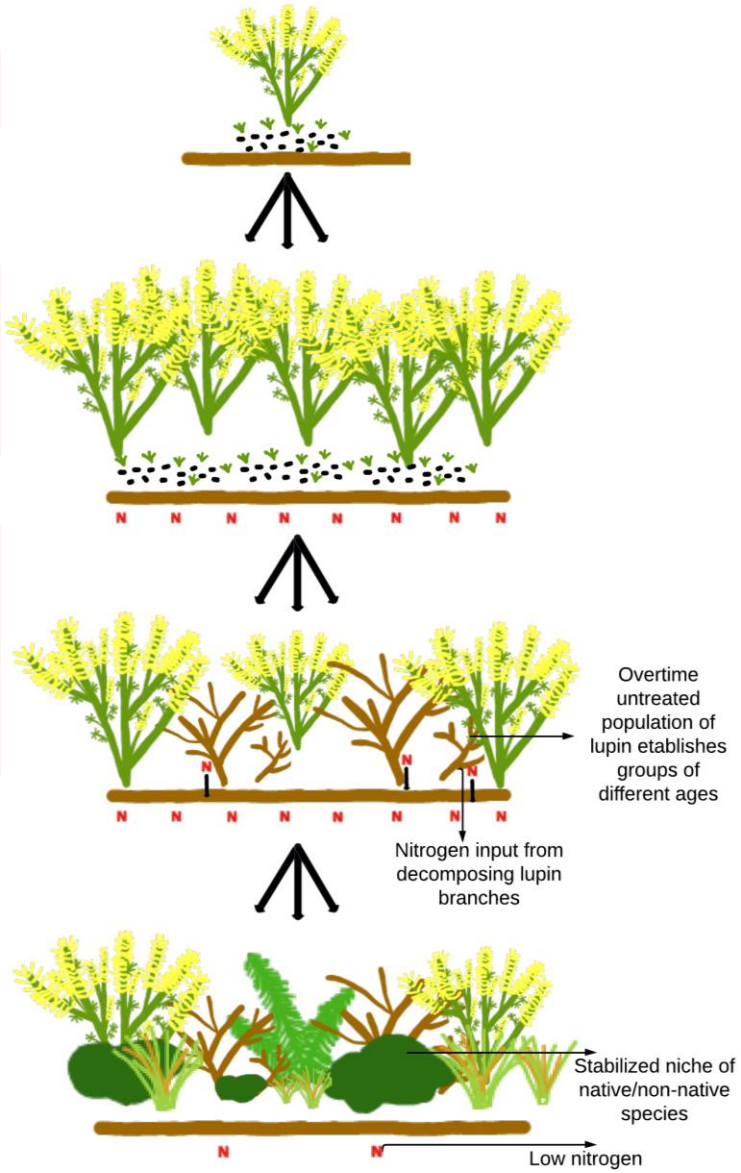
1. Lupin invasion

2. Maturation - nitrogen in soil increases; stability & exotic grass colonisation

3. Additional input of nitrogen from decomposing lupin after treatment; exotic grasses flourish

4. Nitrogen remains in soil, further input of nitrogen from deer scat; seed germination suppressed (… for how long?)

Untreated (decadal) lupin (e.g. Mutton Flat)



1. Lupin invasion

2. Development of lupin population, nitrogen in soil increases (as plants die?)

3. Untreated lupin population - complex demographic develops over time; N sustained

4. Community of lupin and native/non-native species forms; N declines

Initial Nitrogen Results

Big Sandhill A: <1.0 mg/Kg to 21.7 mg/Kg (following sudden canopy collapse)

Big Sandhill B: nondetectable levels

Mutton Flat A: 2-5 mg/Kg (reflecting a mixed population / leaching / colonization by other species?)

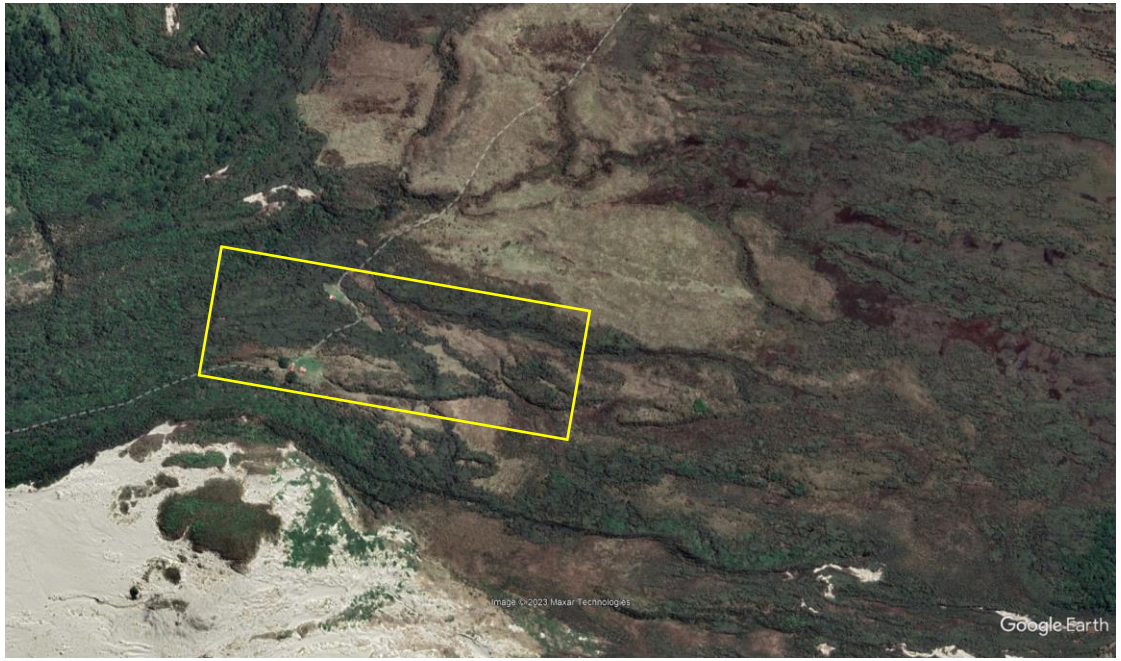
Mutton Flat B: 1-2 mg/Kg

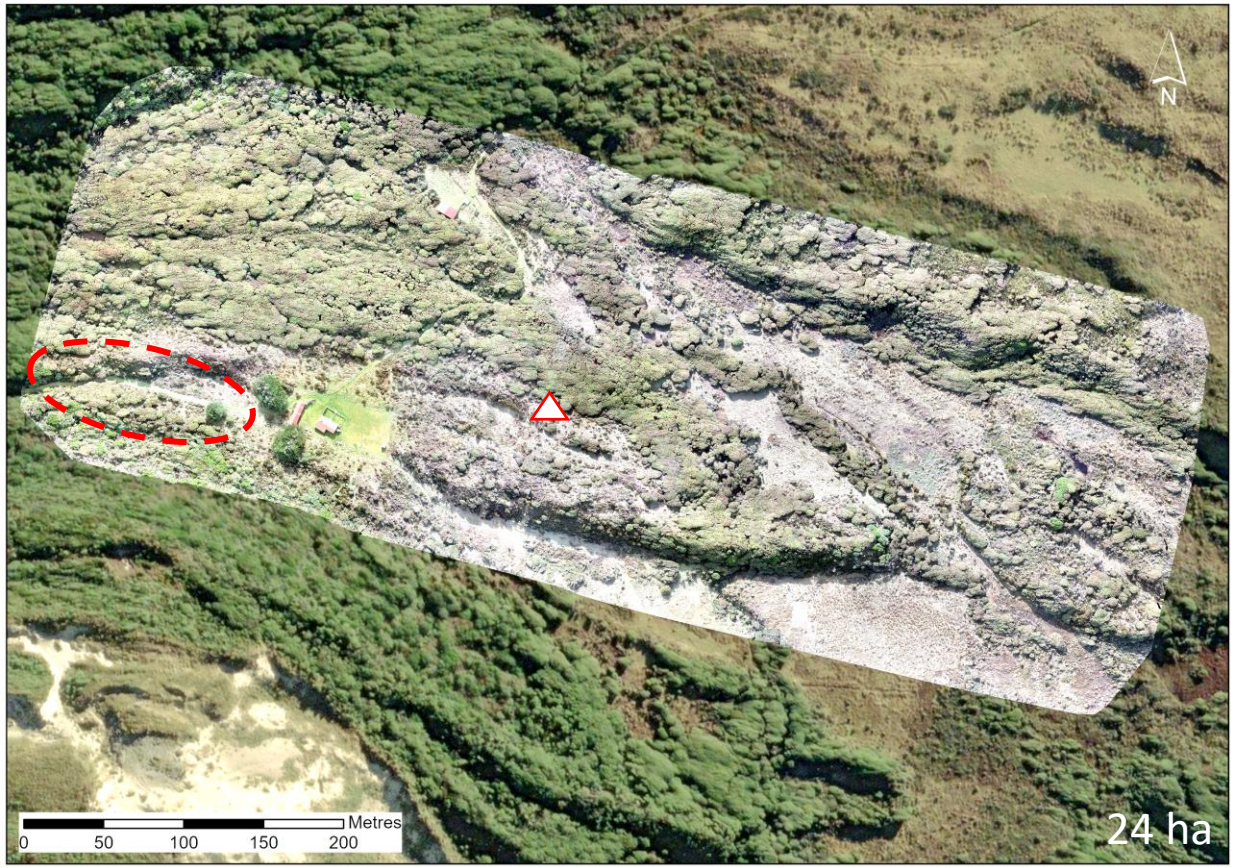
Special Place (stack): 0 - 5.76 mg/Kg (leaching following biomass decay?)

Note: C:N data will be completed in the next couple of weeks, which may show a more accurate representation of the nitrogen - specifically in the organic matter/surface samples

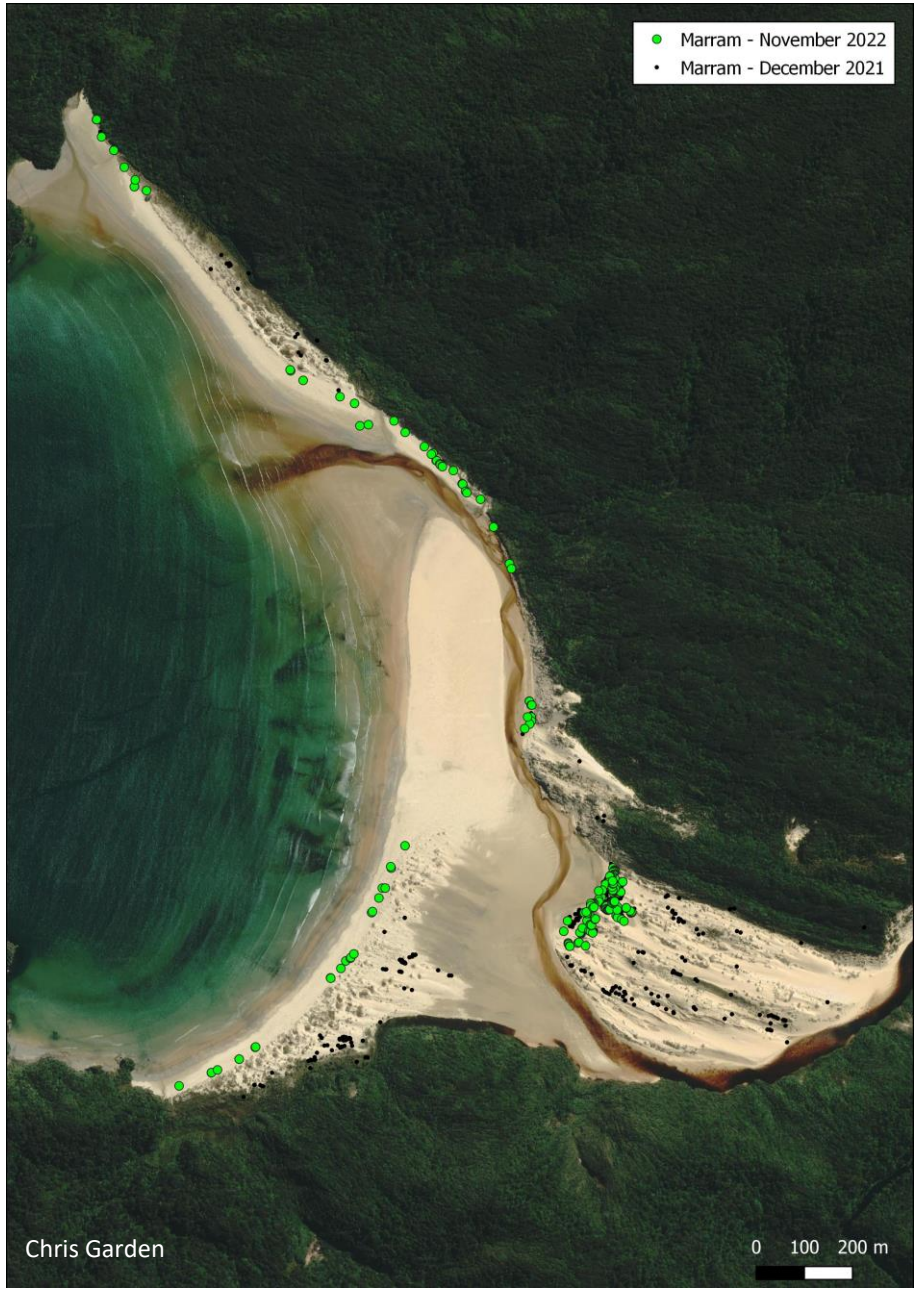
Darwin's Barberry UAV & ground survey – 25th August 2023

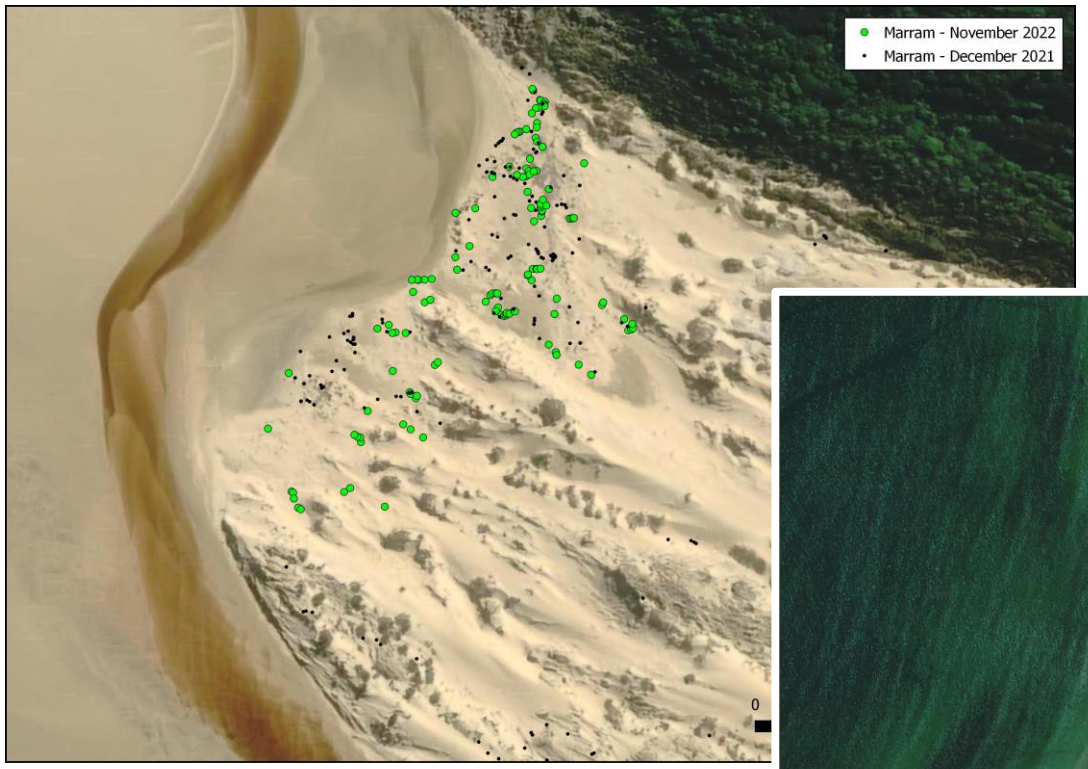
- Two surveys (Homestead & Homestead east) – no Barberry identified in orthophotograph (700 images) or during ground search
- historic records of Barberry in the vicinity of the Homestead?
- *Almost all viable seeds germinated in the spring following dispersal, indicating that B. darwinii does not form a persistent seed bank*. Kate McAlpine PhD (2005)
  - which suggests there must be a local mother plant?





Doughboy – remaining marram (November 2022)

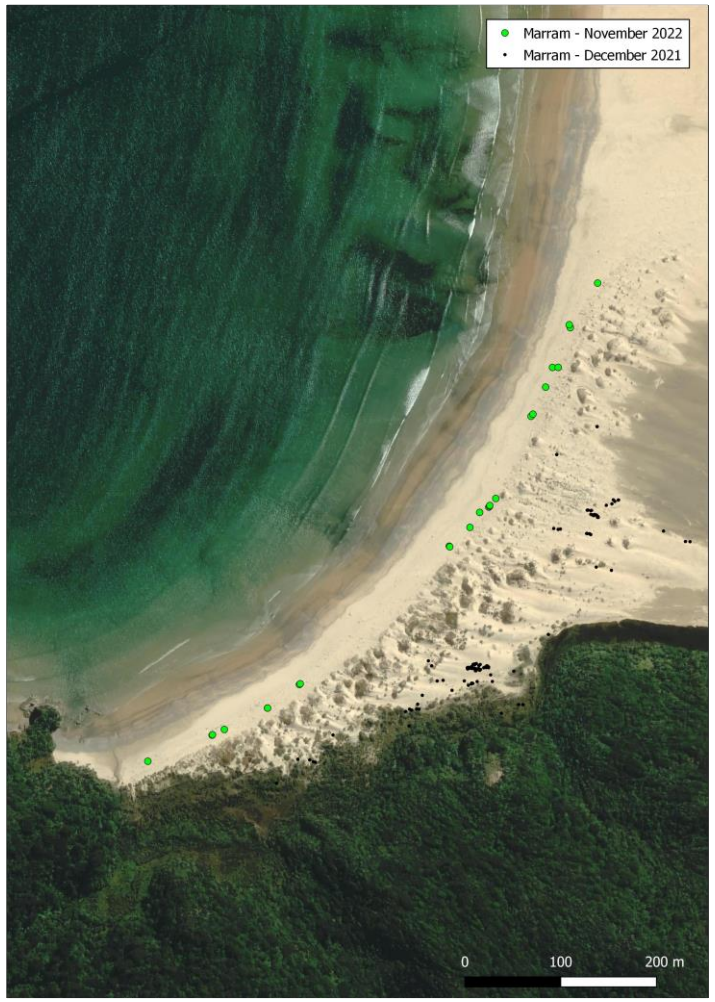




Nov 2022 marram is a new cohort (seed bank) + rhizome stranding

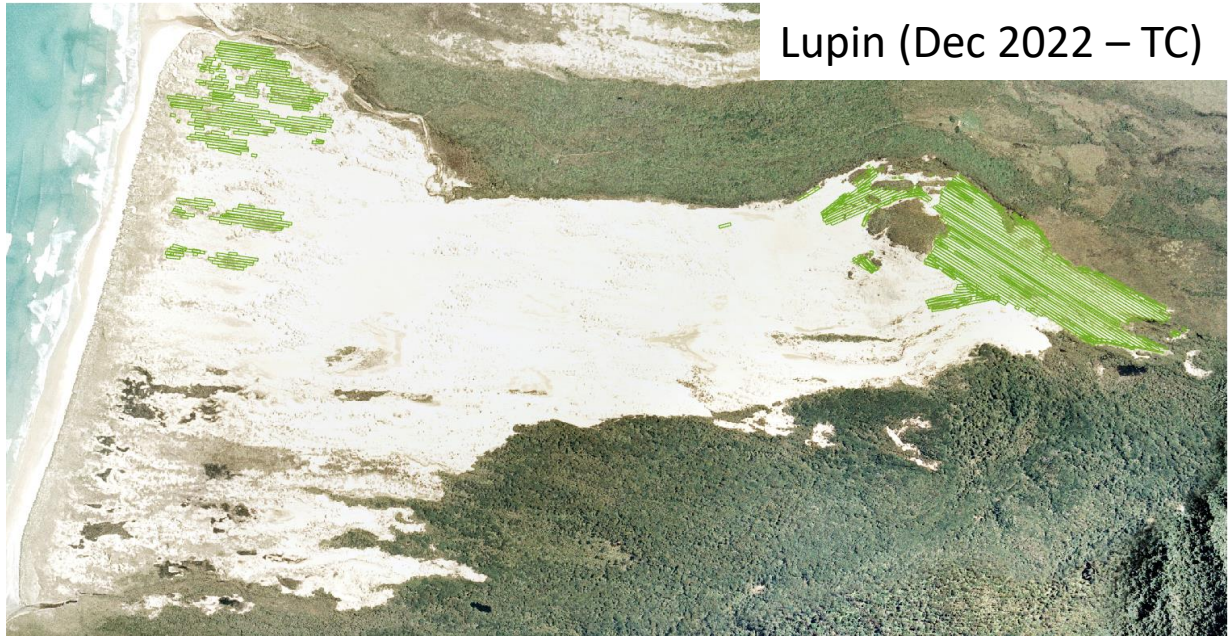
BUT … there's not much around!

- much of the 2022 crop could be removed mechanically



Marram / lupin die-back

Operations 2022/23



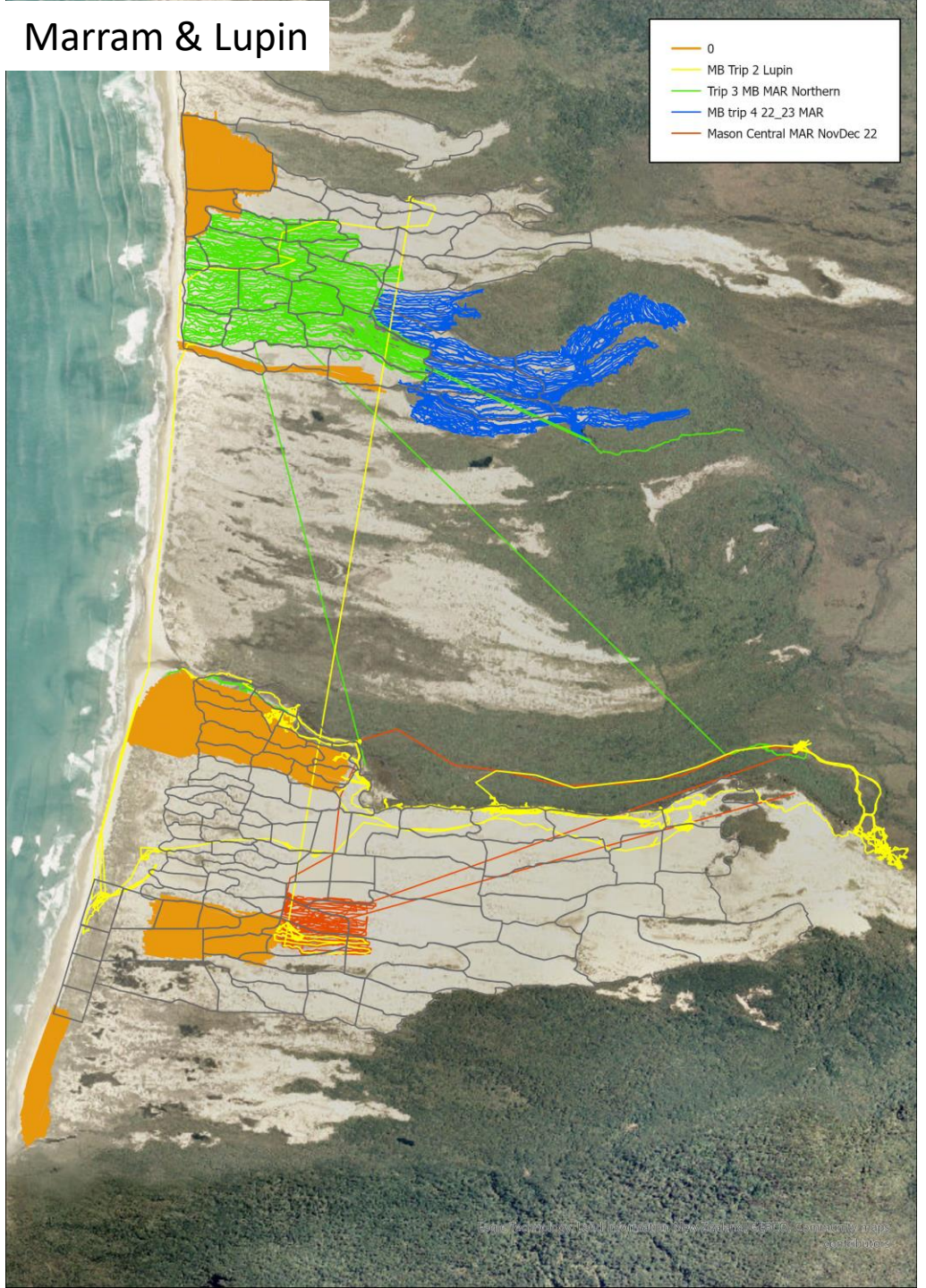
Lupin (Dec 2022 – TC)

Heli-ops (marram) (6/23)

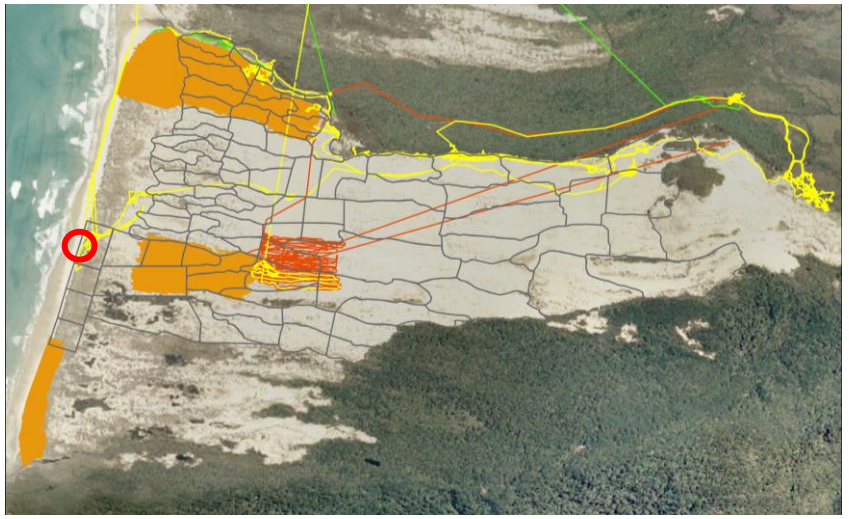
Ground (marram)

Ground (Lupin)

Marram & Lupin

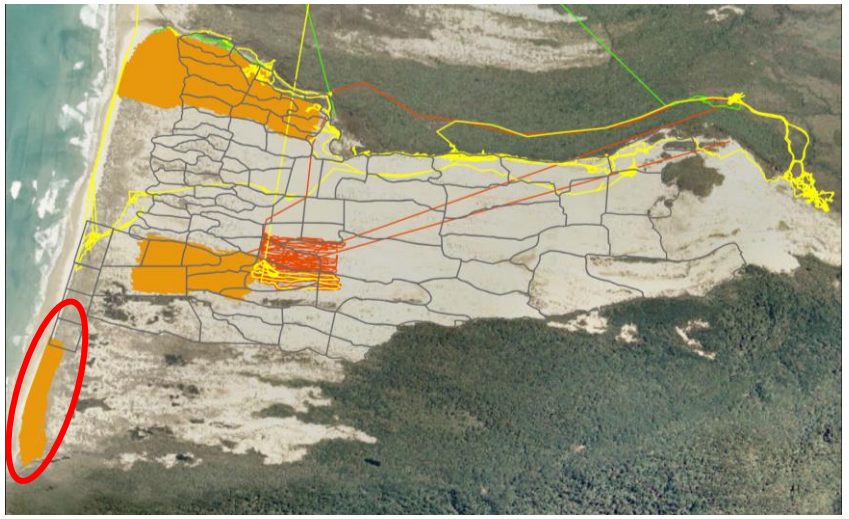


Marram / lupin die-back



August 2023

Marram / lupin die-back



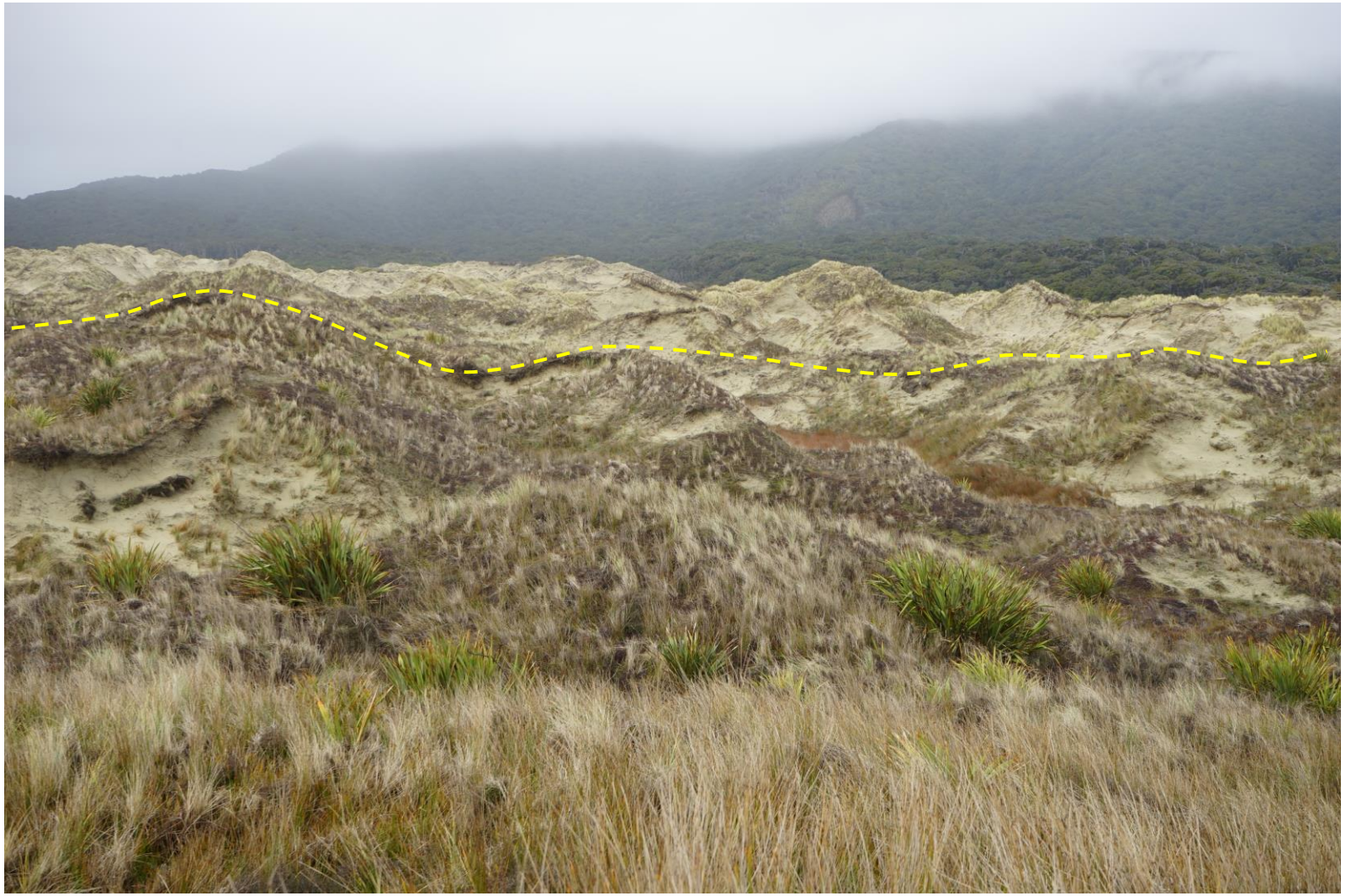
Sprayed June 2023

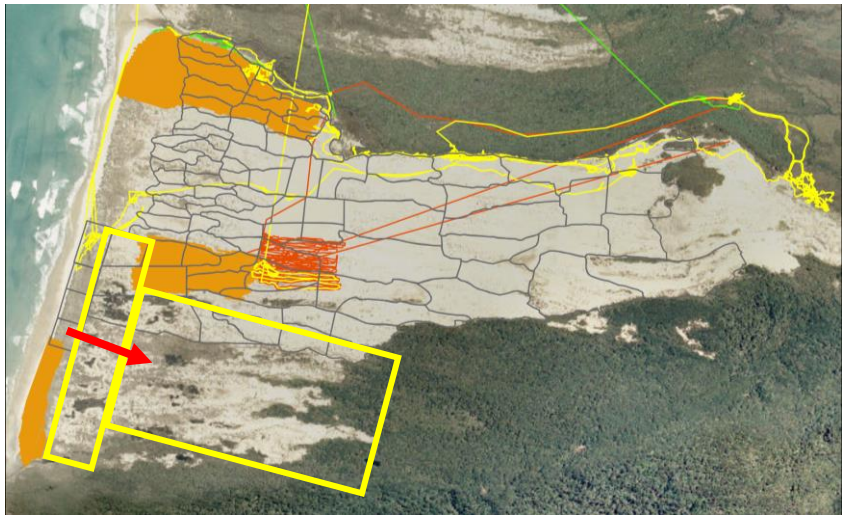
Less obvious die-back / more vigour along stoss

August 2023

Marram / lupin die-back

Sprayed April / May 2021

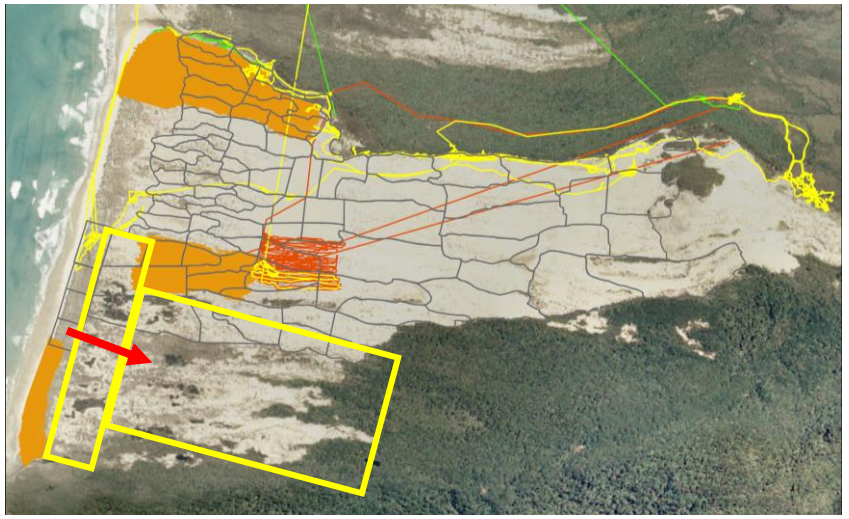




August 2023

Marram / lupin die-back

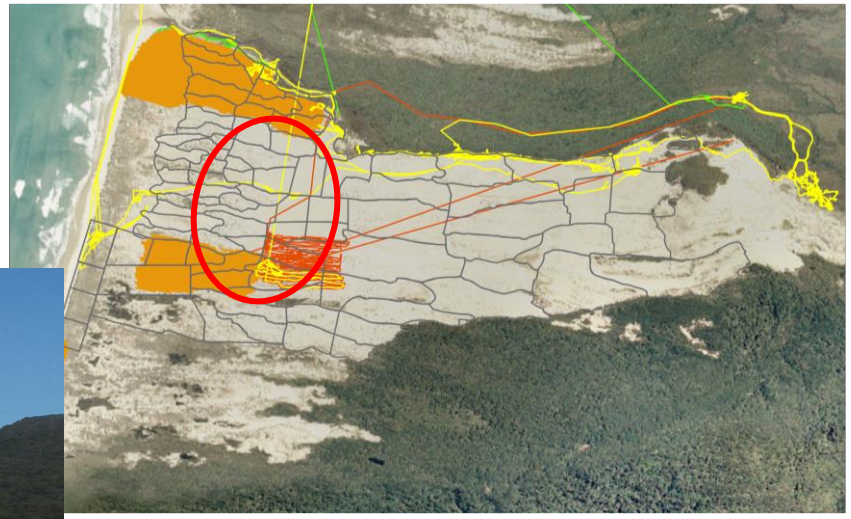
Sprayed April / May 2021 (TC)

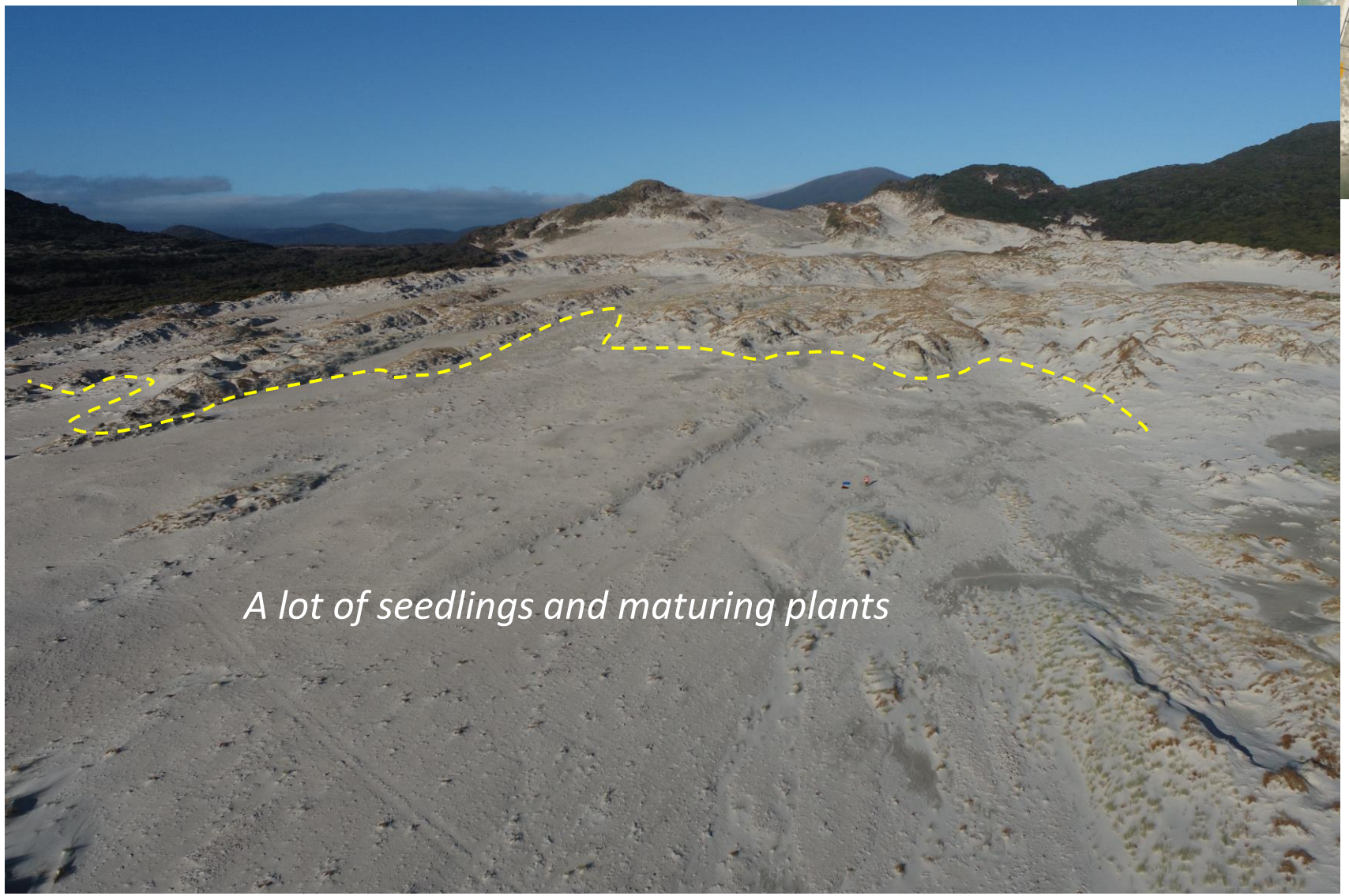


August 2023

Marram / lupin die-back

Great Stonefield - sprayed 20/21

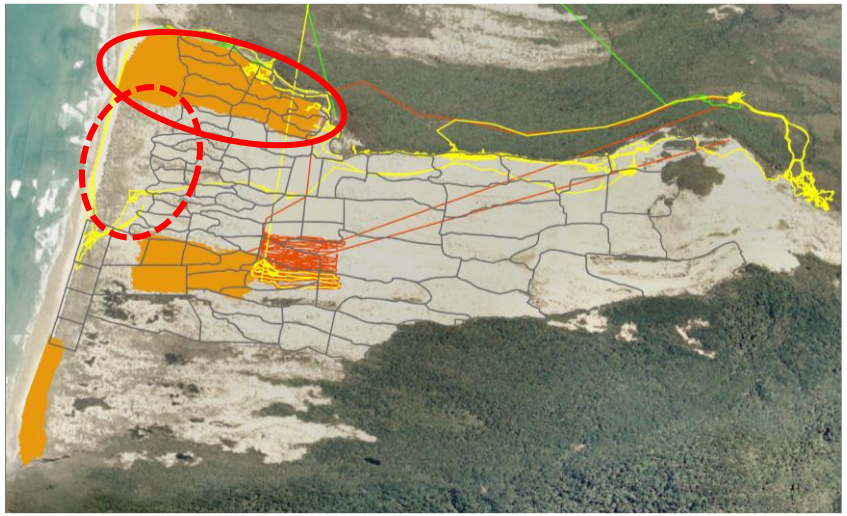




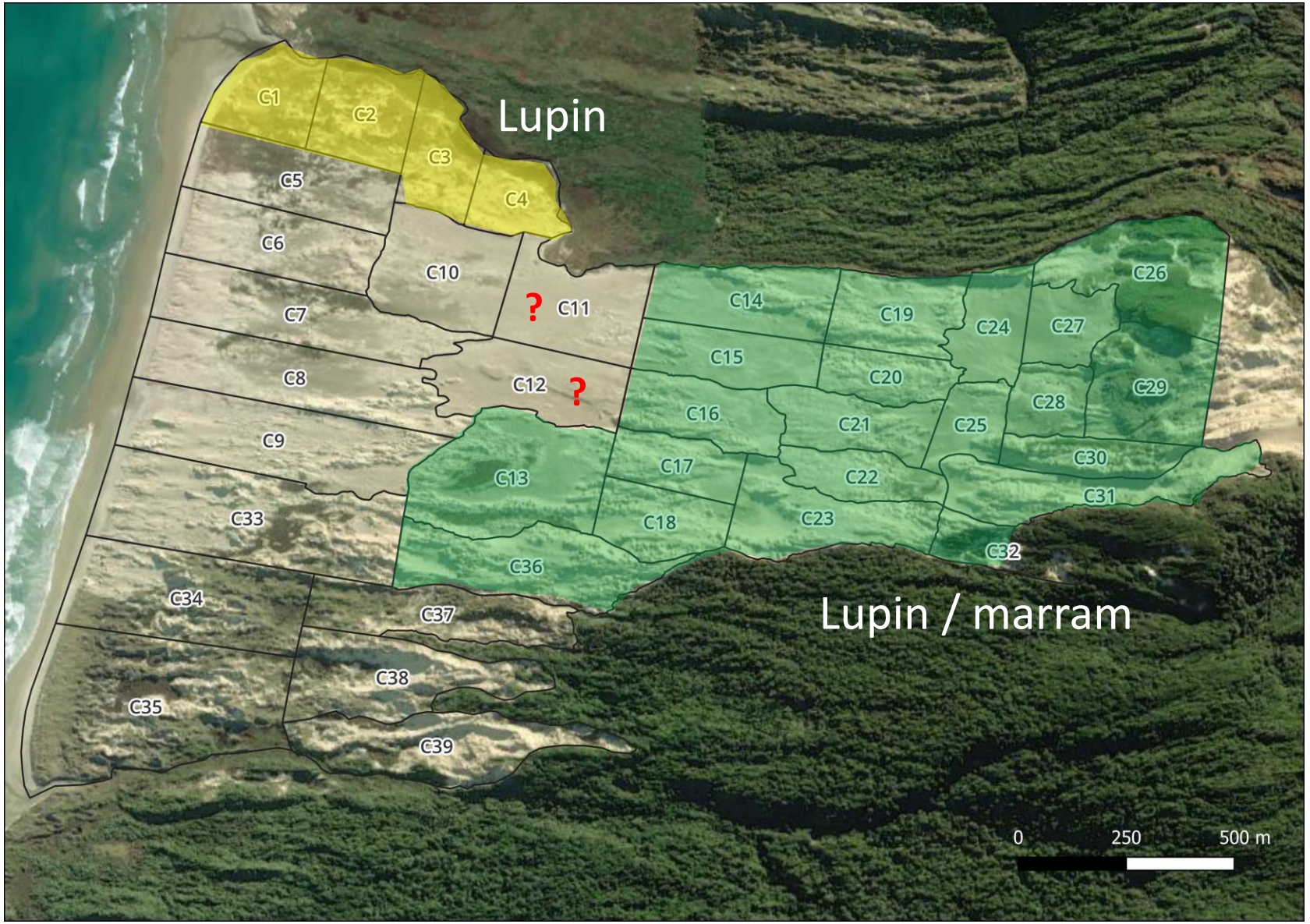
August 2023

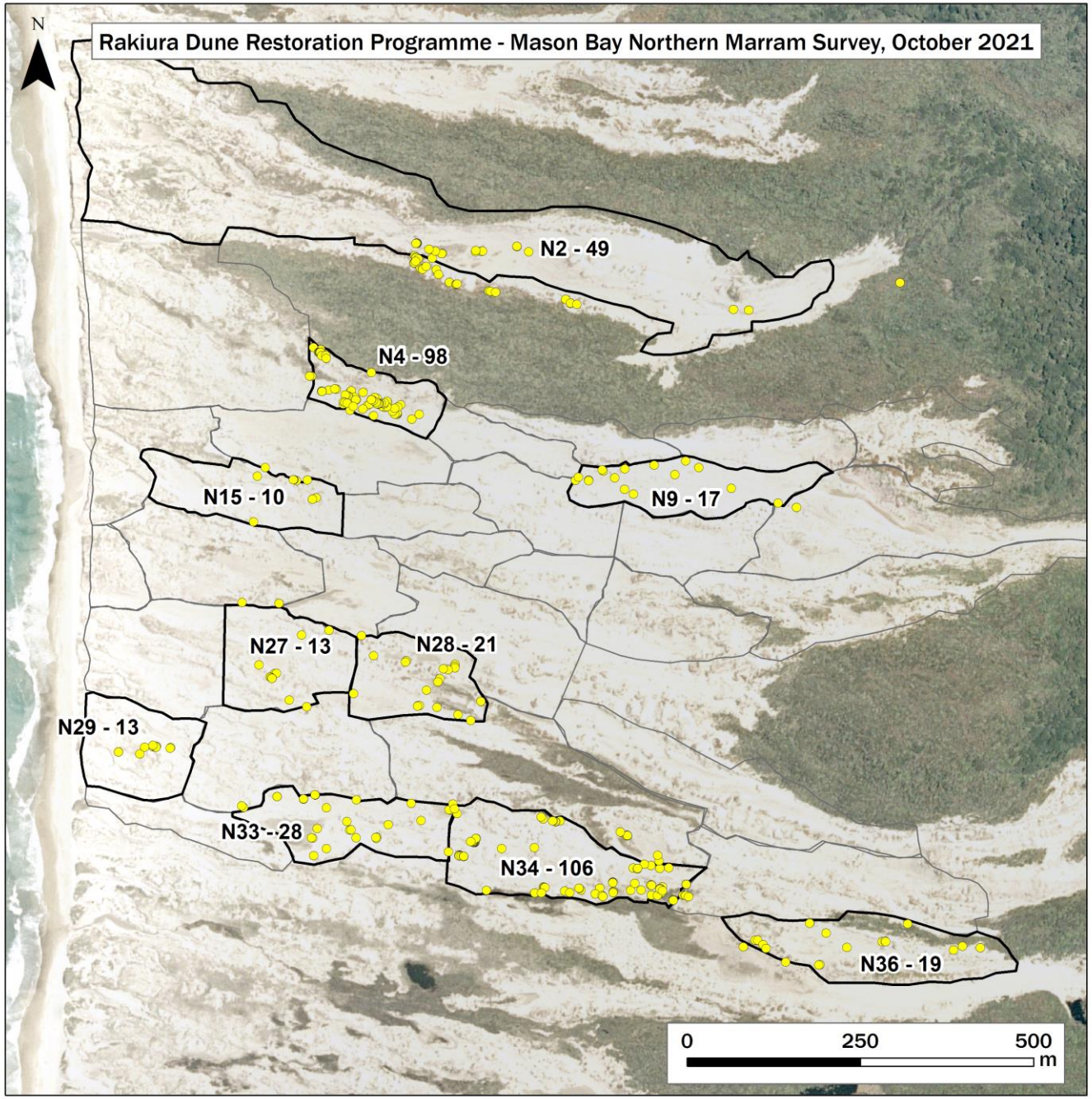
Marram / lupin die-back

Duck Creek - sprayed June 2023 – hinterland looking good, ongoing stoss face vigour



Central Dunes – management units / marram/lupin volly trip




N
Rakiura Dune Restoration Programme - Mason Bay Northern Marram Survey, October 2021
N2 - 49
N4 - 98
N15 - 10
N9 - 17
N27 - 13
N28 - 21
N29 - 13
N33 - 28
N34 - 106
N36 - 19
0
250
500
m

3. Botany

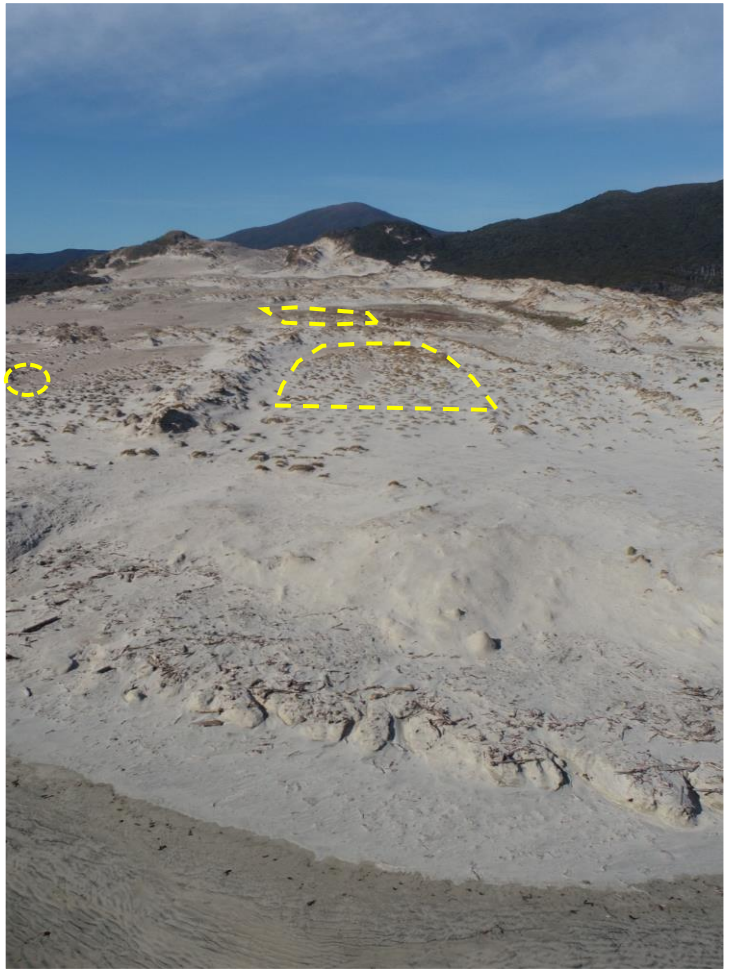
Euphorbia glauca translocation trial, August 2023

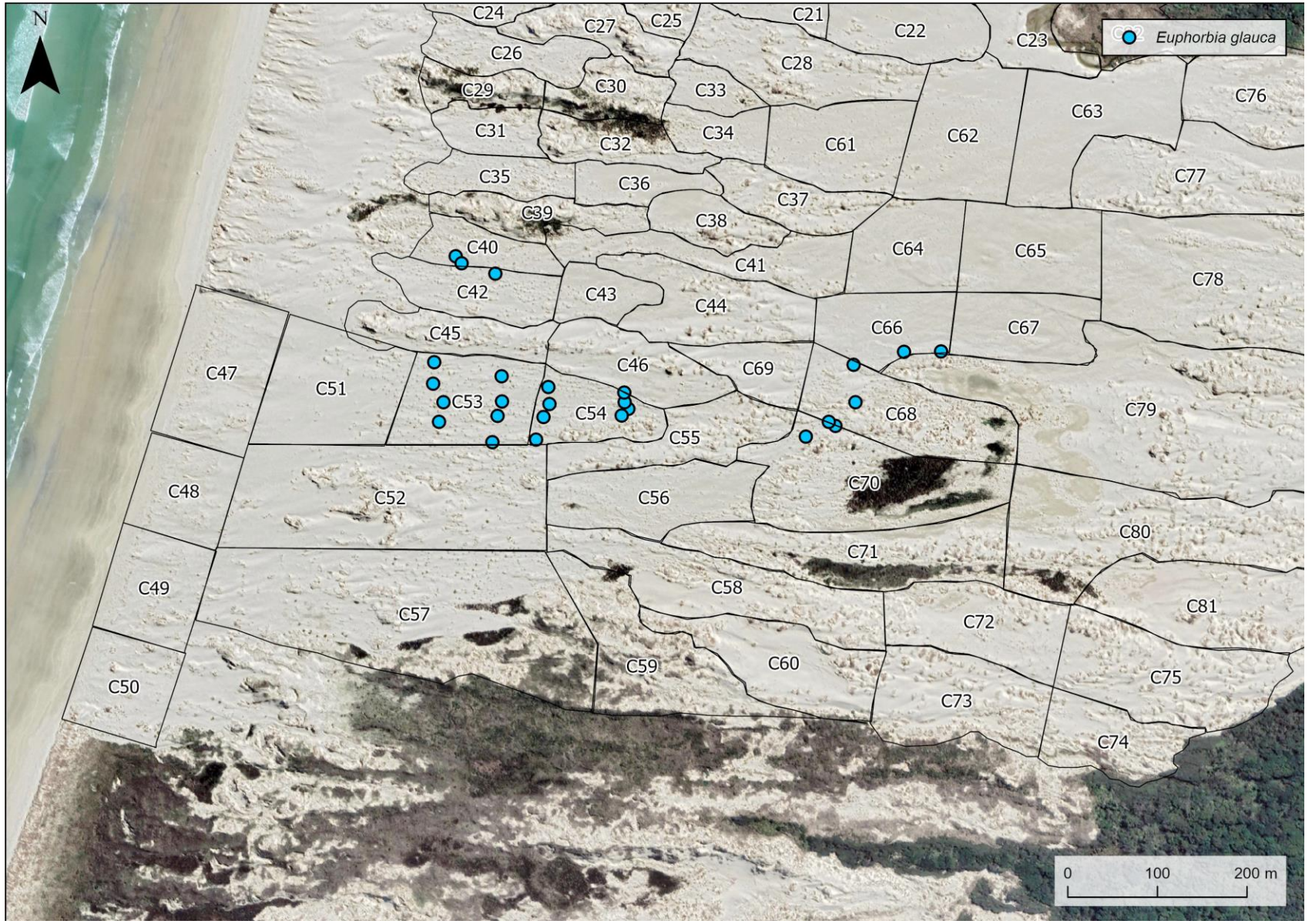
"Phred"

"Brian"

Euphorbia glauca translocation trial sites

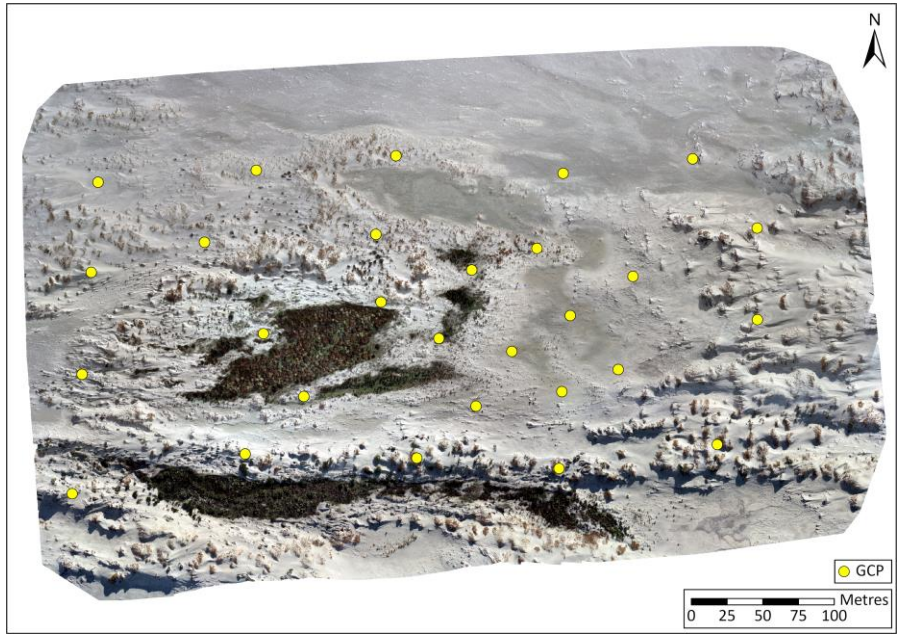
- P6 deflation
- P5 deflation (3 x bare rooted)
- Dune margins downwind of P6



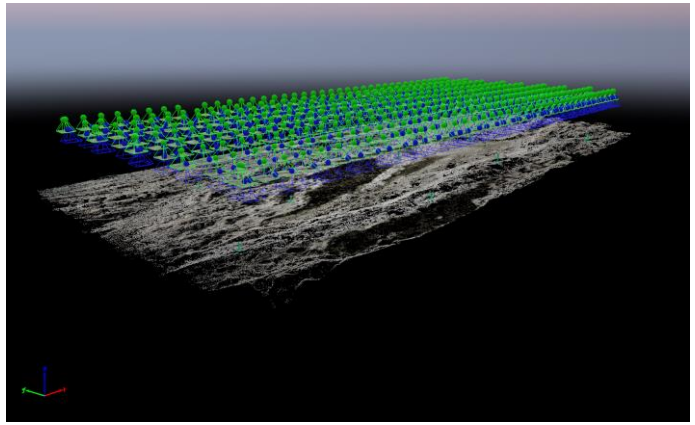


2. Monitoring morphodynamics / changing landscapes

- erosion / accretion stakes in permanent quadrats
- shore-normal profiles
- digital surface models derived (RTK-GPS controlled UAV photogrammetry)

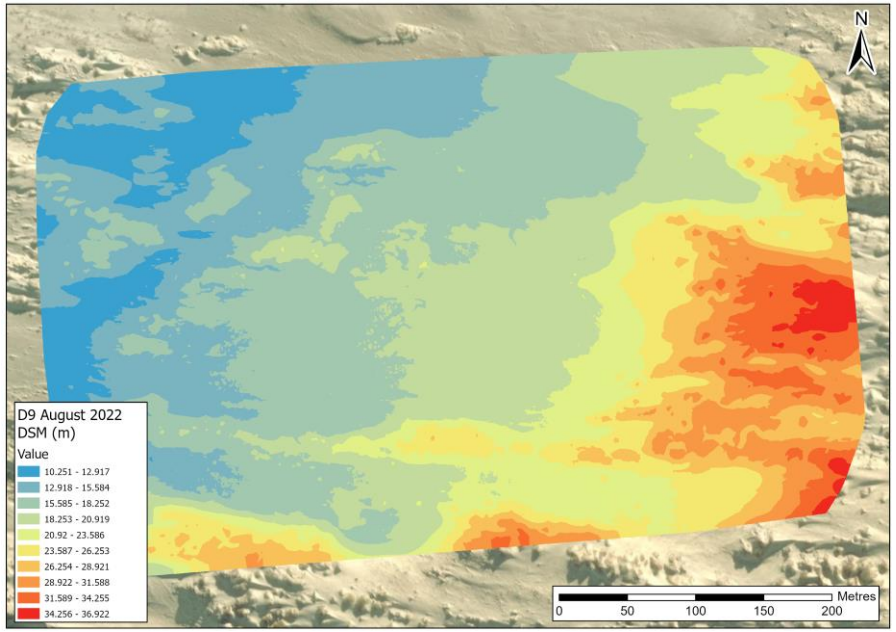


1. GCP (ground control tiles)



3. Flight – 400 vertical aerial images, 80% overlap, 1cm resolution

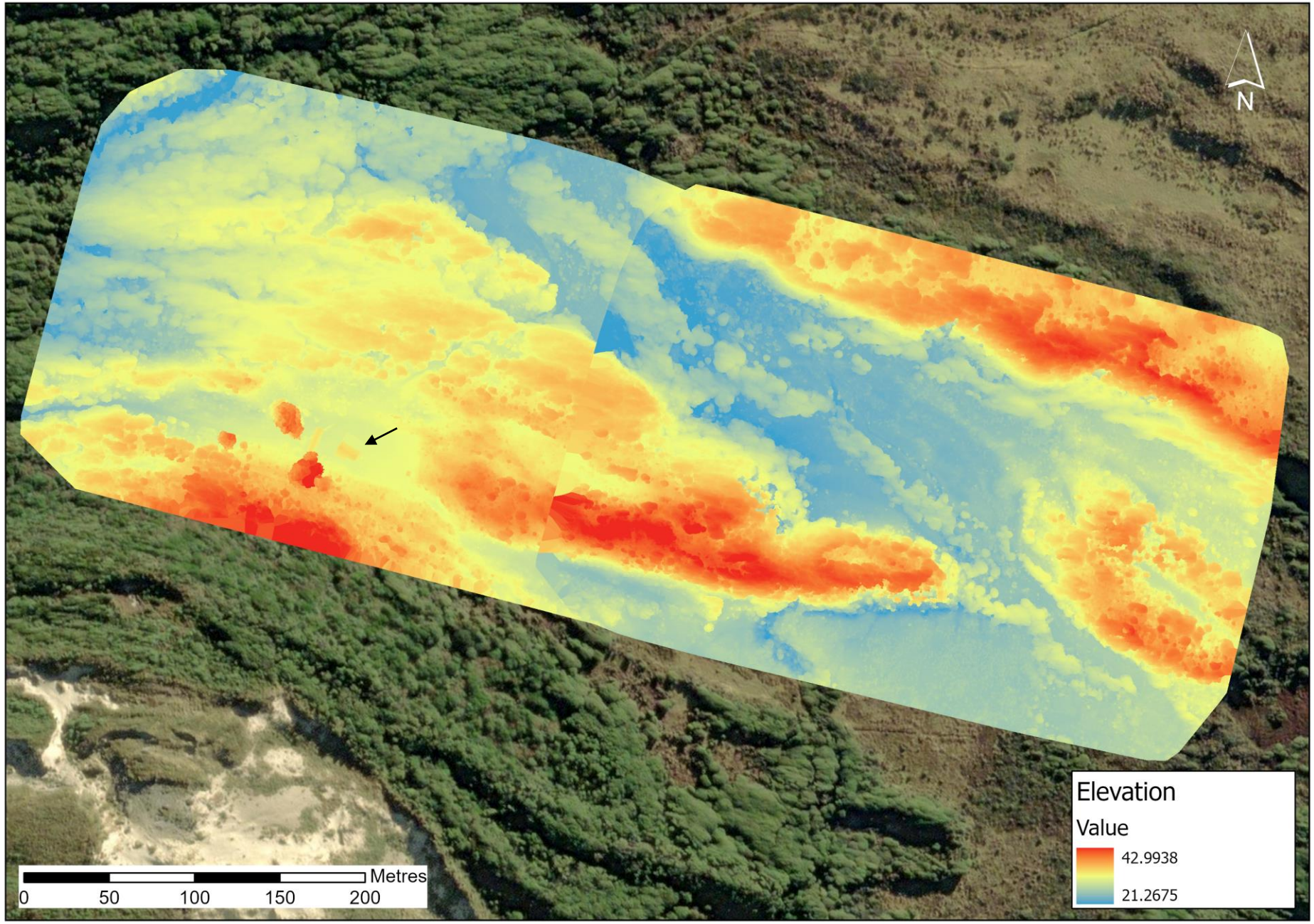
2. RTK-GPS survey relative to Big Sandhill mark



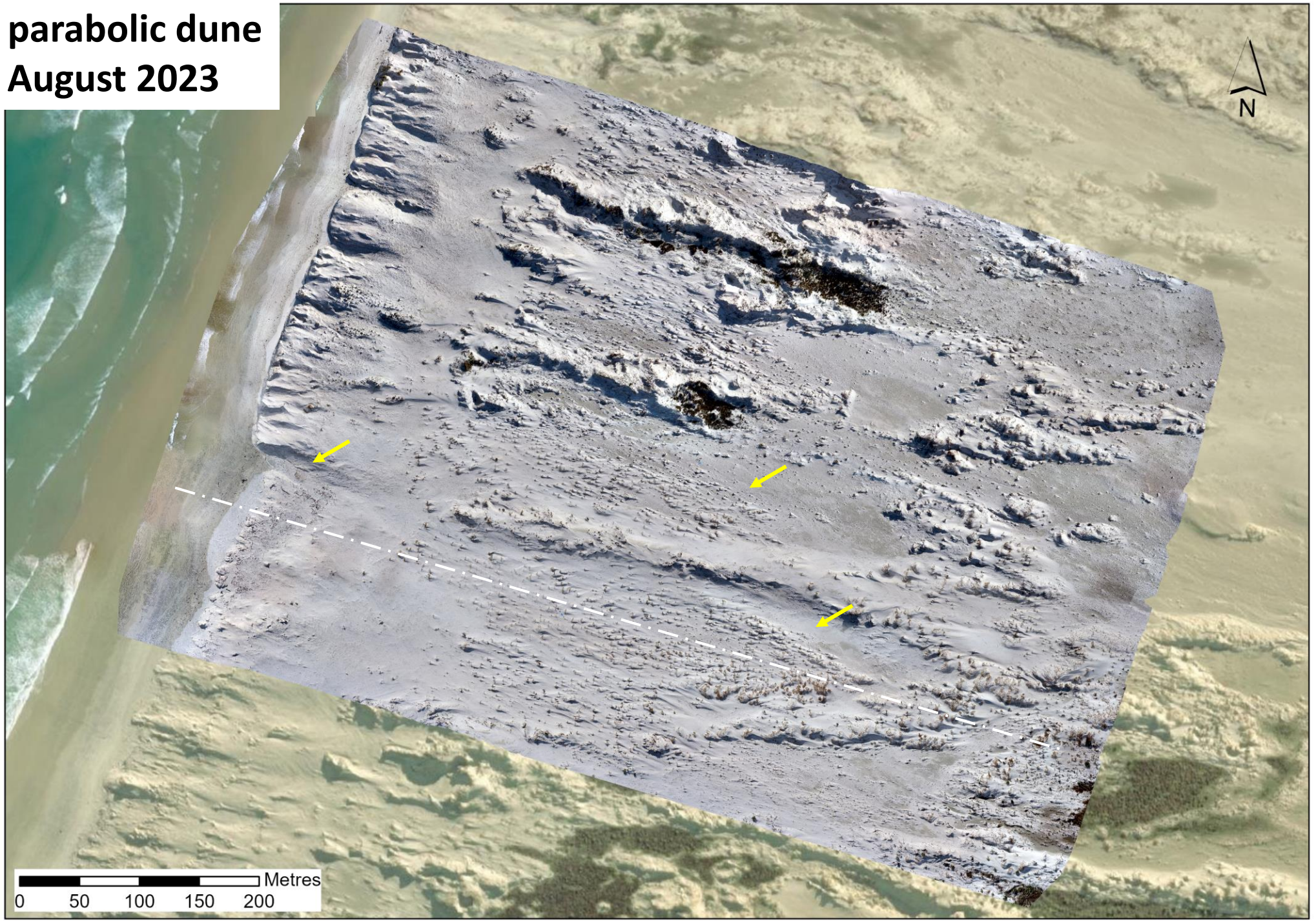
3. Pix4D analysis – DSM & orthphoto

Digital surface model – 2 flights (each 12ha)

Homestead



Foredune / parabolic dune Landscape, August 2023



Pre-marram beach (gravels)

Ongoing growth of size & extent of pīkao nebkha

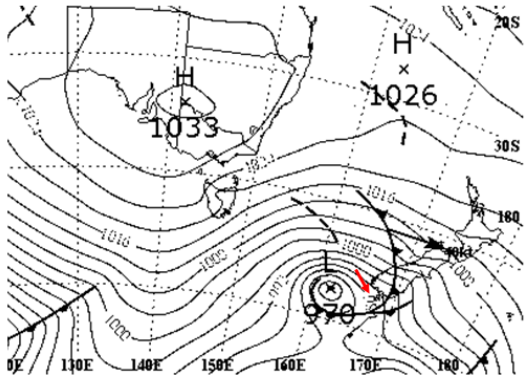
P4

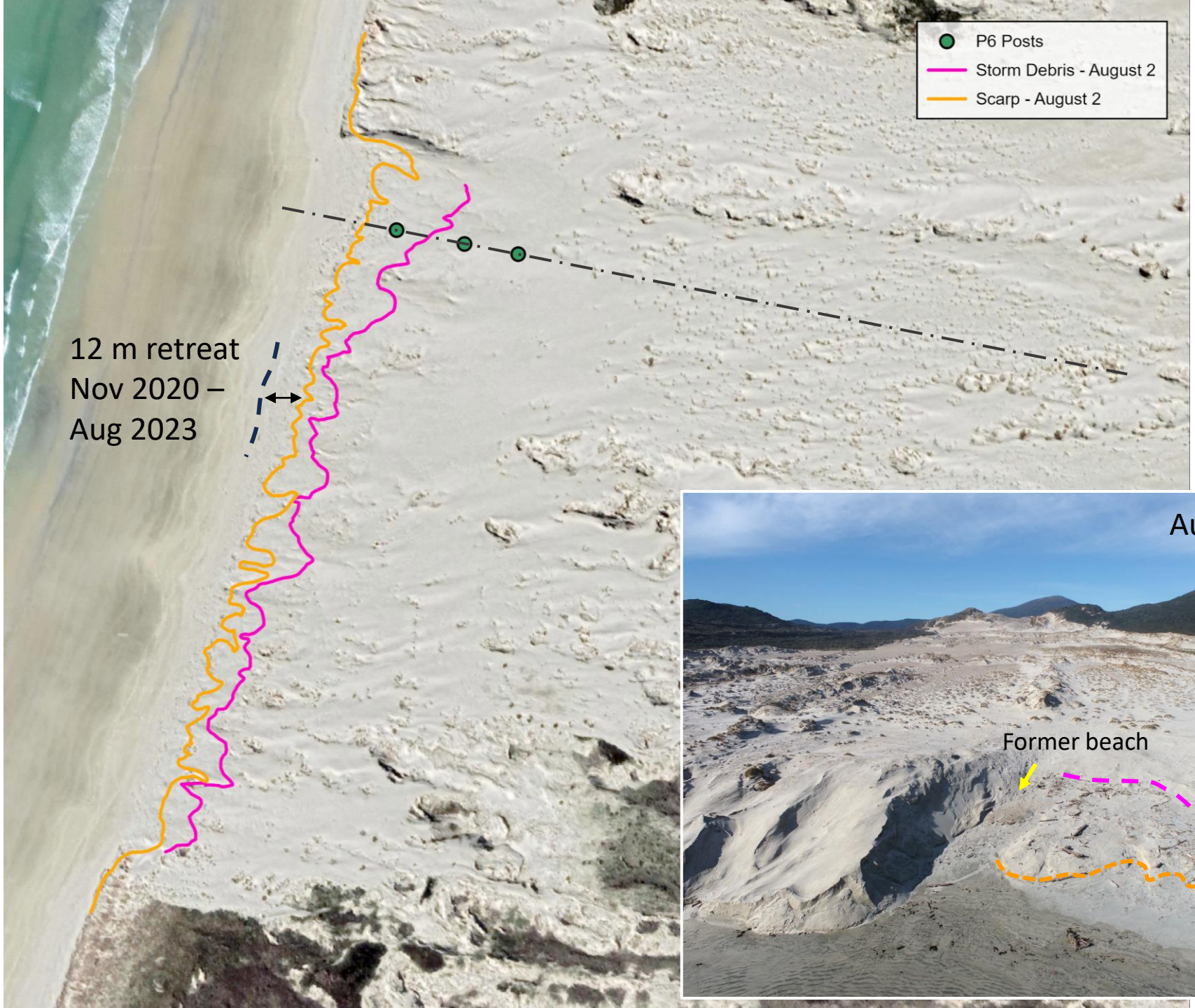
P5

P6

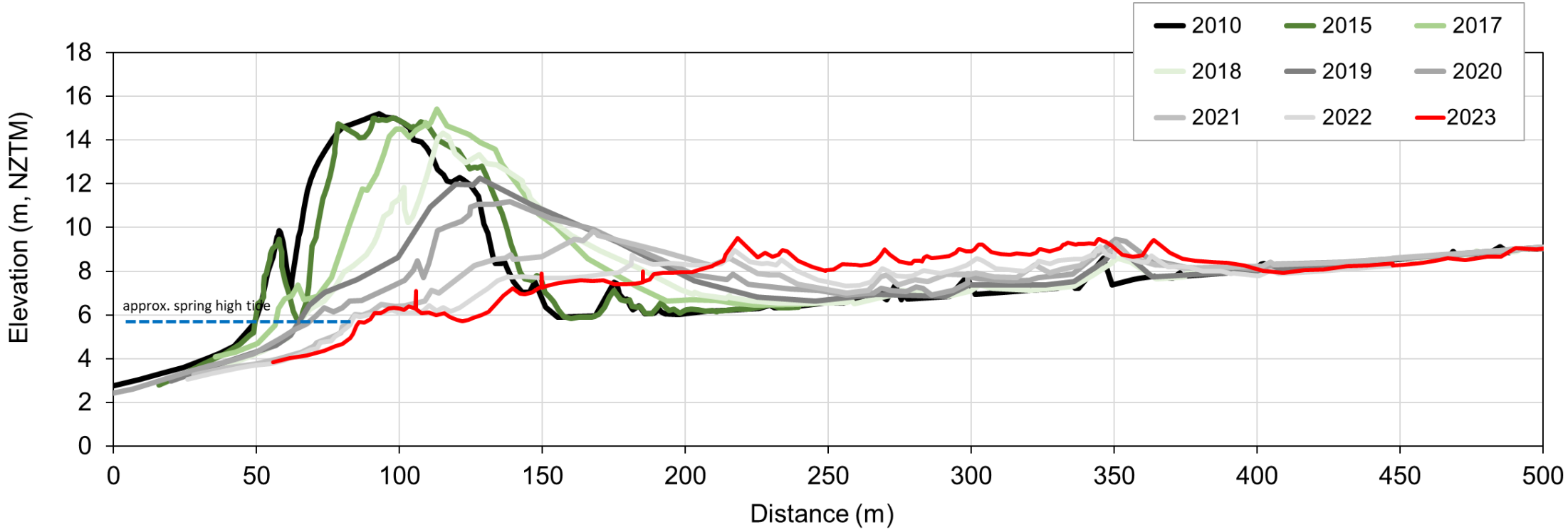
Shoreline dynamics

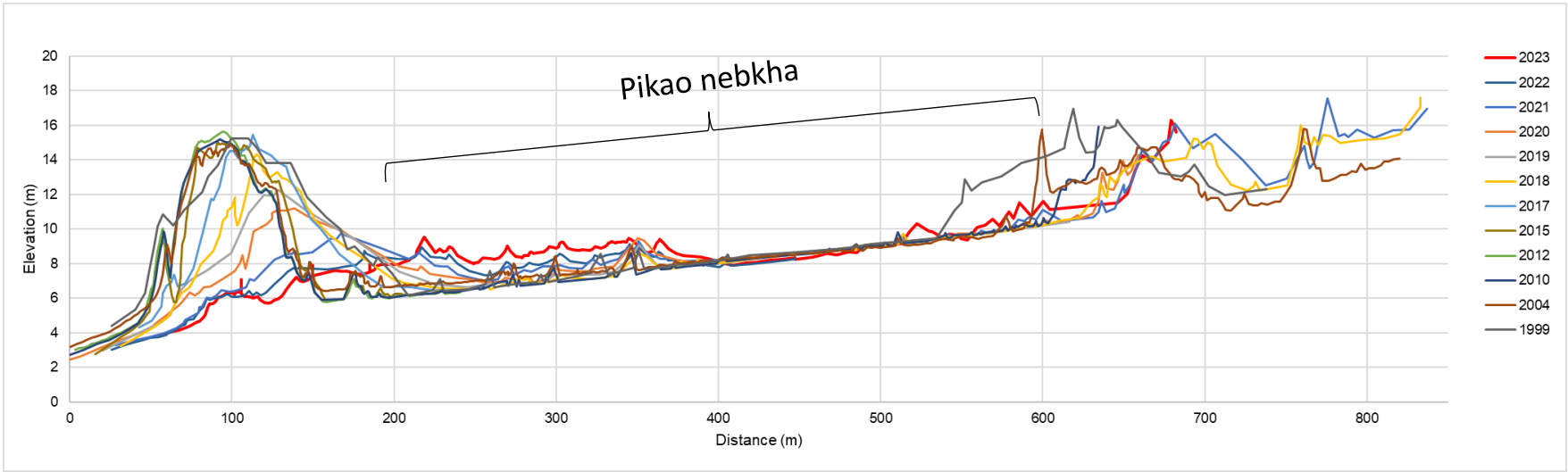
- Scarping & debris deposition during weather event 1-2 August 2023



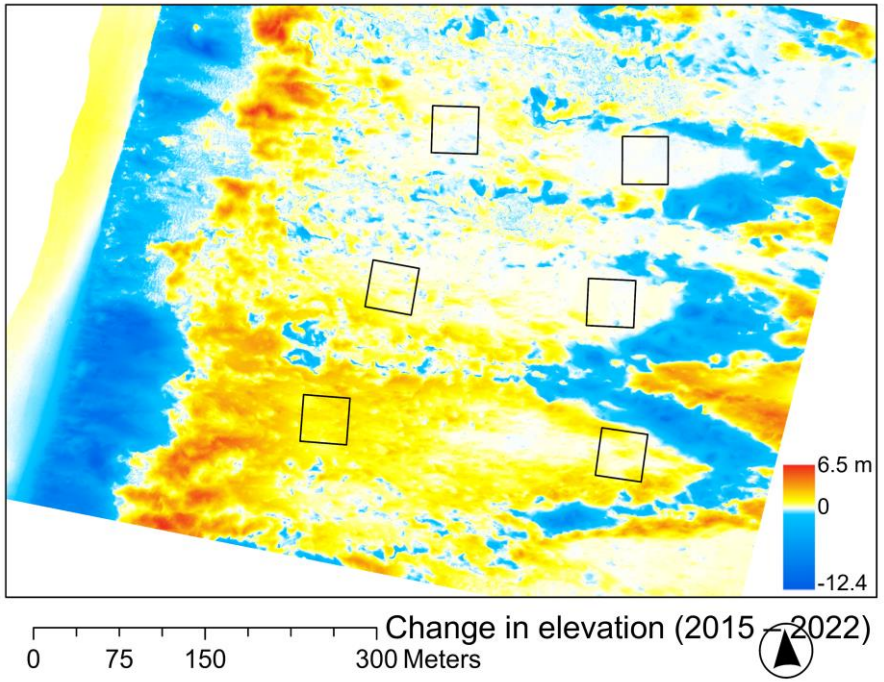


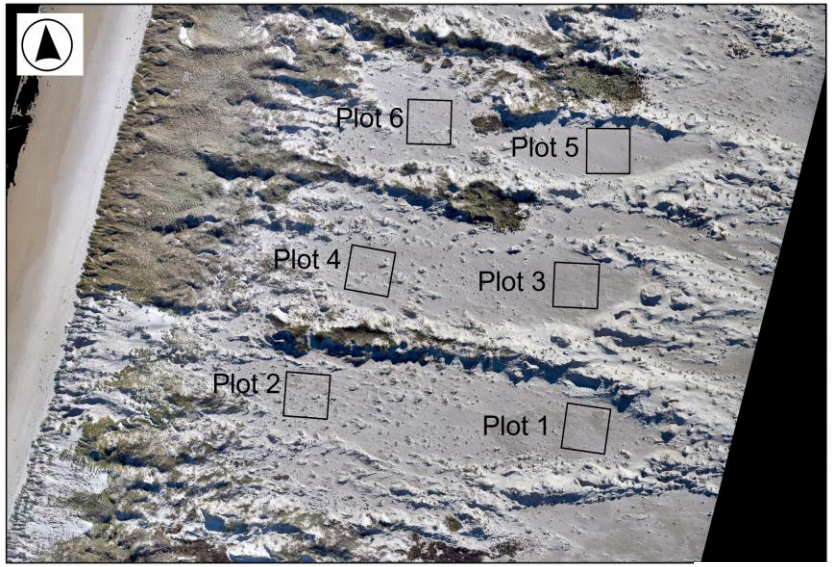
P6 profile surveys 1999/2010 – August 2023



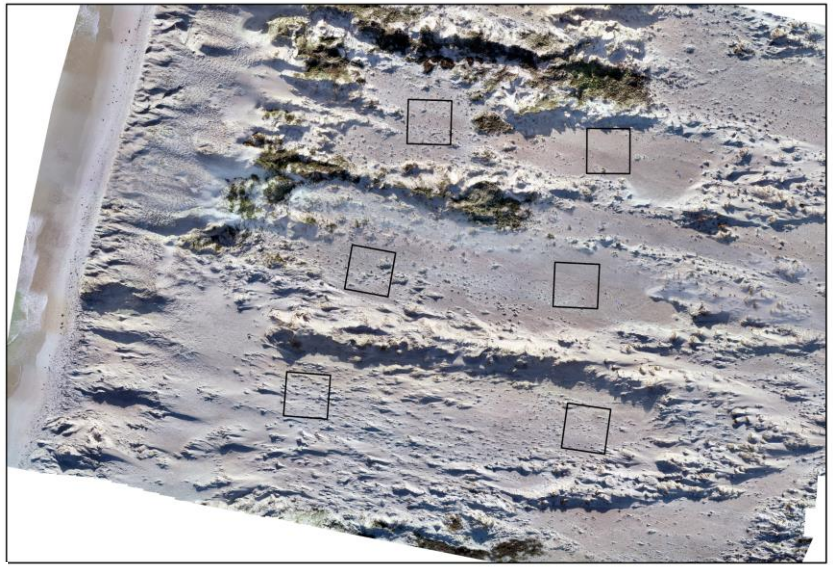


Change in elevation P4 - P6
2015 - 2022

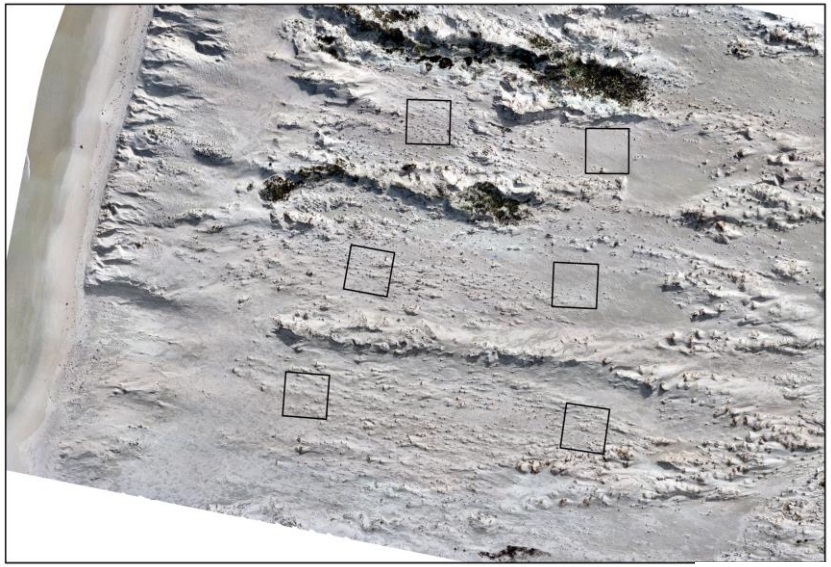




2015



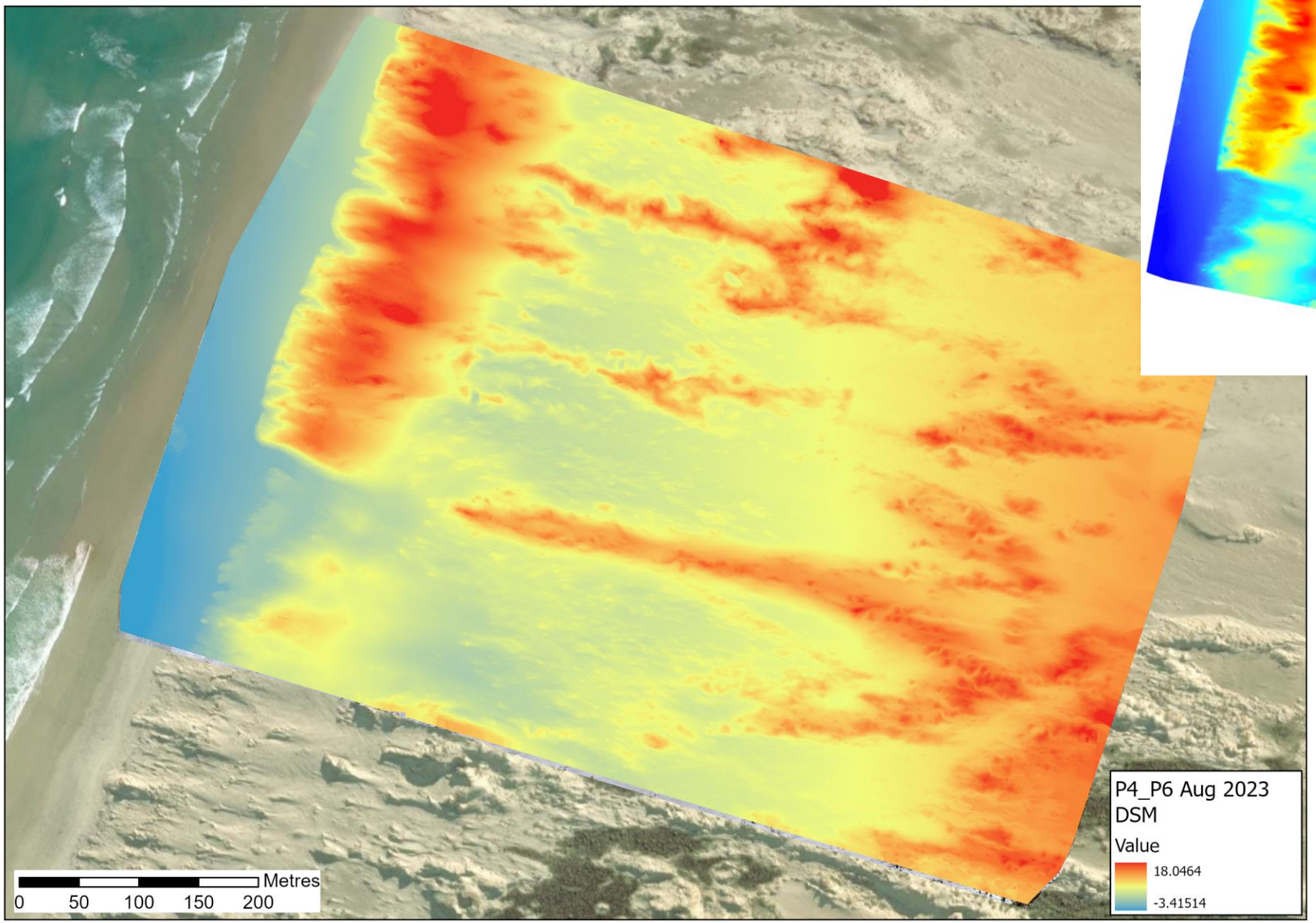
2020

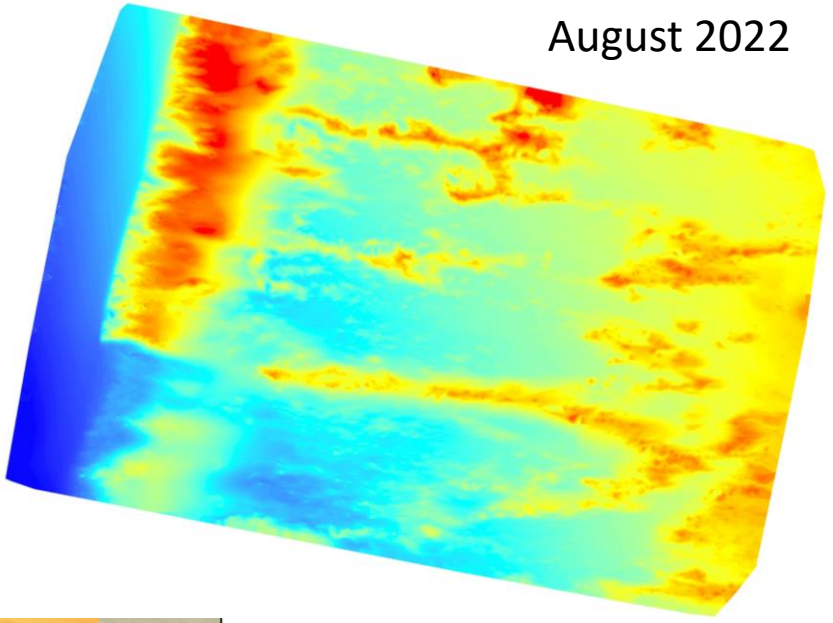


2022

Digital surface model – August 2023 (non-controlled)

August 2022





Is the Great Stonefield becoming more sandy & dunal?

A little, in places,
very slowly.

Ella Buckley survey area (2017)

- will repeat asap

August 2023

4. Post-graduate research (slides follow):

Campbell McCusker (MSc) – The ecology of seepage/wetland communities (submitting Nov. 2023)

Jen Talbot (MAppSci) – Lupin invasion, nitrogen enrichment and plant community structure, Mason Bay (sub. Dec. 2023)

Maddie Brown (PhD) – Barrier development and pīkao recovery / sand transport, Doughboy Bay (sub. Dec. 2023)

Deflation complex plant communities

Campbell McCusker

Rushland/ Sedgeland

Apodasmia similis

Phormium tenax

Ficinia nodosa

Turf

Ranunuclus acaulis

Gunnera arenaria

Cushionfield

Triglochin striata

Isolepis cernua

Streamside

Limosella lineata

Lilaeopsis novae-zealandiae

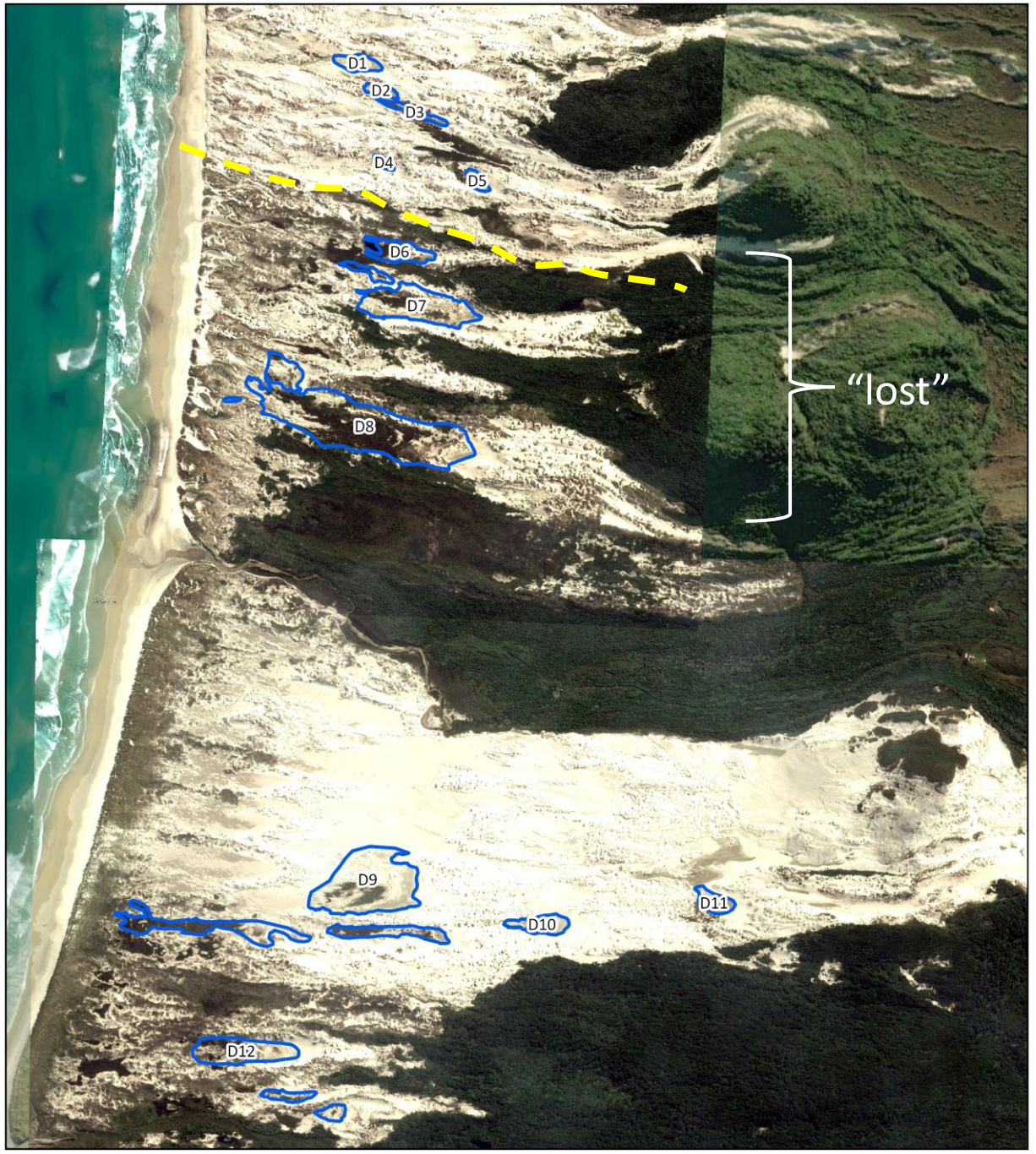
Dune

Ficinia spiralis

Poa billardierei

Active deflation complexes – Mason Bay (2013)

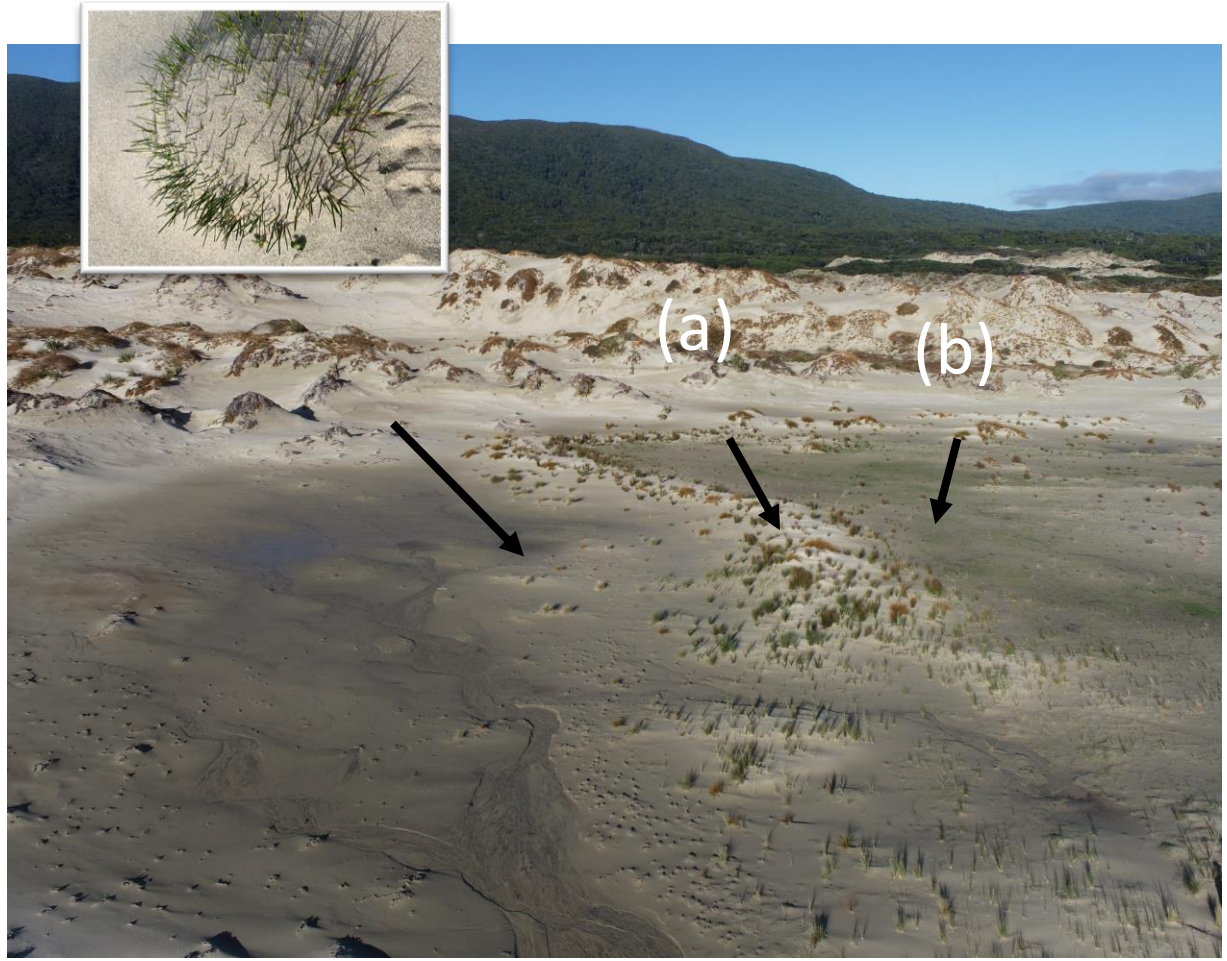
- active deflation complexes occur throughout the Mason Bay dune system.
- these environments support a range of wetland and dune communities.
- they cover an area of approximately 25 hectares of the dune system at Mason Bay.



Basemap: Google Earth 2013

Dynamic dunes – Deflation complexes

- The first colonizer of the moist bare sand is *I. cernua.*
- *I. cernua* trap sand, creating small dunes, that can be colonized by dune builders (pīkao and sand tussock) which form dunes (a) or wetland herb species which form wetland turfs (b)
- However, *I. cernua is* reliant on the migration of the inland dune to create more moist bare sand for it to colonise and start the process again.



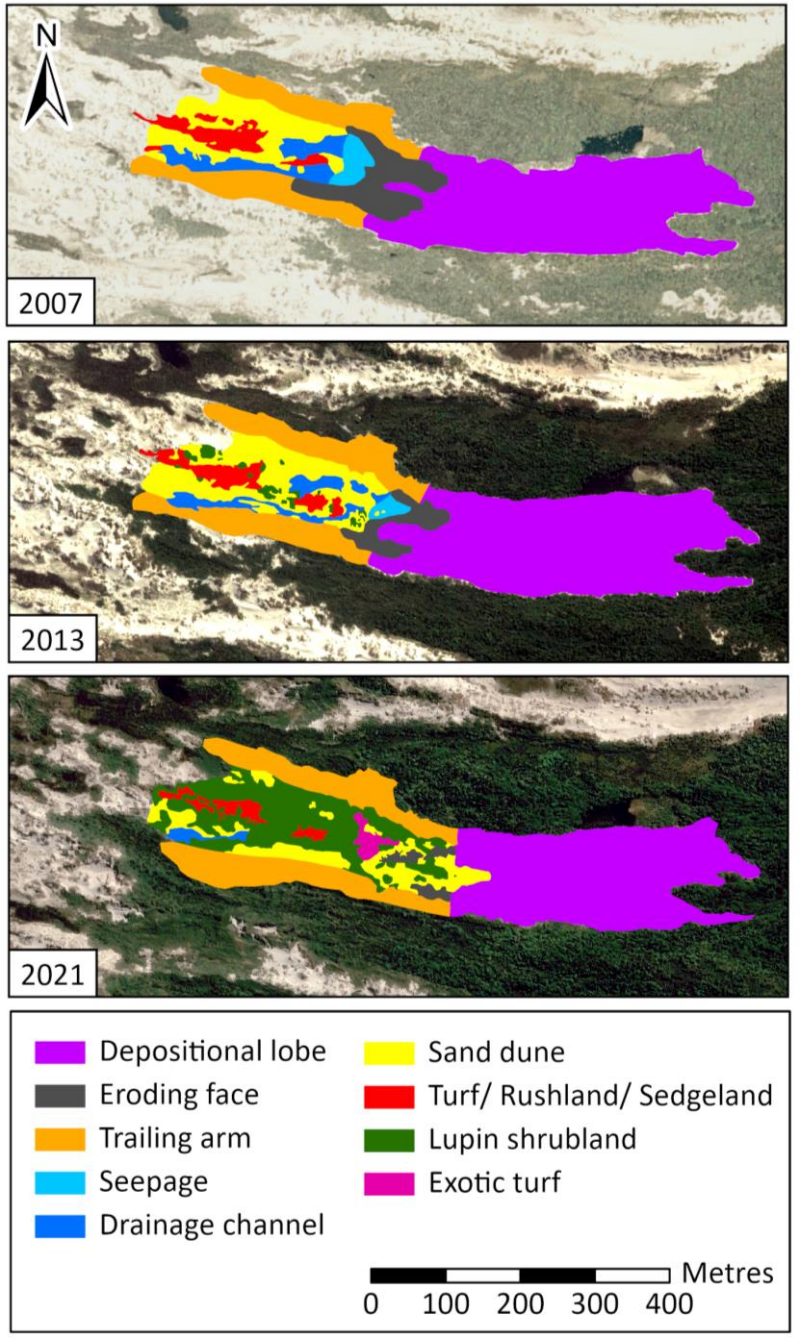
(a) Gegenwalle dunes (“counter ridge”) – ridges of sand formed by offshore (NE winds)

Deflation seepage and wetland communities are displaced by tree lupin

- dunes stabilized by marram and lupin do not migrate, resulting in the loss of moist sand for *I. cernua.*
- this has occurred in three areas in the Northern Dunes (outside of the lupin/marram management zone).
- the seepage and wetland turf communities have been displaced by marram and lupin.

Active deflation complex
D5 (Northern Dunes) January 2022

Stabilized deflation complex
D6 (Northern Dunes) January 2022



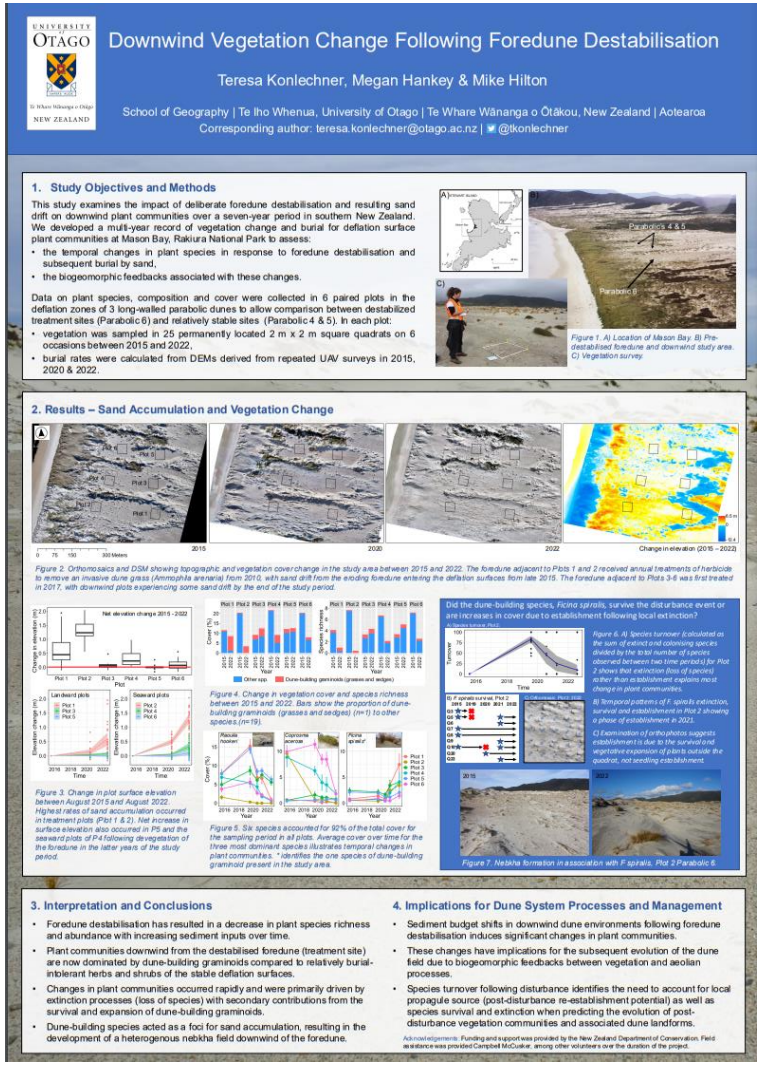
Deflation complex 7 (D7) 2007 - 2021

Nitrogen Fixation by *Lupinus arboreus* in Coastal Dunes

Jen Talbot (MAppSci (Environmental Management))

Konlechner *et al.* (2023)

Downwind Vegetation Change Following Foredune Destabilisation



Downwind Vegetation Change Following Foredune Destabilisation

Teresa Konlechner, Megan Hankey & Mike Hilton

School of Geography | Te Iho Whenua, University of Otago | Te Whare Wānanga o Ōtākou, New Zealand | Aotearoa

Corresponding author: teresa.konlechner@otago.ac.nz | @tkonlechner

1. Study Objectives and Methods

This study examines the impact of deliberate foredune destabilisation and resulting sand drift on downwind plant communities over a seven-year period in southern New Zealand. We developed a multi-year record of vegetation change and burial for deflation surface plant communities at Mason Bay, Rakiura National Park to assess:

- the temporal changes in plant species in response to foredune destabilisation and subsequent burial by sand,
- the biogeomorphic feedbacks associated with these changes.

Data on plant species, composition and cover were collected in 6 paired plots in the deflation zones of 3 long-walled parabolic dunes to allow comparison between destabilized treatment sites (Parabolic 6) and relatively stable sites (Parabolic 4 & 5). In each plot:

- vegetation was sampled in 25 permanently located 2 m x 2 m square quadrats on 6 occasions between 2015 and 2022.
- burial rates were calculated from DEMs derived from repeated UAV surveys in 2015, 2020 & 2022.

Figure 1. A) Location of Mason Bay. B) Pre-destabilised foredune and downwind study area. C) Vegetation survey.

2. Results – Sand Accumulation and Vegetation Change

Figure 2. Orthomosaics and DSM showing topographic and vegetation cover change in the study area between 2015 and 2022. The foredune adjacent to Plots 1 and 2 received annual treatments of herbicide to remove an invasive dune grass (*Ammophila arenaria*) from 2010, with sand drift from the eroding foredune entering the deflation surfaces from late 2015. The foredune adjacent to Plots 3-6 was first treated in 2017, with downwind plots experiencing some sand drift by the end of the study period.

Figure 3. Change in plot surface elevation between August 2015 and August 2022. Highest rates of sand accumulation occurred in treatment plots (Plot 1 & 2). Net increase in surface elevation also occured in P5 and the seaward plots of P4 following devegetation of the foredune in the latter years of the study period.

Figure 4. Change in vegetation cover and species richness between 2015 and 2022. Bars show the proportion of dune-building graminoids (grasses and sedges) (n=1) to other species (n=19).

Figure 5. Six species accounted for 92% of the total cover for the sampling period in all plots. Average cover over time for the three most dominant species illustrates temporal changes in plant communities. * identifies the one species of dune-building graminoid present in the study area.

Did the dune-building species, *Ficinia spiralis*, survive the disturbance event or are increases in cover due to establishment following local extinction?

Figure 6. A) Species turnover (calculated as the sum of extinct and colonising species divided by the total number of species observed between two time periods) for Plot 2 shows that extinction (loss of species) rather than establishment explains most change in plant communities.

B) Temporal patterns of *F. spiralis* extinction, survival and establishment in Plot 2 showing a phase of establishment in 2021.

C) Examination of ortho photos suggests establishment is due to the survival and vegetative expansion of plants outside the quadrat, not seedling establishment.

Figure 7. Nebkha formation in association with *F spiralis*. Plot 3 Parabolic 6.

3. Interpretation and Conclusions

- Foredune destabilisation has resulted in a decrease in plant species richness and abundance with increasing sediment inputs over time.
- Plant communities downwind from the destabilised foredune (treatment site) are now dominated by dune-building graminoids compared to relatively burial-intolerant herbs and shrubs of the stable deflation surfaces.
- Changes in plant communities occurred rapidly and were primarily driven by extinction processes (loss of species) with secondary contributions from the survival and expansion of dune-building graminoids.
- Dune-building species acted as a foci for sand accumulation, resulting in the development of a heterogenous nebkha field downwind of the foredune.

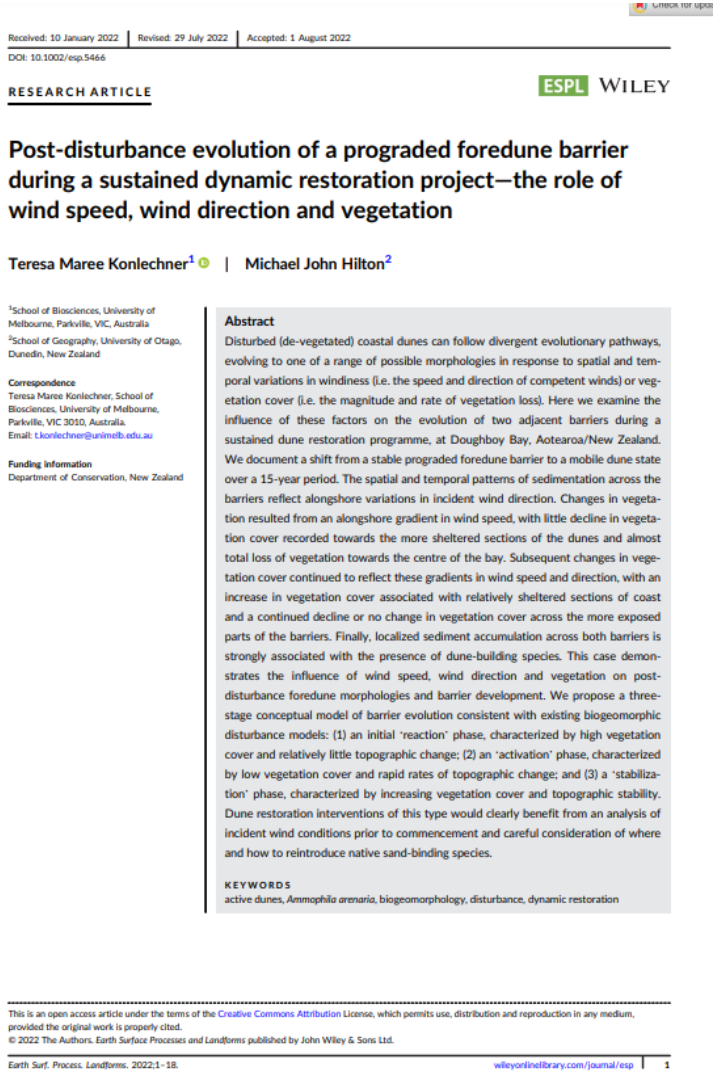
4. Implications for Dune System Processes and Management

- Sediment budget shifts in downwind dune environments following foredune destabilisation induces significant changes in plant communities.
- These changes have implications for the subsequent evolution of the dune field due to biogeomorphic feedbacks between vegetation and aeolian processes.
- Species turnover following disturbance identifies the need to account for local propagule source (post-disturbance re-establishment potential) as well as species survival and extinction when predicting the evolution of post-disturbance vegetation communities and associated dune landforms.

Acknowledgements: Funding and support was provided by the New Zealand Department of Conservation. Field assistance was provided Campbell McCusker, among other volunteers over the duration of the project.

Konlechner & Hilton (2022)

Biogeomorphic evolution of the Doughboy Bay Barriers



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RESEARCH ARTICLE

ESPL WILEY

Post-disturbance evolution of a prograded foredune barrier during a sustained dynamic restoration project—the role of wind speed, wind direction and vegetation

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Funding information
Department of Conservation, New Zealand

Abstract

Disturbed (de-vegetated) coastal dunes can follow divergent evolutionary pathways, evolving to one of a range of possible morphologies in response to spatial and temporal variations in windiness (i.e. the speed and direction of competent winds) or vegetation cover (i.e. the magnitude and rate of vegetation loss). Here we examine the influence of these factors on the evolution of two adjacent barriers during a sustained dune restoration programme, at Doughboy Bay, Aotearoa/New Zealand. We document a shift from a stable prograded foredune barrier to a mobile dune state over a 15-year period. The spatial and temporal patterns of sedimentation across the barriers reflect alongshore variations in incident wind direction. Changes in vegetation resulted from an alongshore gradient in wind speed, with little decline in vegetation cover recorded towards the more sheltered sections of the dunes and almost total loss of vegetation towards the centre of the bay. Subsequent changes in vegetation cover continued to reflect these gradients in wind speed and direction, with an increase in vegetation cover associated with relatively sheltered sections of coast and a continued decline or no change in vegetation cover across the more exposed parts of the barriers. Finally, localized sediment accumulation across both barriers is strongly associated with the presence of dune-building species. This case demonstrates the influence of wind speed, wind direction and vegetation on post-disturbance foredune morphologies and barrier development. We propose a three-stage conceptual model of barrier evolution consistent with existing biogeomorphic disturbance models: (1) an initial 'reaction' phase, characterized by high vegetation cover and relatively little topographic change; (2) an 'activation' phase, characterized by low vegetation cover and rapid rates of topographic change; and (3) a 'stabilization' phase, characterized by increasing vegetation cover and topographic stability. Dune restoration interventions of this type would clearly benefit from an analysis of incident wind conditions prior to commencement and careful consideration of where and how to reintroduce native sand-binding species.

KEYWORDS
active dunes, *Ammophila arenaria*, biogeomorphology, disturbance, dynamic restoration

Wish list:

1. Vegetation response to burial (Masons) using long data set (Teresa, Mike & Megan)
2. Processes of marram foredune accretion and erosion & implications for dune system sediment budgets (Mike, Megan, T.)
3. Relationship between wetland biodiversity and dune system dynamics (with Campbell)
4. Nitrogen enrichment – implications for tree lupin control & restoration prioritisation (with Jen / Teresa)
5. National dune flora database
6. Dune system guides

National Dune Flora Database

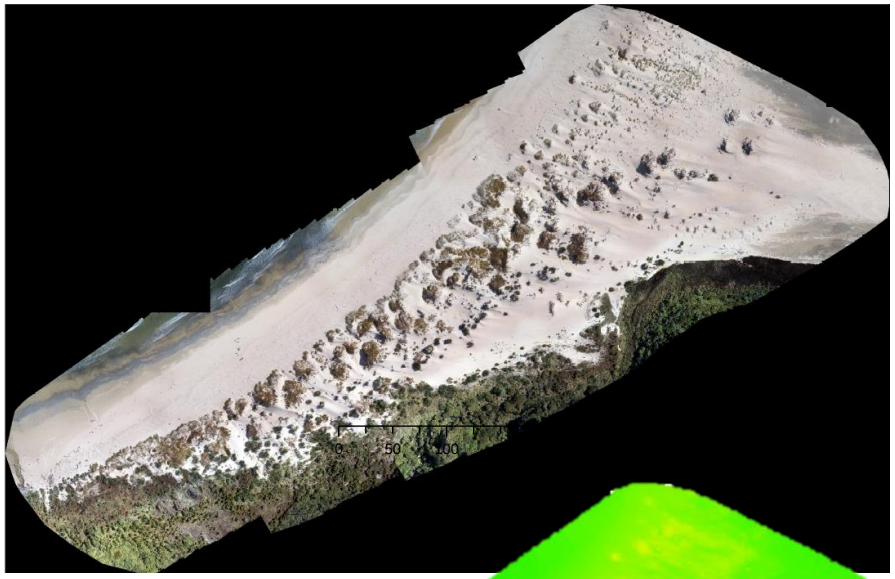
Mason Bay contains more nationally threatened plant species than any other dune system

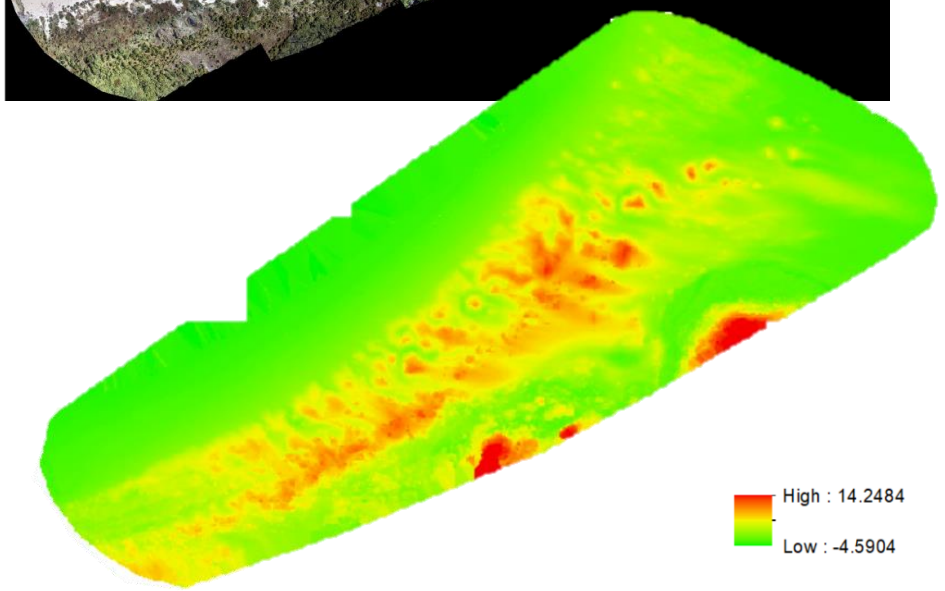
And outreach …

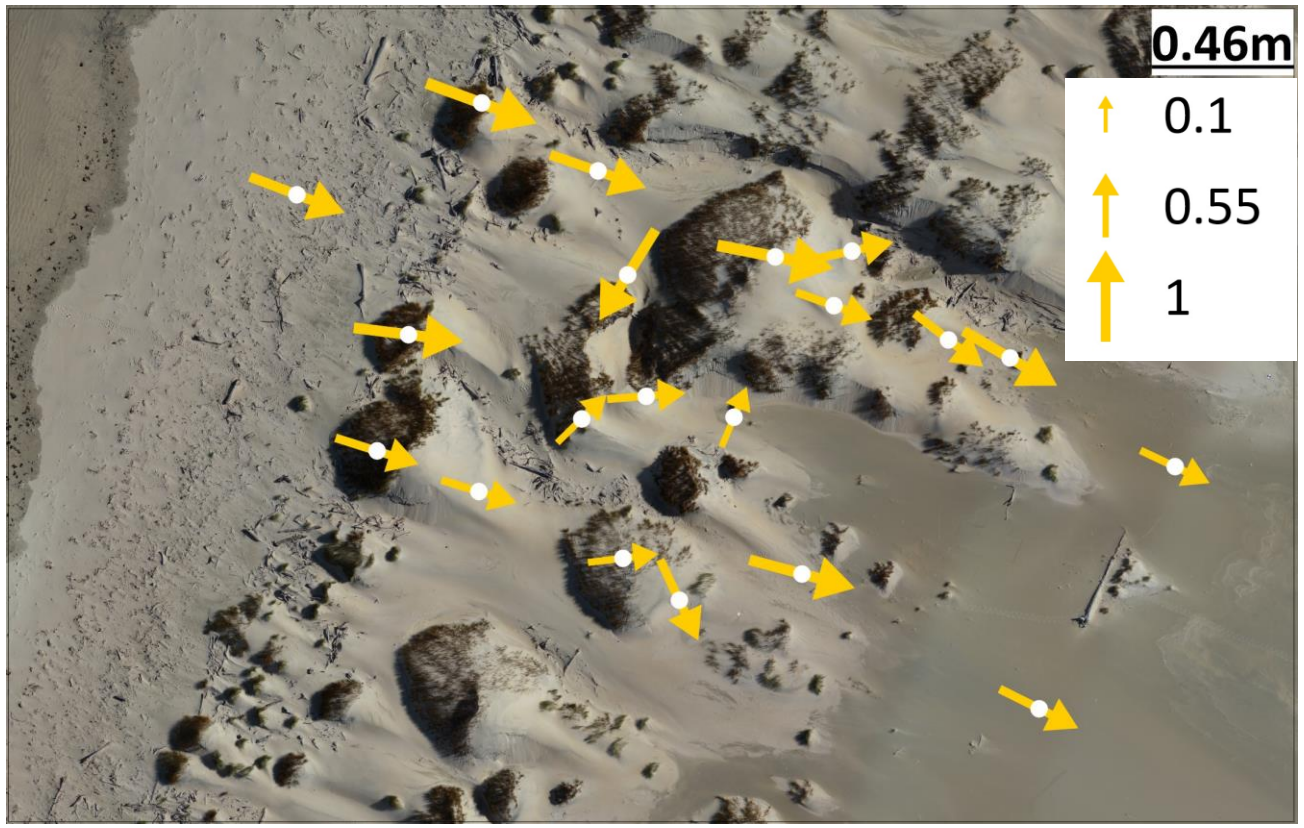
https://storymaps.arcgis.com/

Quantifying the relationship between vegetation density, wind speed and sand transport

Maddy Brown



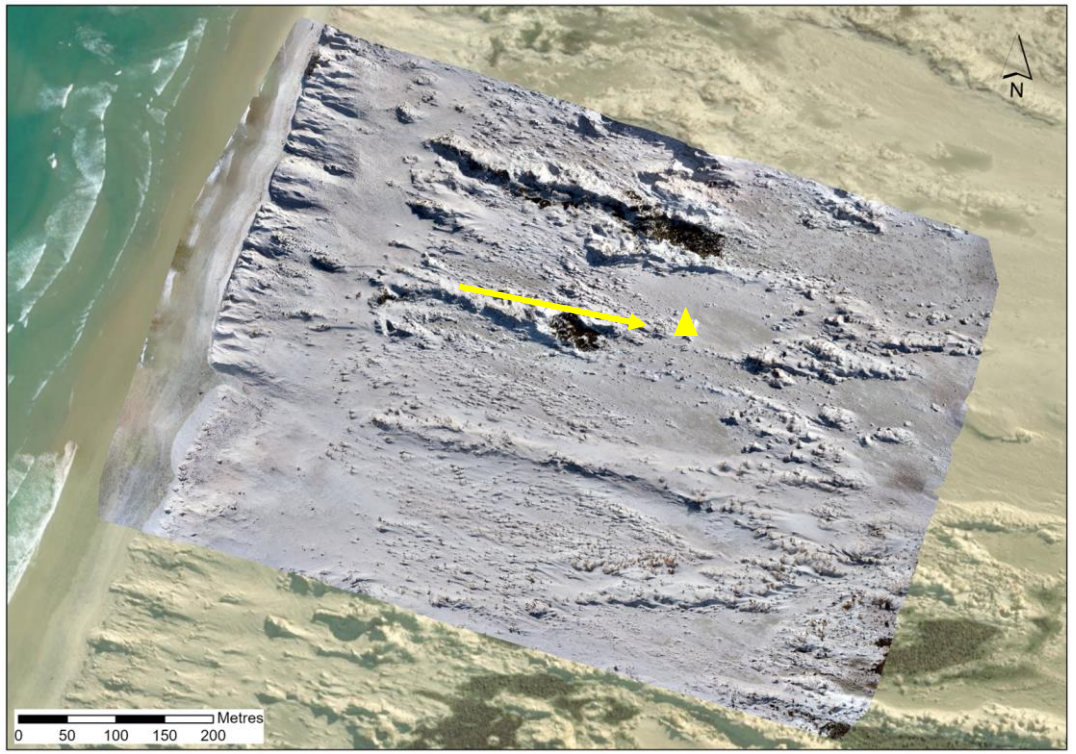




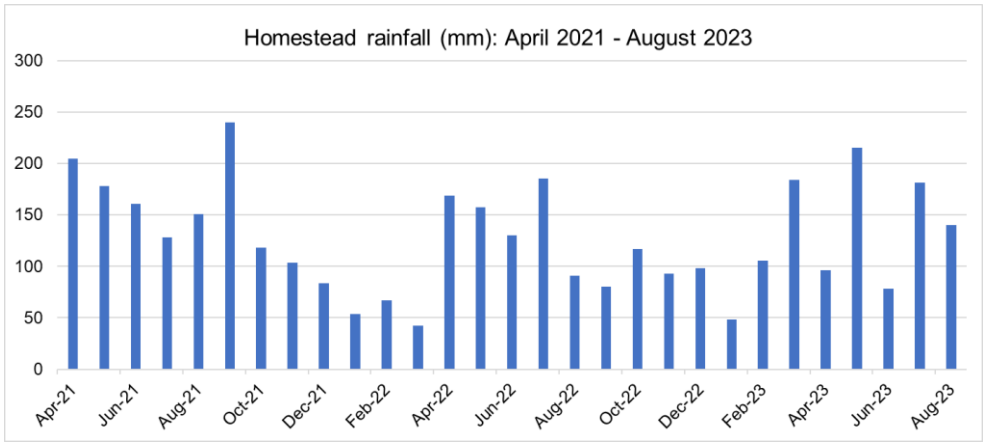
Doughboy Bay
December 2022

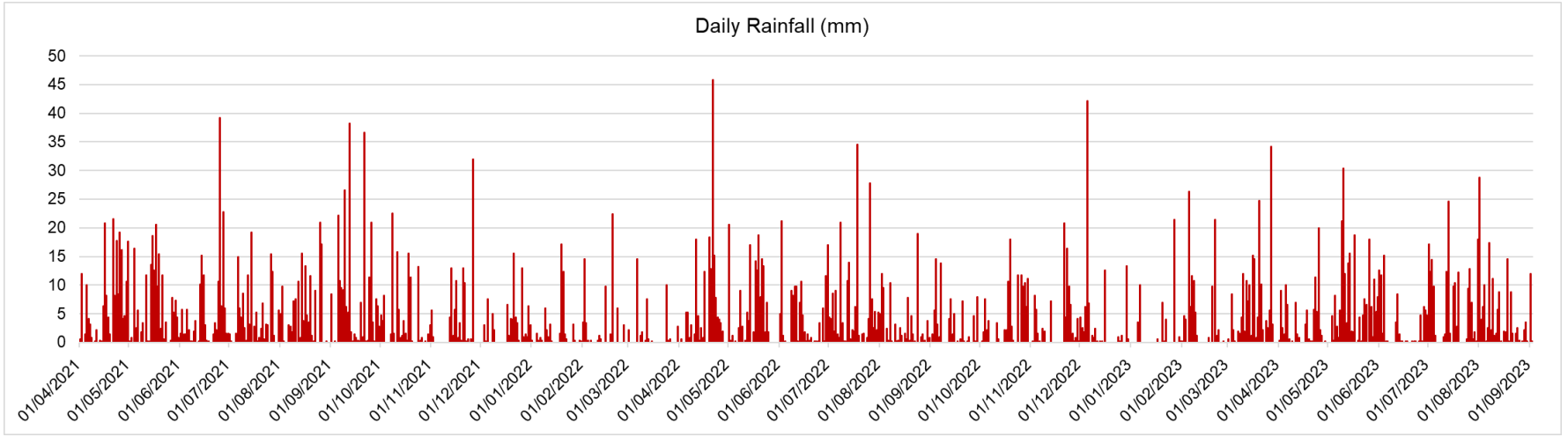
5. Other:

- new rain gauge and logger at Homestead
- replacing Scott Burn water level recorder 14th October 2023
- excavated (just in time) and shifted store bin 100m inland (P4)
- maintained P4-P6 permanent quadrats (120)
- re-established Duck Creek track marker pole



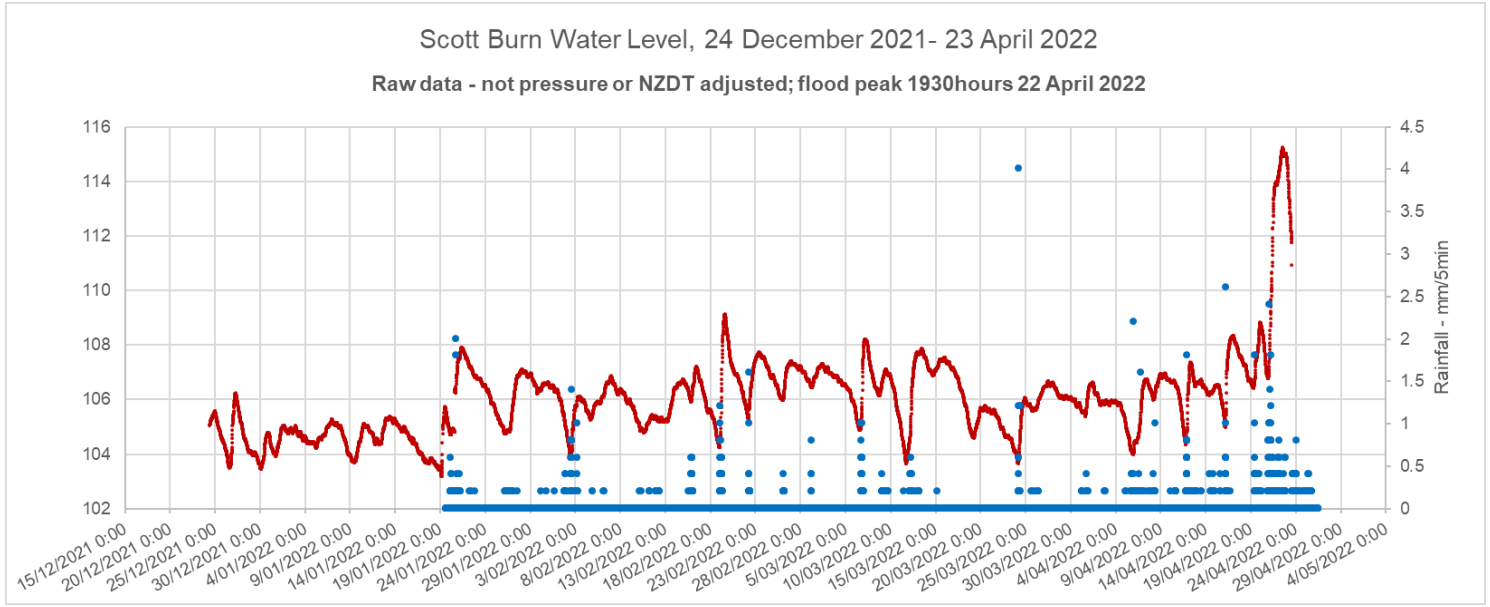
Bin

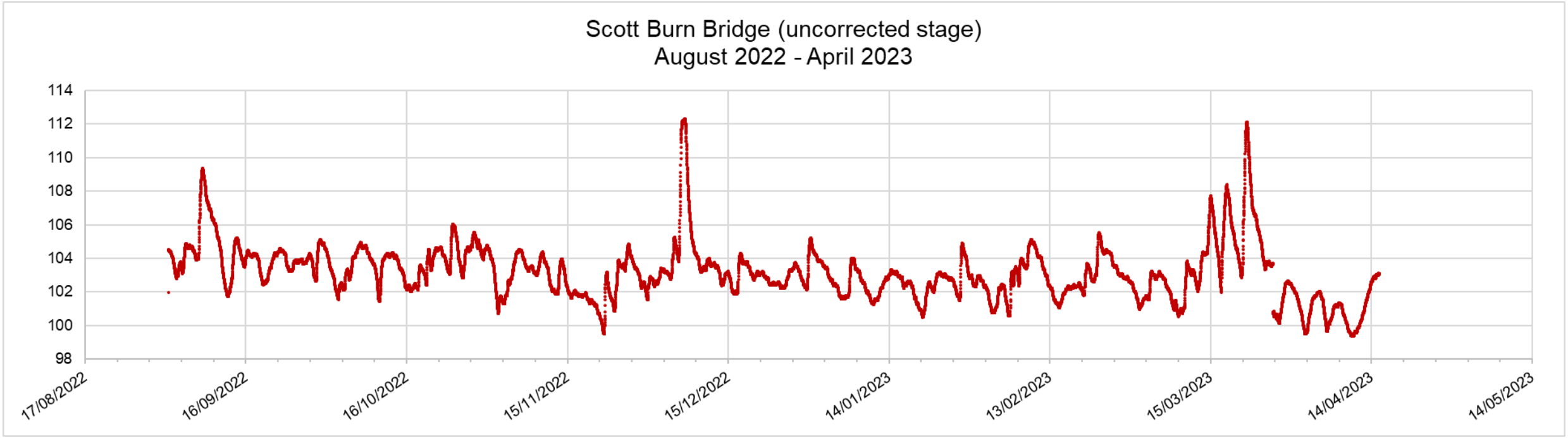




Scott Burn water level / track inundation

- the Scott Burn record indicates a catchment with low storage storage capacity and a close association between rainfall and channel flow
- which makes it easy to predict episodes of track inundation based on Oban / Homestead rain gauge correlation





New equipment:

- New RTK-GPS DJI UAV (3x survey capacity) with multi-spectral camera
    - Estimates of plant vigour
    - 30minute flying time / battery
- R12 Trimble RTK-GPS survey equipment
- New CR6 logger / tipping bucket rain gauge at Homestead