Native Planting Survey at Tūmai Beach Sanctuary

A report for Tūmai Beach Sanctuary prepared by
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Executive Summary

Tūmai Beach Sanctuary is a farm park development on the Pleasant River Estuary, 47 Km north of Dunedin, and 5 Km north east of Waikouaiti. It encompasses Stage 2 with 16 private house lots spaced throughout 36 ha of communally-owned pasture land and Stage 3 of 20 ha, as yet undeveloped but with consent for 6 more house lots. Resource Management Act consent for the farm park was granted in 2008 and stipulated that about half of the communal pasture will be replanted with native forest and tussock. An arm of the Pleasant River estuary that had historically been drained for paddocks was reinstated to tidal flow. The first part of this report reviews the history and planning documents of the project to provide background and a baseline summary for identifying future land management options.

Peter and Irene Walton (Waltons Ltd), the developers of the Tūmai Beach Sanctuary, began planting native shrubs in winter 2009. Stock were removed and over fourteen thousand native plants were planted. The second part of this report documents the results of a survey carried out in the summer of 2011/12 of that initial planting in 2009. Our survey sought to:

i. measure the overall effectiveness of that first planting,
ii. identify the species with best survival and growth at Tūmai,
iii. recommend optimum species and places for future planting,
iv. identify management needs to accelerate restoration of the coastal forest at Tūmai, and
v. provide baseline measures and maps of plants already established at Tūmai so that a randomly selected subset can be efficiently monitored in future years.

This survey is intended to meet the monitoring requirements of the Dunedin City Council's Resource Consent and also to set the benchmark for further planting and for similar restoration projects.

The main findings of the survey were:

- A first tranche of planting in 2009 has established 4,568 shrubs from 36 species.
- Some of the plants are growing very well and will need little care from now on.
- Overall 15.19 ha of 29.24 ha of land reserved for forest and native tussock restoration has received some woody plants.
- Overall survival has been low (32%) and patchy, mainly because of smothering by grasses.
- Browsing by hares and perhaps frost and accidental poisoning have also contributed to the low (32%) survival of the plants.
- The ratios of plants inserted did not follow a designated ecological restoration plan.

We conclude that a great start has been made to restoring native forest at Tūmai. However, density of native species is too low and very patchy, and large parts of the existing replanted zones now will need further enrichment planting to accelerate canopy closure. An additional 14.05 ha of the Tūmai grassland await first planting of native woody vegetation or native tussock grasses in the coming years in order to fulfil the Resource Management Act consent that created the farm park subdivision.

We recommend that future planting efforts incorporate the following steps:

1. Establish and then follow a designated plan designed to hasten and reduce the expense of attaining a fully functioning indigenous coastal forest ecosystem at Tūmai (this might be a reversion to the original plan provided by Wildlands or incorporate significant additions)
2. Consolidate the more dense areas identified in the heat map (Figure 18, p 29) to hasten canopy closure and create solid patches of vegetation that can then in turn shelter new plantings on their periphery.
3. Concentrate on smaller more manageable patches in new areas once the existing patches are fortified (as in 2 above).
4. Plant more of the proven successful species from this survey, but extend especial care to release and protect important additional species that have not done so well. Priority should be given to establishing canopy species that were identified as most likely to have been present at Tūmai before clearance for farming, but are not established in large numbers so far.
5. Wait until plants are more grown before planting them out so they will require less releasing before they outstrip the grass and also become less vulnerable to hare browsing.
6. Establish a second tier of forest species (ones not yet able to survive) to be planted only once the canopy has closed on several patches and the grasses eliminated.
7. Ensure that species which provide good nectar and fruit sources are included to attract birds.
8. In general, invest more in follow-up care of plants in the first 3-5 years after planting, including:
    a. use mulching where possible to reduce grass as a competitor for nutrients and light and to help retain moisture in dry periods.
    b. use cone shields on the sprayer wand when poisoning around plants.
    c. use weed eaters to clear around established small shrubs to avoid herbicide applications being brushed onto the shrubs
    d. hand weed near the stem of plants to reduce competition and avoid accidentally ring barking a plant when using automated weed eaters
    e. instigate a vigorous hare and rabbit shooting program to reduce browsing damage
    f. protect plants with ‘cages’ if sufficient hare control cannot be achieved.
9. Eliminate the broom colonizing the northern most point of Tūmai Beach Sanctuary as soon as practicable and maintain two-yearly control efforts to flush the broom’s seed bank.
10. Keep records of future planting and follow-up measurements on a stratified random selection of the plants mapped and measured in this initial survey so that continuous learning from experiences at Tūmai can help guide cost-effective coastal forest restoration in the east coast of South Island.
11. Take photographs from the same GPS point intermittently to visually record changes.

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Acknowledgements

Soren Moller assisted with field work. Ecosystems Consultants Ltd funded the field survey and this report, and commissioned Chris Garden to prepare the GIS and plots. Irene Walton provided photos of the removal of the causeway (Figure 3).

Native Planting Survey at Tūmai Beach Sanctuary

Introduction

Tūmai Beach Sanctuary Concept

Tūmai Beach Sanctuary is a farm park development situated 47 km north of Dunedin and about 5 km north of the small township of Waikouaiti (Figure 1). "The land has outstanding rural and coastal views from a rolling hill landscape reaching 46m above the Pleasant River Estuary and river margin"[1]. The eastern edge of the farm park is in a Coastal Landscape Preservation Area. Most of the building platforms and the mown pasture land are on "undulating terrace tops"[2]. Native species are currently being planted on the hill side slopes around the estuary and in selected areas across the tops.

Background

The land was grazed until 2009 when Waltons Ltd began the development. Stage 1 restored tidal flow to the drained estuary arm. Stage 2 on the eastern side of the restored estuary arm has 16 lots which are now selling (Figure 2). Following the farm park concept, these are smaller lots for building houses and closer together than are usually permitted in a rural area. The farm park model retains productive land in communal ownership. There are 16 private lots (0.36 - 0.85 ha; average 0.5 ha) surrounded by a 35.6 ha lot which is to be managed in common by a 'Body Corporate' legal structure called *Tūmai Beach Services Ltd*. 'Every purchaser is allocated a share in the ownership of that communal lot and thereby has voting rights and responsibilities for maintenance of services and land management. Funds earned from harvesting baleage from the pasture remaining on the communal lot will be used by Tūmai Beach Services Ltd to defray rates, and to maintain roads and walkways, water and electricity supply to individual house lots'[3]. Planting of native species is a condition of the consent to develop the project and the developers have agreed to complete the planting within 10 years of the resource consent being granted (therefore by 2018)[4].

Prior to the resource consent application for the development Waltons Ltd contracted various reports. The reports below develop the native vegetation restoration concept:

The first report by Wildland Consultants in August 2007 was an *Ecological Assessment of the Waltons Ltd Property*[5] documenting the degraded state of the land (solely pasture with practically no trees) and of the estuary and recording the presence of flora and fauna and avifauna. The report recommended restoring tidal flow to the [drained] estuary arm; fencing to exclude stock from the estuary; retiring the coastal hill slopes from grazing; planting indigenous species and monitoring that planting. It also included a table of native species suitable for the area (see appendix) with the

[1] Moller, H., and Moller, S. I. (2012) *Environmental and Lifestyle Values at Tūmai beach Sanctuary*. Ecosystems Consultants Report No 2012/03. 32+v pages.

[2] Robins, M.J. (2007) *Geotechnical Assessment for Proposed Subdivision – Pleasant River Farm Park.* Geolink report, GTR 56.

[3] Moller, H., and Moller, S. I. (2012) *Environmental and Lifestyle Values at Tūmai beach Sanctuary*.

[4] Tūmai Beach Sanctuary website: http:/www.tumaibeach.co.nz accessed January 2013.

[5] Wildland Consultants (2007) *Ecological Assessment of the Waltons Ltd Property*, Contract Report No. 1773.

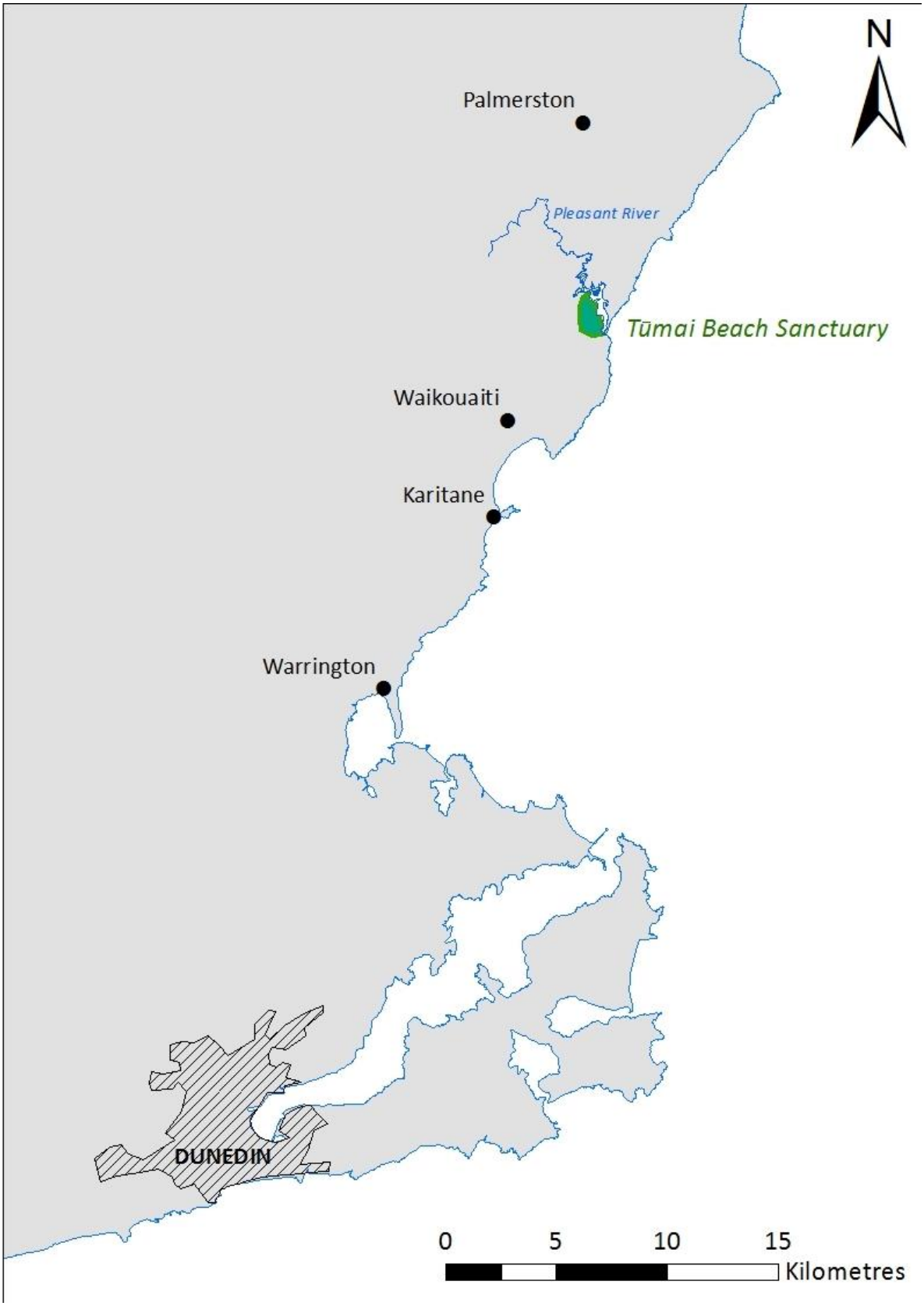

Figure1: Location of Tūmai Beach Sanctuary.

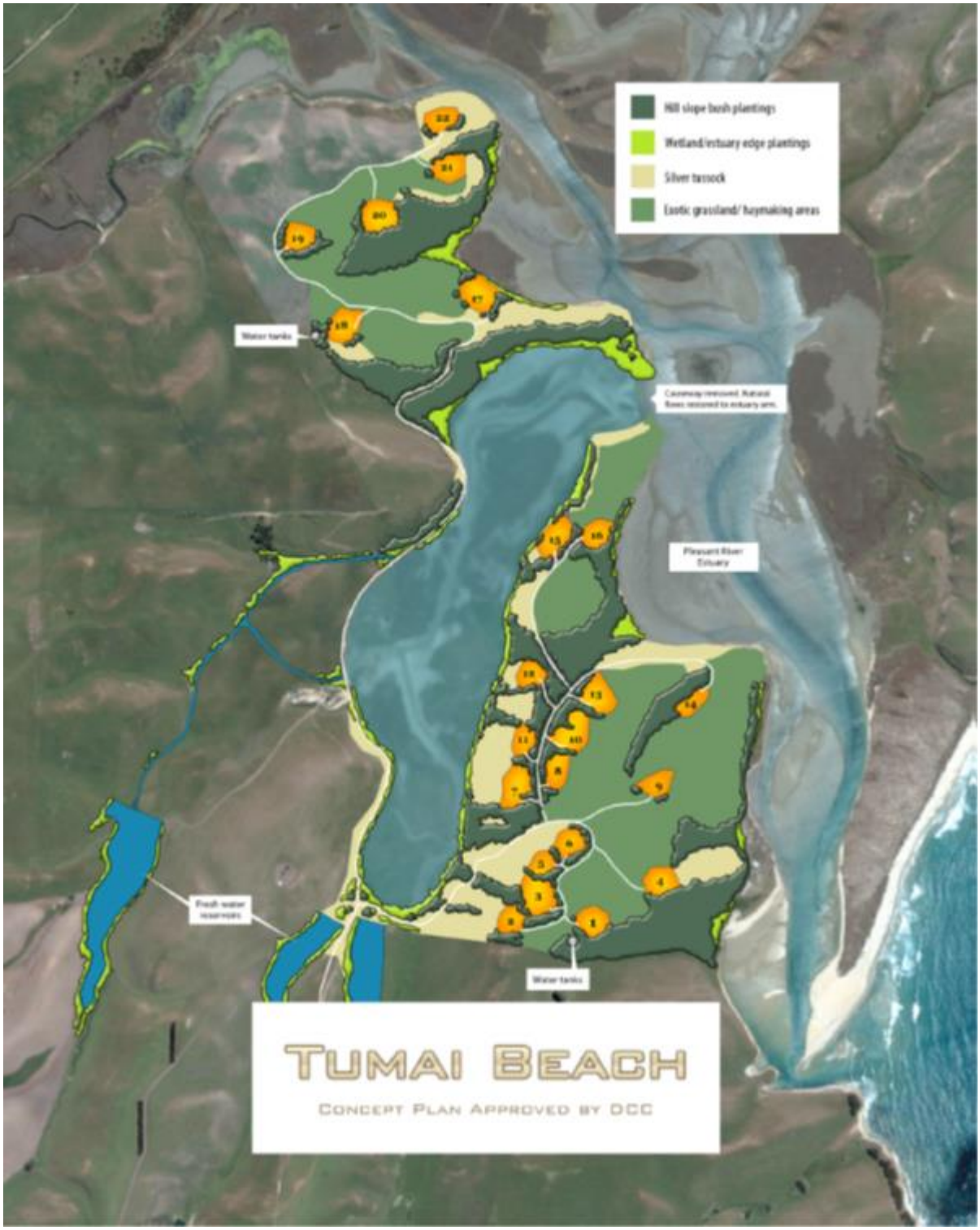

Figure 2: Tūmai Beach Sanctuary concept and ecological restoration plan from the website:

http://www.tumaibeach.co.nz

particular habitat of each species noted i.e. freshwater swamp, estuarine strip, margin of estuary arm or hill slopes.

Next landscape architect, Mike Moore, prepared the *Waltons Ltd Farm Landscape Assessment Report* (28 September 2007) that covered the landscape values of the 384.2ha farm before any subdivision proposal. It considered two options: maintaining the farm as it was or ecologically enhancing the area.

In October, 2007 Mike Moore produced another report introducing the idea of a farm park on the coastal part of the Waltons Ltd farm. This was the *Landscape Development Concept for the Proposed Farm Park Report*[6]. He stated a key component of the proposed farm park is "the establishment of significant areas of native vegetation for both environmental enhancement and to mitigate the effects of additional buildings". He noted that "building sites have also been chosen based on the potential to integrate buildings with a comprehensive planted framework." He summarized the planting plan in general terms as:

- "Native forest establishment focused on the wetter gully areas and steep slopes
- Wetland/estuary edge planting following the coastal fringe, freshwater streams and drains and reservoir edges
- Native tussock on the steep dry slopes".

Also in October 2007, Wildland Consultants produced an *Ecological Impact Assessment of the Proposed Coastal Farm Park*[7]. It covers avoidance, remediation, and mitigation of potential adverse effects of developing the farm park. It recommended a comprehensive planting plan be prepared. The report concluded that the development was "likely to result in a net ecological gain".

November 2007 Wildlands Consultants produced *Ecological Management Plan for a Proposed Coastal Farm Park, Pleasant River, Otago*[8]. This plan covers management zones, weed control, planting guidelines, plant sourcing, and habitat enhancement for terrestrial fauna and fisheries management. It reads as a practical guide to native plant restoration for this specific area. The report is very sympathetic to the scale of the task of restoration and suggests practical ways to manage this. "In order to keep plantings to a manageable size and costings at reasonable levels" it recommends only planting 7ha of the hillside slopes initially and in small compact groves that eventually natural colonization would spread from.

Resource Consent for Waltons Ltd Farm Park was granted in June 2008.

Mike Moore prepared the *Landscape/Ecological Development and Management Plans Lots 1-16 and Lot 23 for Waltons Ltd Farm Park*, in May 2010[9]. This plan detailed the planting on each individual lot 1-16. For the communal Lot 23 this plan advises that the plant list and density recommendations from *Wildland Consultants Ecological Management Plan* be followed. This list is in the appendix.

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[6] Mike Moore (Oct 2007), *Landscape Development Concept for the Proposed Farm Park.*

[7] Wildlands Consultants (Oct 2007), *Ecological Impact Assessment of the Proposed Coastal Farm Park*, Contract Report No. 1838.

[8] Wildlands Consultants (Nov 2007) *Ecological Management Plan for a Proposed Coastal Farm Park, Pleasant River, Otago,* Contract Report No. 1839.

[9] Mike Moore (May 2010) *Landscape/Ecological development and Management Plans Lots 1-16 and Lot 23, Waltons Ltd Farm Park.*

In 2009 Waltons Ltd removed the causeway blocking an arm of the Pleasant River Estuary, allowing the tide to flow again (Figure 3). They removed stock from the whole farm park and maintained hay growing on terraced tops and began planting native species on the hillside areas.

2009 Planting

Between July and September 2009, Waltons Ltd bought 14,148 plants from Oregon Nurseries in Waitaki. The opportunity to purchase this many plants at a reduced price meant Waltons Ltd went for a large scale approach to planting in one season rather than smaller areas being gradually extended over time. Planting sites were prepared six weeks earlier with glyphosate and seed retardant spraying at 1-metre intervals. The plants' sizes were constrained by being in root trainers or up to 1 litre pots. Most of the planting area was moderate slope to steep hillside. No records were kept of where each species were planted, nor how many of each species were planted. Nor was there apparently any plan for arranging or spreading the plants. Instead they were inserted 'in the order they came off the trailer'[10]. Fortunately, the nursery was able to supply a copy of the receipts for the payment for the plants, and these included a count of each species supplied. We therefore set out to survey and map the whole area, and by difference, establish the survival rates of the original planting.

Firstly, we used a GPS to track the outline of all the long grass areas containing plants. The resulting map "Plantings on DP 429126" May 2011 (Figure 4) records the areas planted in 2009 which covered 15.19 ha. The map also indicates the proposed staging of the remaining areas. This map was intended as a rough guide and the later plantings have been delayed. The plan is that 29.24 ha, equivalent to 43% of the farm park's total 68.5 ha, will eventually be planted in native species, mainly native forest, but including areas of Silver Tussock (*Poa cita*) in 'viewing chutes' near the house lots.

After planting Waltons Ltd employed workers to carry out poison spray programmes around the shrubs across all the planted areas to release the native plants from the vigorous growth of pasture grasses that threaten to smother the shrubs[11]. It is not known how many programmes were undertaken but the last one was in the summer of 2011/12.

Ecosystems Consultants Ltd surveyed the 2009 plantings in the summer of 2011/12.

This report shows the results of that survey. The survey sought to:

i. measure the overall effectiveness of that first planting,
ii. identify the species with best survival and growth at Tūmai,
iii. recommend optimum species and places for future planting,
iv. identify management needs to accelerate restoration of the coastal forest at Tūmai, and
v. provide baseline measures and maps of plants already established at Tūmai so that a randomly selected subset can be efficiently monitored in future years.

This vegetation survey was conducted partly to meet the Dunedin City Council's Resource Consent requirement to monitor and report progress on ecological restoration at Tūmai. However, restoration of coastal forest is a nationally important conservation priority. Most of the east coast of the South Island between the Catlins in the south and Kaikoura in the north are now farmland. Warm and fertile

[10] Peter Walton, pers. comm.
[11] Peter & Irene Walton, pers. comm.

Figure 3: Restoring the tidal flow to the southern arm of the Pleasant River Estuary in 2009.
The top photo shows the paddocks in the upper reach of the estuary arm before the causeway was removed. Photos by Irene Walton.

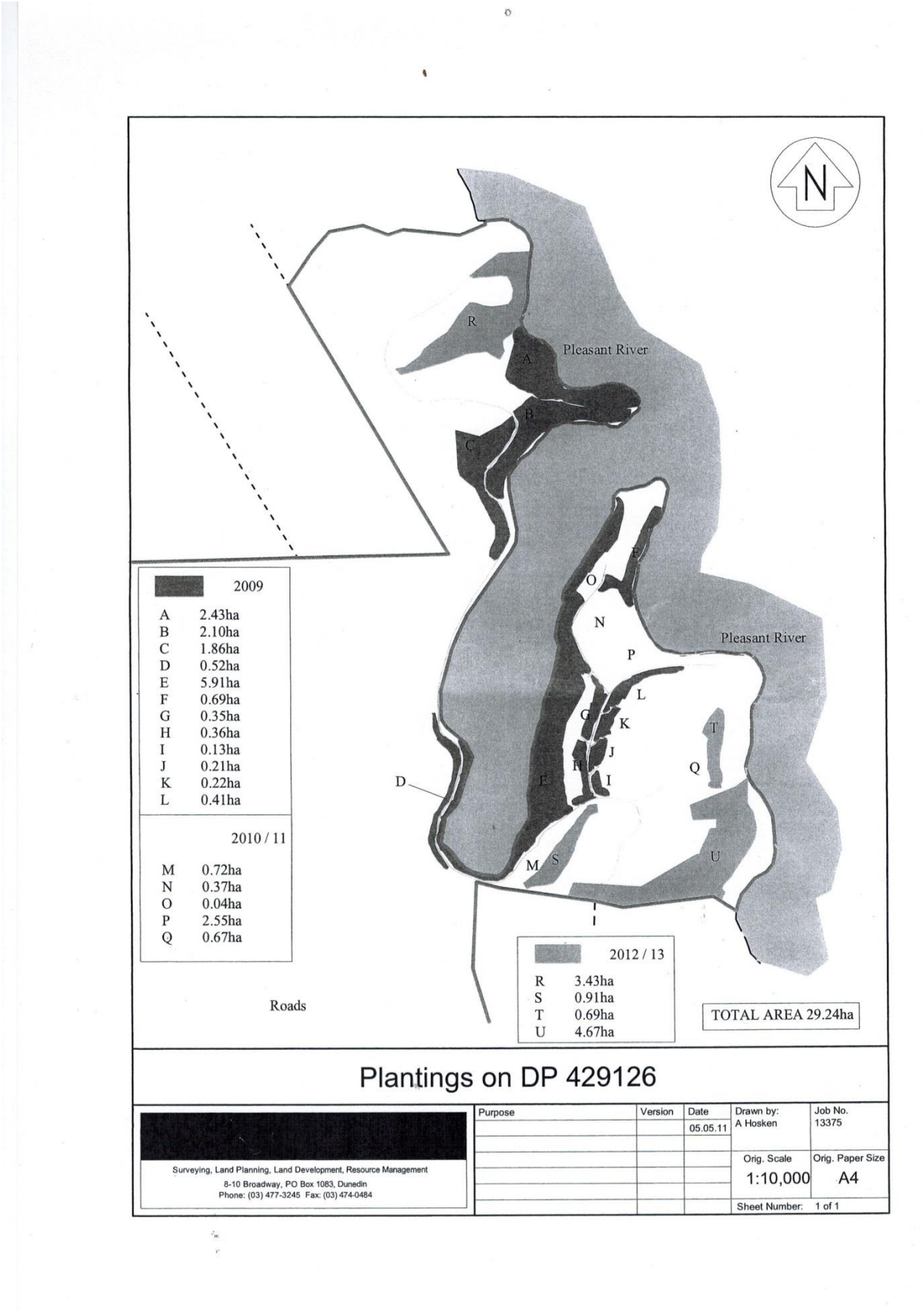

Figure 4: Map of planting schedule by Paterson Pitts Partners Ltd, 5 May, 2011.

coastal sites where biodiversity will naturally flourish (Perley et al. 2001[12]) are important sites for recreation and environmental education. Reinsertion of woody vegetation in farming landscapes helps stabilise land, protect the coast from seawater incursions and climate change, and reduces the amount of sedimentation and nutrient pollution of rivers, estuaries and near-shore ecosystems. Despite the national importance of coastal forest restoration, few quantitative descriptions of the relative success and growth of native planting restoration efforts are recorded in the literature. We hope that this brief survey and establishment of a longitudinal monitoring programme at Tūmai will help guide other restoration programmes in future.

[12] Perley, C. et al. (2001).

Survey Method

This survey of the native plantings (Figure 5), began on 29 November 2011 and concluded 5 May 2012. It took about 18 visits, initially with a team of three, but later only two or occasionally one worker. This team went through all areas which had plantings in 2009 and recorded specific information about every plant they could find and information about the planting areas. A sample recording sheet is in the Appendix.

The information recorded for each plant was:

- Species name (botanical and common or Māori name)
- Height (recorded to highest alive leaves and not to higher dead branches)
- Health of the plant described in a percentage
- Clearance or level of smothering by surrounding grass/weeds (categories: A = 0 – 10 clear, B = 10 – 50% overgrown, C = 50 – 90% overgrown, and D = 90% to 100% smothered)
- Location taken by GPS
- The section/area the plant is in (Polygon identity as taken from Planting Map 5.5.11)
- Comments such as flowering, seeding, insect damage etc.

Additional information recorded was:

- A GPS trace of the particular polygon being mapped (Figure 6)
- Photos of the polygon taken from a vantage point with a GPS waypoint of this point
- The aspect of the polygon recorded from a topographical map.

The survey of the eastern side of the estuary began with polygon 'I' in late spring and most eastern areas were completed by 13 December. This included the rows of Toetoe, which were classified as polygon 'Toetoe' for our survey purposes and not as part of polygon E as recorded on the planting map. Jeff Matheson, a local contractor, was beginning poisoning and the survey team needed to work around his schedule by working either before or after when some rain had fallen to clear the poison. A survey team of three was needed at this stage to fight through the growth and systematically cover an area to find the actual plants, many of which were entirely covered with grass.

Initially, poison patches were recorded where we found no plant. These were areas where obviously the surrounding grass had been poisoned to allow space for a plant to grow, but a plant was no longer present. As the survey progressed through other sites (especially E), poison patches became less clear, and more difficult to identify so they were no longer recorded. The first areas that were surveyed (I, J, K) may have been poisoned but the grass had not died at that stage. Occasional plants were found hidden in grass that had been missed in the poisoning. By the time that the western side of the estuary was surveyed the poisoning had taken affect and killed off most growth immediately surrounding plantings and very few plants had been missed.

Height was recorded by using a wooden stick with a measuring tape attached. This was 1.5 metres tall. If the plant was taller than the tape, then the stick would be lifted up and the rest of the plant could be measured. The measurements would be added together to get the total height of the plant.

Figure 5: Overview of Tūmai Beach Sanctuary at the time of the survey 2011/12.

Figure 6: Polygons of areas planted in 2009 recorded by GPS trace.

Location was recorded using a Garmin GPSmap76CS x device. The GPS waypoints would be transferred to a computer after 1 or 2 days of work.

Clearance or smothering recording had to have a defined standard. The system used was A for clear, B for little bit overgrown, C for mostly overgrown, and D for completely smothered. This was further refined to A for 0-10% clear, B for 10- 50% overgrown, C for 50 – 90% overgrown, and D for 90-100% smothered. The average height of the grass and the much less dense grass seed heads were recorded separately at 10 random sites spread through each polygon.

Identification was made simpler by the provided list from the nursery which supplied the plants. This limited the possibilities. Initially, notes from Poole and Adams[13] were needed as well as visits to the Dunedin Botanical Gardens until we had encountered most species and confirmed their identification. David Blair confirmed the identification of some un-familiar plants on day 3 of the survey. Small size, lack of mature form and possible reactions to poison made some identification difficult.

- **Manuka (*Leptospermum scoparium*)** and **Kanuka (*Kunzea ericoides*)** were difficult to distinguish at this young stage unless they were flowering or had seeds. Only occasionally these factors were present. If there was a definite identification of Manuka or Kanuka that tended to influence how others around it were identified.
- **Southern Kowhai (*Sophora microphyllia*)** and **Northern Kowhai (*Sophora tetraptera*)** caused some uncertainty. A small southern Kowhai is very clear to identify with its tiny leaves and tangled juvenile form and a northern Kowhai is also very clear to identify with it large more oblong leaves, however there is a middle range which could be older southern Kowhai or a continuum of hybrids toward the northern larger leaf. This confusion should resolve with maturing.
- **Lemon wood (*Pittosporum eugenioides*)** is usually very easy to identify but was more challenging here as it often looked sickly.
- ***Pittosporum tenuifolium colensii*** may have been recorded as ***Pittosporum tenuifolium*** in the early stages of the survey as they look very similar. Therefore, they have been combined in the results.
- ***Coprosma parviflora*** and ***Coprosma propingua*** (both known as **Mingimingi**) may have been confused at times therefore they also have been combined in the results.
- ***Hebe buxifolia (Hebe odora)*** and ***Hebe elliptica*** may have also been confused, so have also been combined in the results.

Health was recorded as a percentage where we noted the approximate amount of alive leaves to dead branches present. If there were no dead areas but only a few live leaves, we recorded this as 100% alive but often commented 'spindly'. 'Spindly' is when the amount of leaves in proportion to the height of the stem, stalk, trunk, appears low. Often the alive leaves were only at the head suggesting that the lower branches had died due to the smothering or poisoning or being eaten by hares. We took account of burnt or sickly leaves in measuring alive percentage. We also recorded if plants appeared eaten. On the eastern side any eating seemed to be nibbling perhaps by hares or insects. On the western side in late summer there was more evidence of insect damage.

[13] Lindsay Poole and Nancy Adams (1963) *Trees and Shrubs of New Zealand.*

We treated the ***Cortaderia richardii*** **(Toetoe)** plantings as a separate area and did not initially take waypoints or record height of the Toetoe. This is because this is the only location Toetoe are present (except for 1 or 2 in polygon W) and it would have been very difficult to accurately measure the height of the plants as they were very large and closely crowded. Toetoe therefore does not appear on the graphs recording height. The plants were counted: 189 to the east of the outlet from the dam and 352 to the west of the outlet (541 in total). Other plants present in this polygon were measured and recorded normally. Of the 800 Toetoe bought, Peter Walton said some plants were 'lost to the tide' because they were planted below the high tide mark before the estuary had found its new level. Later we went back to take waypoints of each plant to estimate their overall density.

The height of the grass in each polygon was also measured. In early May at the end of the survey, random readings of the grass height were taken. Ten samples from each of the polygons were measured (except from polygons I and W, where only 8 and 6 readings respectively were taken due to smaller areas). The height of grass as ground cover and the height of seed head stalks were measured and density estimated.

Results

Survival rates

Of the 14,148 plants that were purchased, only 32% (4,568) had survived and been recorded. Survival varied enormously between the species. Of the 14,148 plants bought, 7,406 of them were of species with a survival rate higher than 40%, and 6,742 were of species which experienced a survival rate lower than 20% (Figure 7). Overall survival rate was supressed by the failure of a few select species which had a high amount purchased, yet scored a survival rate lower than 20% (Figure 7): *Kunzea ericoides* (15% survived of 1462 planted); *Nothofagus fusca* (10% of 998); *Coprosma parviflora/propinqua* (3% of 820); *Nothofagus solandri* (3% of 711). There is a group of 13 species which have a survival rate below 20%, of which 8 are below 10%, 2 being 0%. The two species that scored 0% also had a small number of plants purchased compared to other species. At the other extreme, all 180 *Plagianthus regius* survived. There are only three species which had greater than 600 plants purchased and still had a survival rate higher than 40%: *Pittosporum tenuifolium/colensoi* (56% of 1,497 plants); *Cortaderia richardii* (68% of 800); and *Podocarpus totara* (59% of 640).

Cortaderia richardii (Toetoe) was planted in a suitable habitat at the edge of the estuary and 541 plants have thrived. They have grown quickly and higher than grass, crowding it out. Some were inadvertently planted below the high tide mark[14] which accounts for their 68% survival which otherwise could easily have been 100%.

Myoporum laetum (Ngaio) was the only species planted in a block which we have called W[15]. Ngaio has vigorous growth and while the plants were not particularly tall they were wide (width was not measured in the survey) and they looked very healthy when surveyed on 22 April 2012. Their survival rate was 51% when surveyed. When this area was revisited in early summer most of the Ngaio appeared dead[16]. Ngaio will tolerate a light frost but Otago did have snow to sea level that winter[17]. Ralph Allen in his book *Native Plants of Dunedin and its Environs,* says of Ngaio that "though in winter it can withstand heavy frosts, even light frosts in spring when the sap is rising, can cause its death. It is still a common coastal tree in this district."

Remaining species composition

A combination of variable numbers planted and their differential survival rate means that a few species are far more common than others (Figure 8). The most common species are *Pittosporum tenuifolium/colensoi* (18%), *Cortaderia richardii* (10%); *Podocarpus totara* (8%) and *Cordyline australis* (8%) of the plants each. Altogether 36 different species have been established in the first tranche of planting at Tūmai. Two species, *Carpodetus serratus* and *Olearia avicenniifolia* failed to establish anywhere on the plot.

[14] Peter Walton, pers. comm.
[15] for Walton's lot.
[16] Peter Walton wonders if they were not a locally sourced species and therefore not tolerant of the climate at Tūmai.
[17] On 27 July 2013, we observed that twenty-one Ngaio plants had recovered fully from the earlier damage.

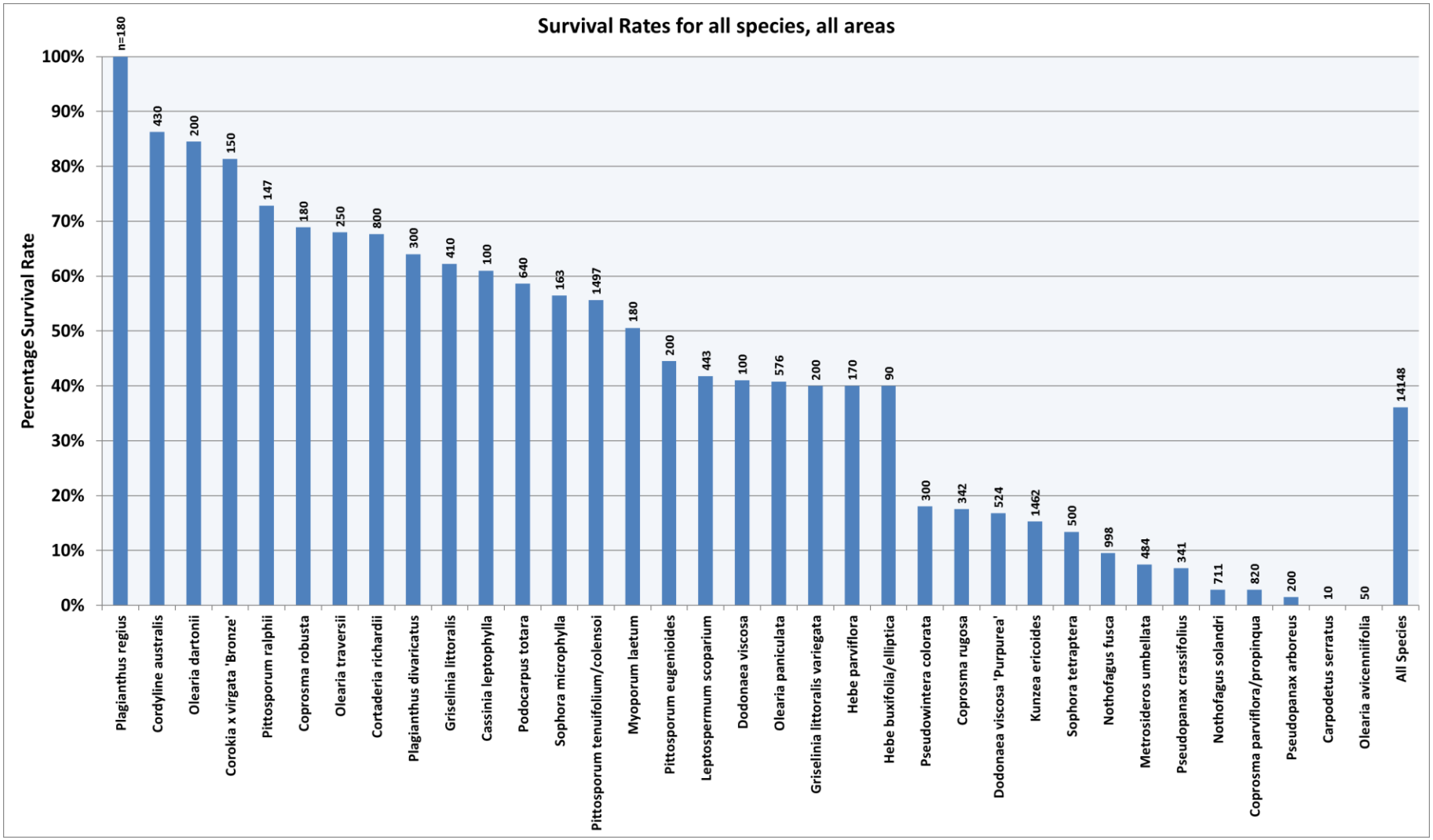

Figure 7: Survival rates for all species, all areas. *n* = number planted.

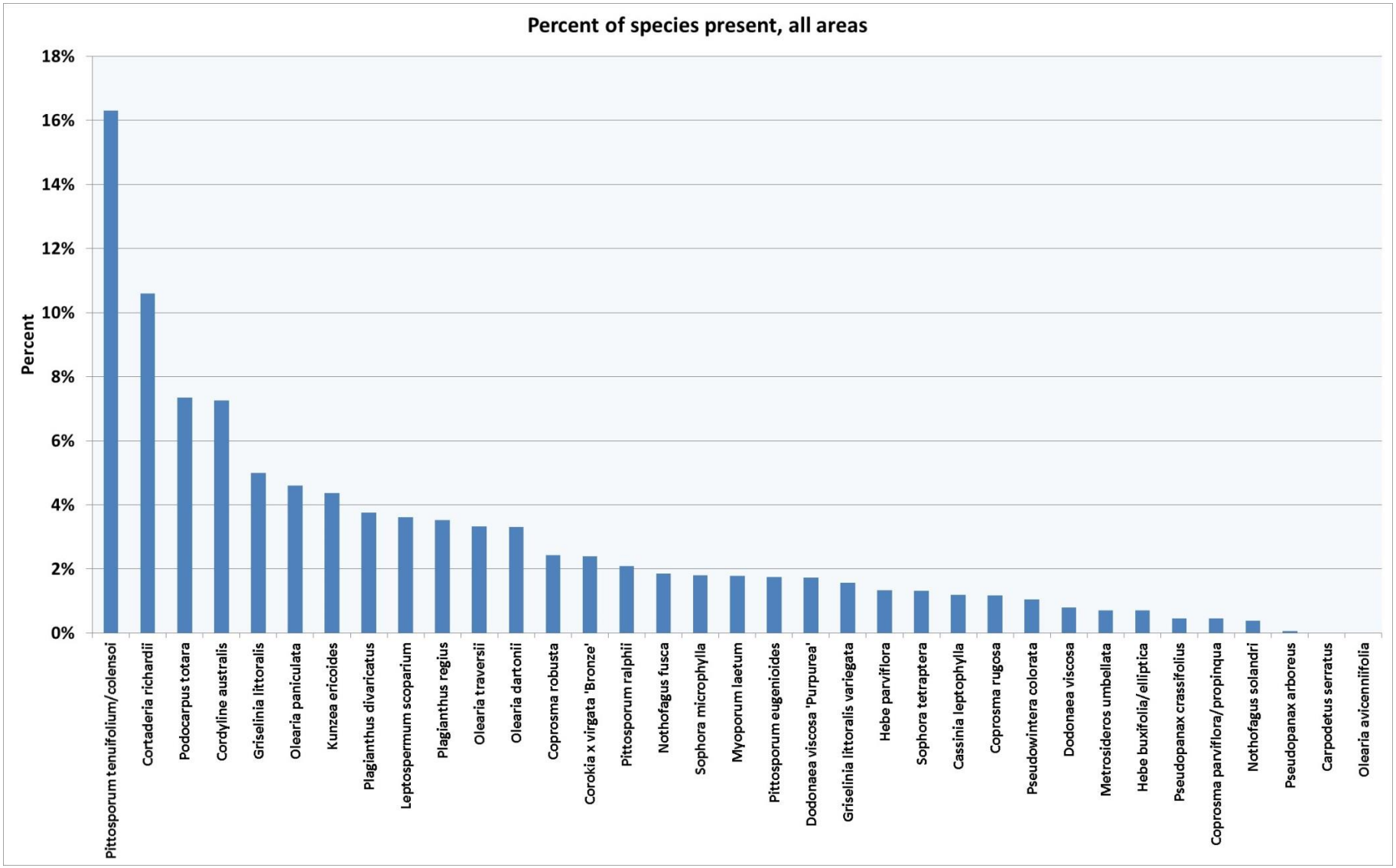

Figure 8: Percent of species present, all areas.

Plant growth, escape from grass competition, and exposure

Most species had an average height between 0.5 and 1.0 metres and only 7 species have an average higher than 1.0 metres (Figure 9). The average height of all species is 0.92 metres with a standard deviation of 0.39 metres. *Plagianthus regius* and *Olearia dartonii* were by far the taller (averages above 1.5 metres). Four species averaged below 0.5 metres, the lowest of which was *Pseudowintera colorata* (0.24 metres).

The average height of the grass is 0.54 metres (Figure 9) with a standard deviation of 0.17 metres, while the grass seed heads have an average height of 1.19 metres and a standard deviation of 0.23 metres. Even the top error bar for *Pseudowintera colorata* does not reach the bottom error bar for the grass height. Most of the surviving species have an average height which is greater than the average height of the grass sward. However, only the top 5 species have an average which is greater than the average height of the seed heads.

On average 79% of all surviving specimens were 'completely clear' of grass, 11% were 'mostly clear', 6% were 'mostly covered', and 3% were 'completely covered' (Figure 10). This varied a lot between species. Those few species that are doing extremely well have over 90% of their surviving population classed as completely clear of grass, whereas four species at the opposite end of the spectrum had less than 60% of their surviving population 'completely clear' of grass.

Thirteen percent of *Pseudowintera colorata* were 'completely covered', and a further 8% were 'mostly covered'. It had the shortest height recorded and presented with a very short stunted form with a dense mat of leaves. This is not its natural habit and we surmise this was due to being smothered or knocked back by the poison and then recovering after release with a new crop of leaves starting from ground level again. Forty-two percent of *Hebe buxifolia/elliptica* were either mostly or completely covered.

Smothering by grass clearly causes a lack of vigour, defoliation and death of parts of some shrubs. Three species are particularly hard hit in terms of carrying dead shoot and leaf tissue close to the ground: *Dodonaea viscosa* 'Purpurea', *Dodonaea viscosa*, and *Cassinia leptophylla*, all of which had 'Health' scores (percentage of shoot judged to be alive) below 20% for 0.01 to 0.50 metres (Figure 11). Many species show a trend for increasing health as the shrubs height increases. In some species only 60% of the remaining plant was alive between 0.01 and 0.50 metres, compared to > 85% for shrubs 0.51 - 1.00 m, and >95% for shrubs over 1 metre tall. However, *Leptospermum scoparium* follows the trend until it reaches 96% at 1.5 - 2 m, but then health drops to 65% for >2 m. *Pittosporum tenuifolium/colensoi* does a similar drop from 100% to 53% alive at 2-2.5 m. It is likely that these latter two exceptions result from wind or salt burn as their leading shoots emerge from the protection of the grass, but insect damage may also have contributed to defoliation, especially at the northern end of the western side of the restored estuary arm.

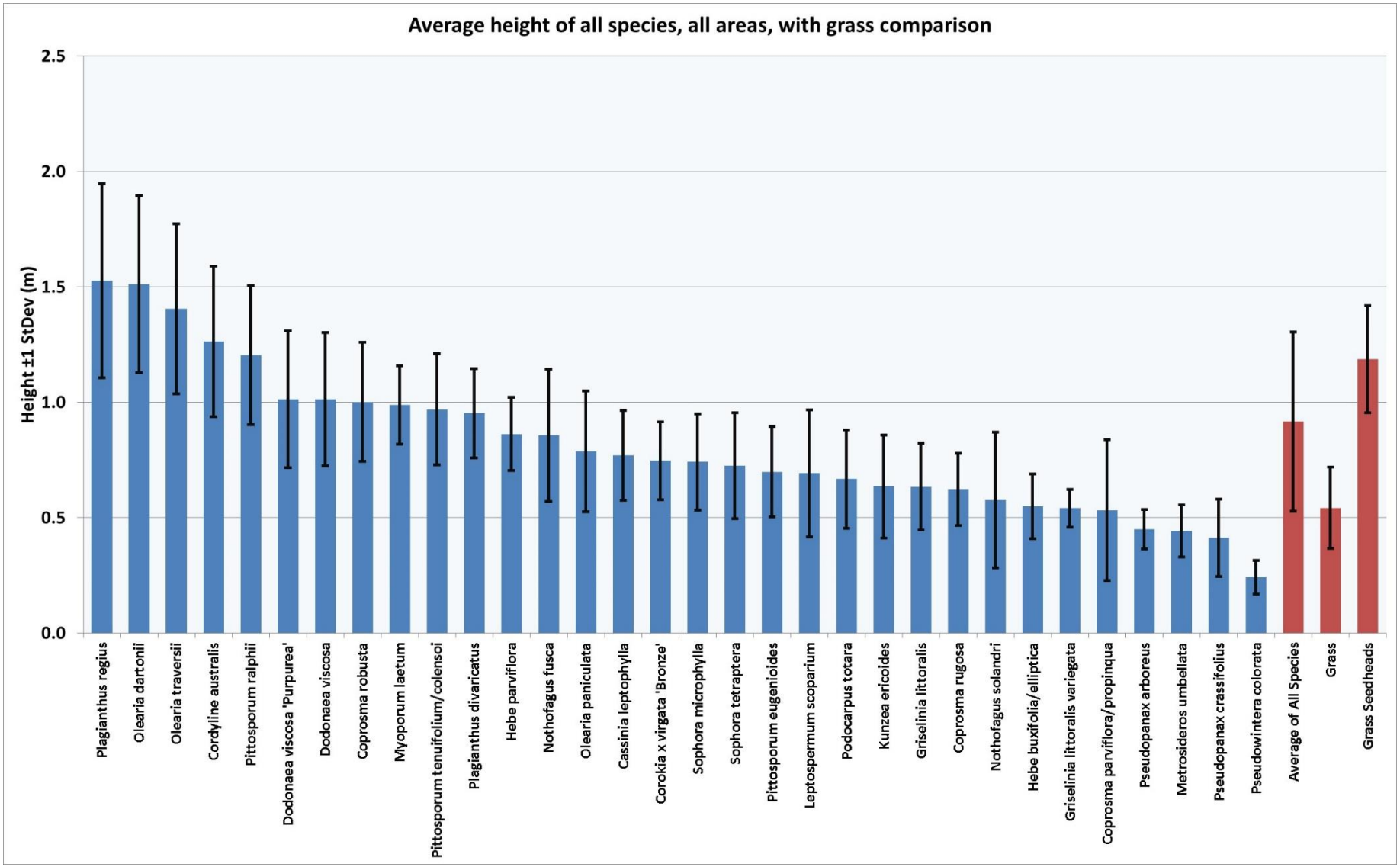

Figure 9: Average height of all species, all areas, with grass comparison.

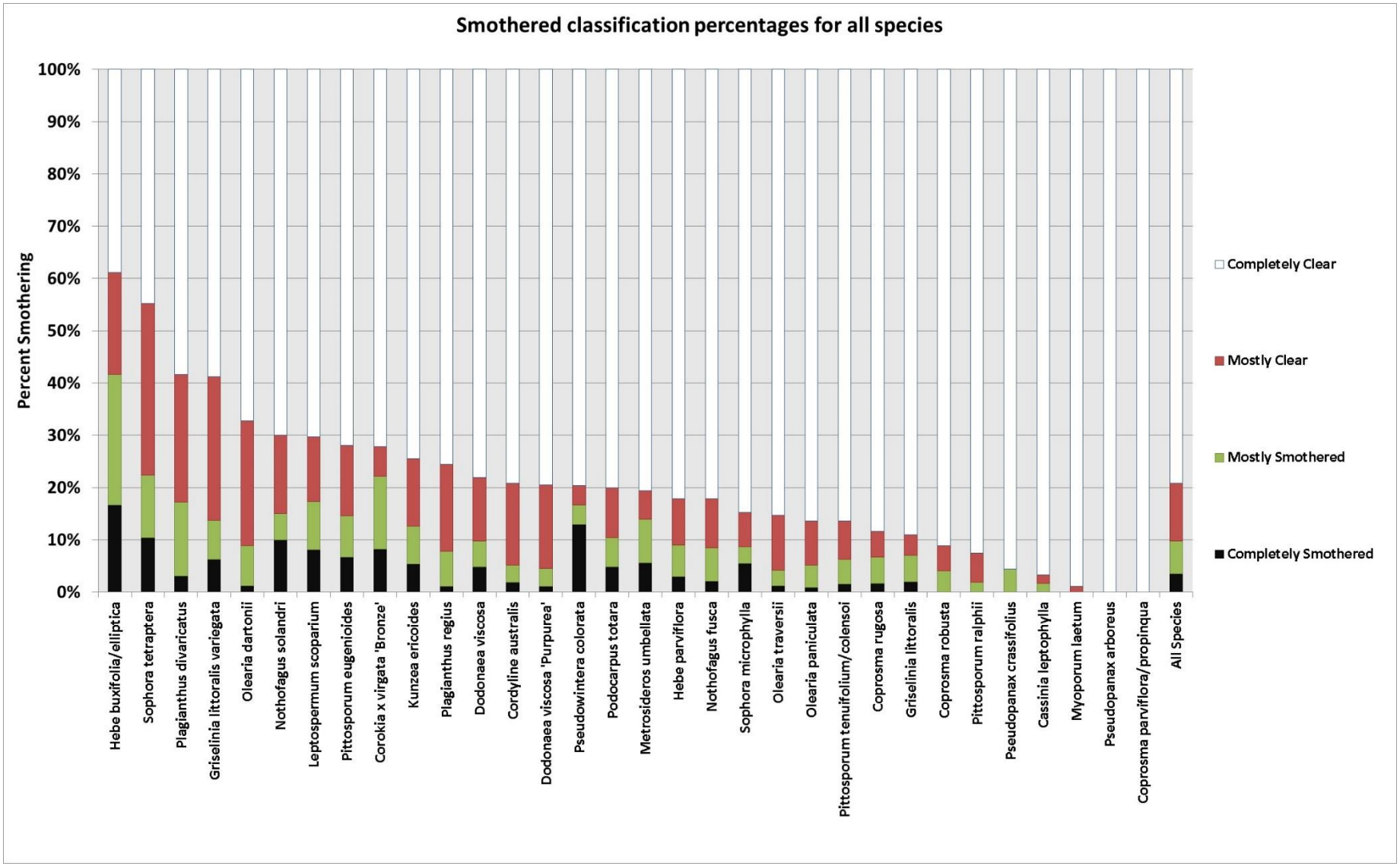

Figure 10: Smothering classification percentages for all surviving specimens.

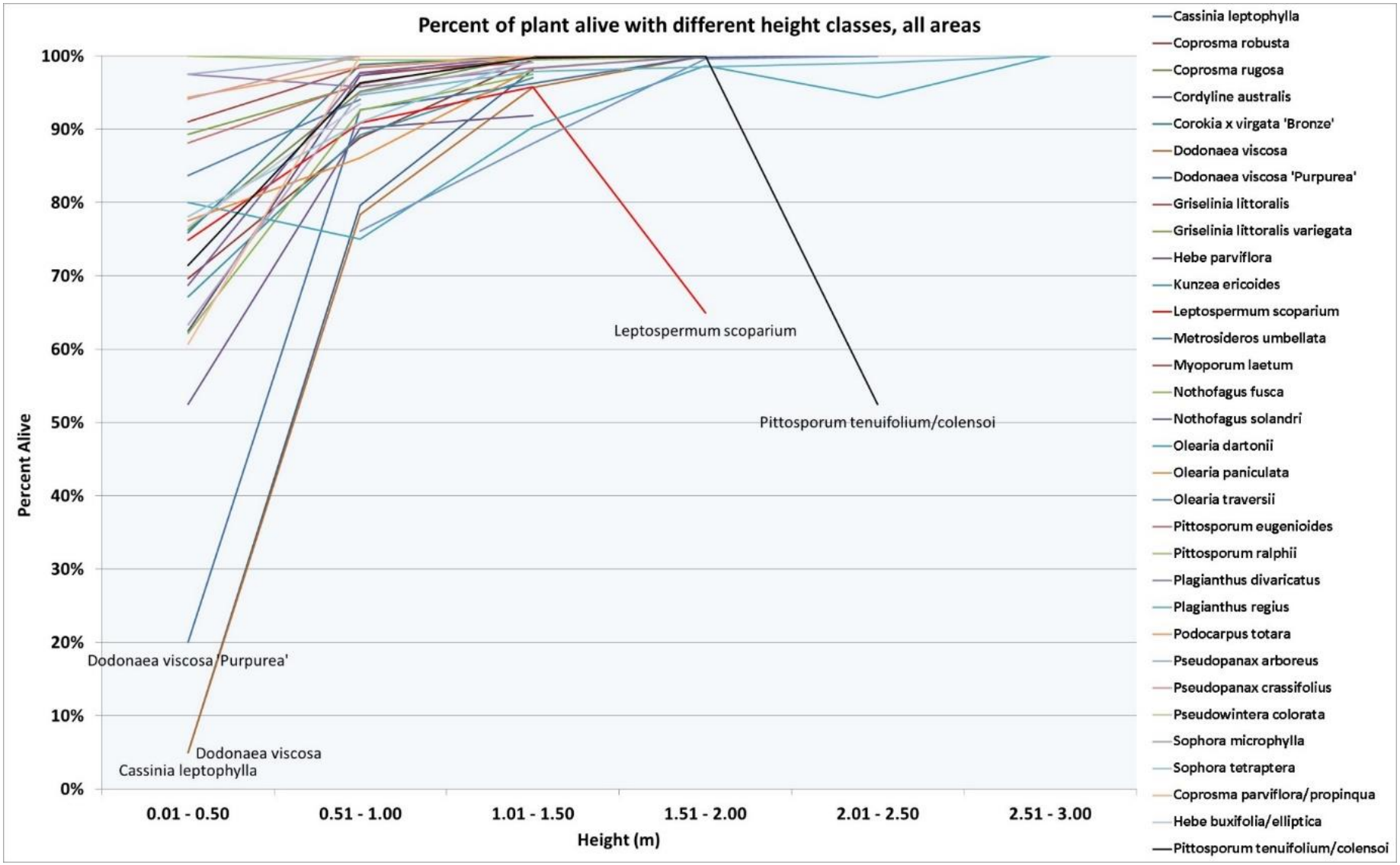

Figure 11: Percent of plant alive with different height classes, all areas.

Growth rate

The obvious evidence in the graph of smothering, and low overall survival of some species, suggests that there is a premium for rapid growth to escape competition from grasses in the Tūmai restoration project. Exposure to winds, which can be severe, cold and salt-laden at Tūmai, is an obvious potential driver of variation in growth rate and survival. However, we found no evidence of associations between the predominating aspect of each polygon and the height of 4 most common species for which we have adequate data (Figures 12-15).

Density of each area

Area D and Toetoes had the highest densities, more than 1.2 plants per square metre (Figure 16). Eight of the nineteen areas have a density which is less than 0.4 plants per square metre. The result is a somewhat sparse and patchy emergence of shrubs (Figure 17).

The heat map (Figure 18) indicates that some areas are notably more successful than others. Many of the most successful restoration are in less-dry, more moist gullies, others are the eastern facing slopes. These eastern facing slopes are sheltered from the south westerly wind and Peter also surmised that shade from the western sun would have helped their survival.

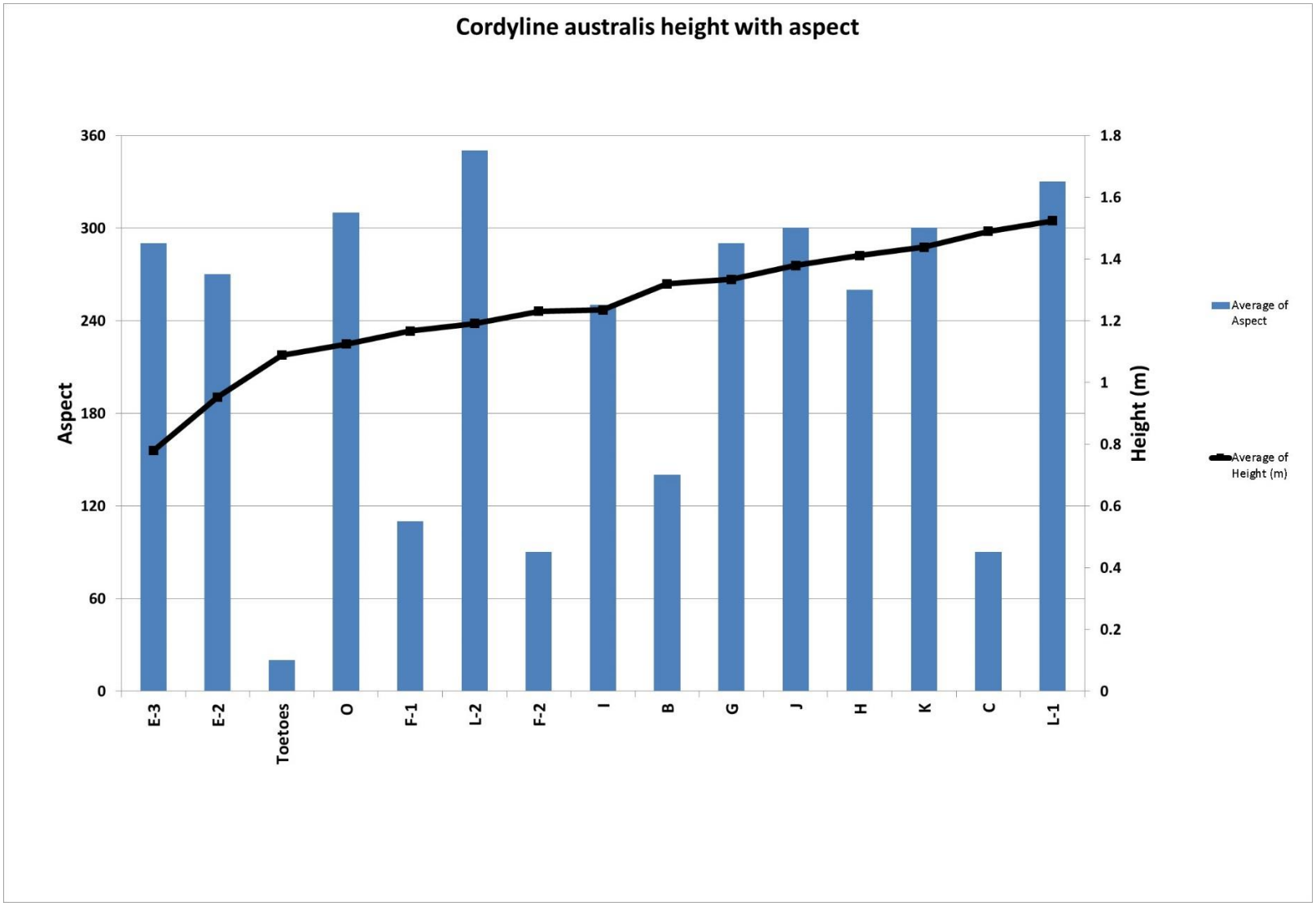

Figure 12: *Cordyline australis* height with aspect. Polygons are arranged in order of increasing average height measured in degrees.

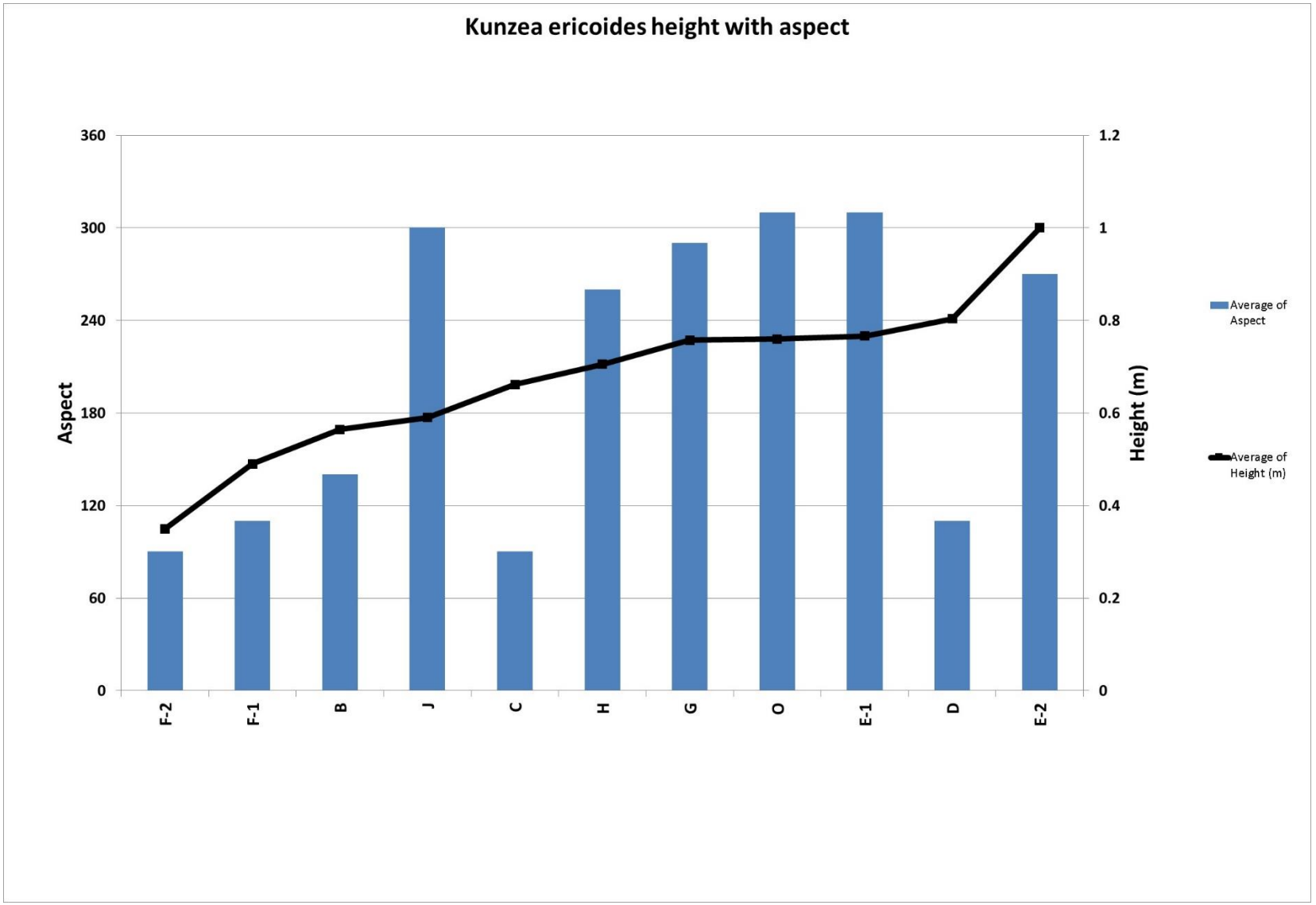

Figure 13: *Kunzea ericoides* height with aspect.

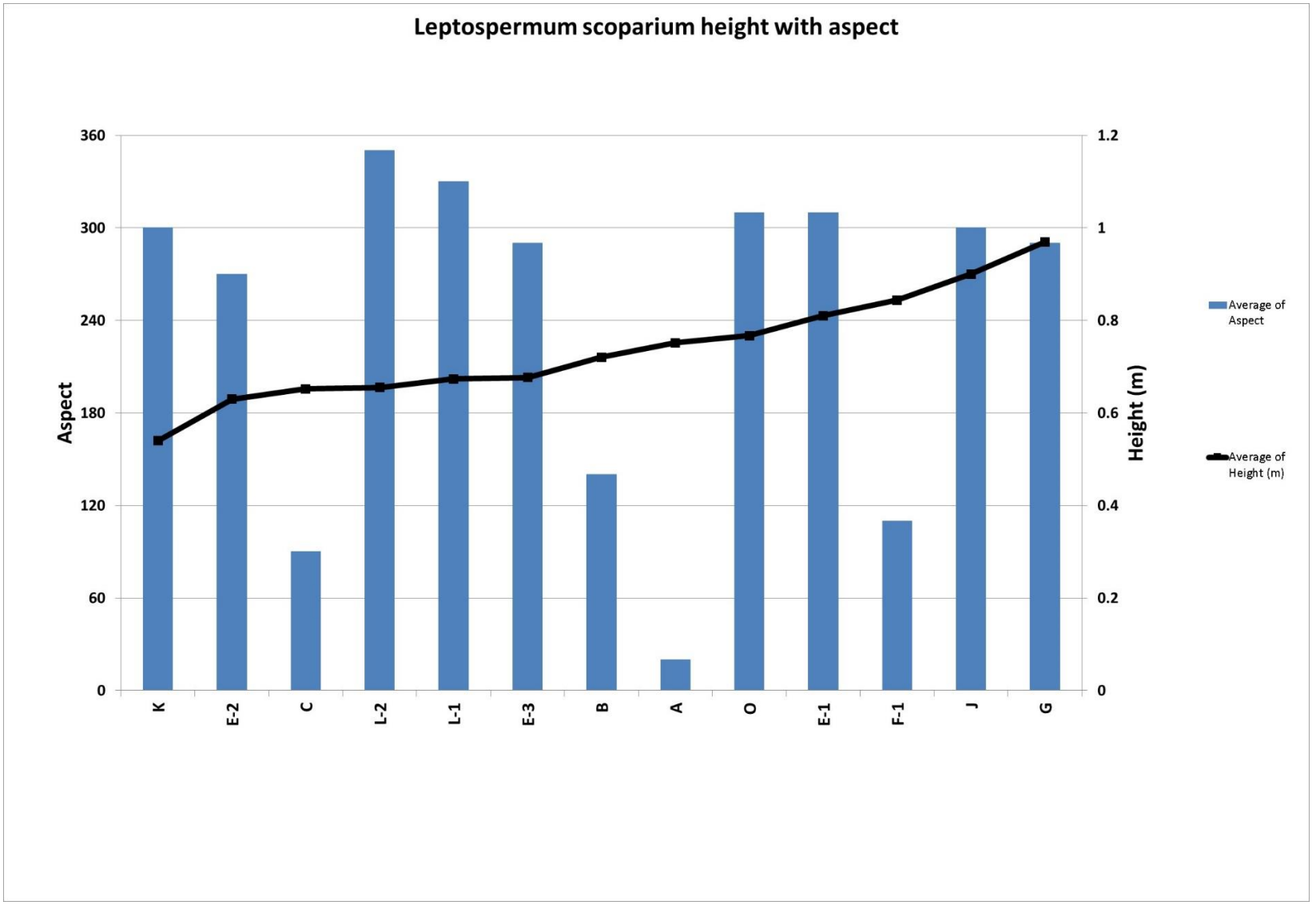

Figure 14: *Leptospermum scoparium* height with aspect.

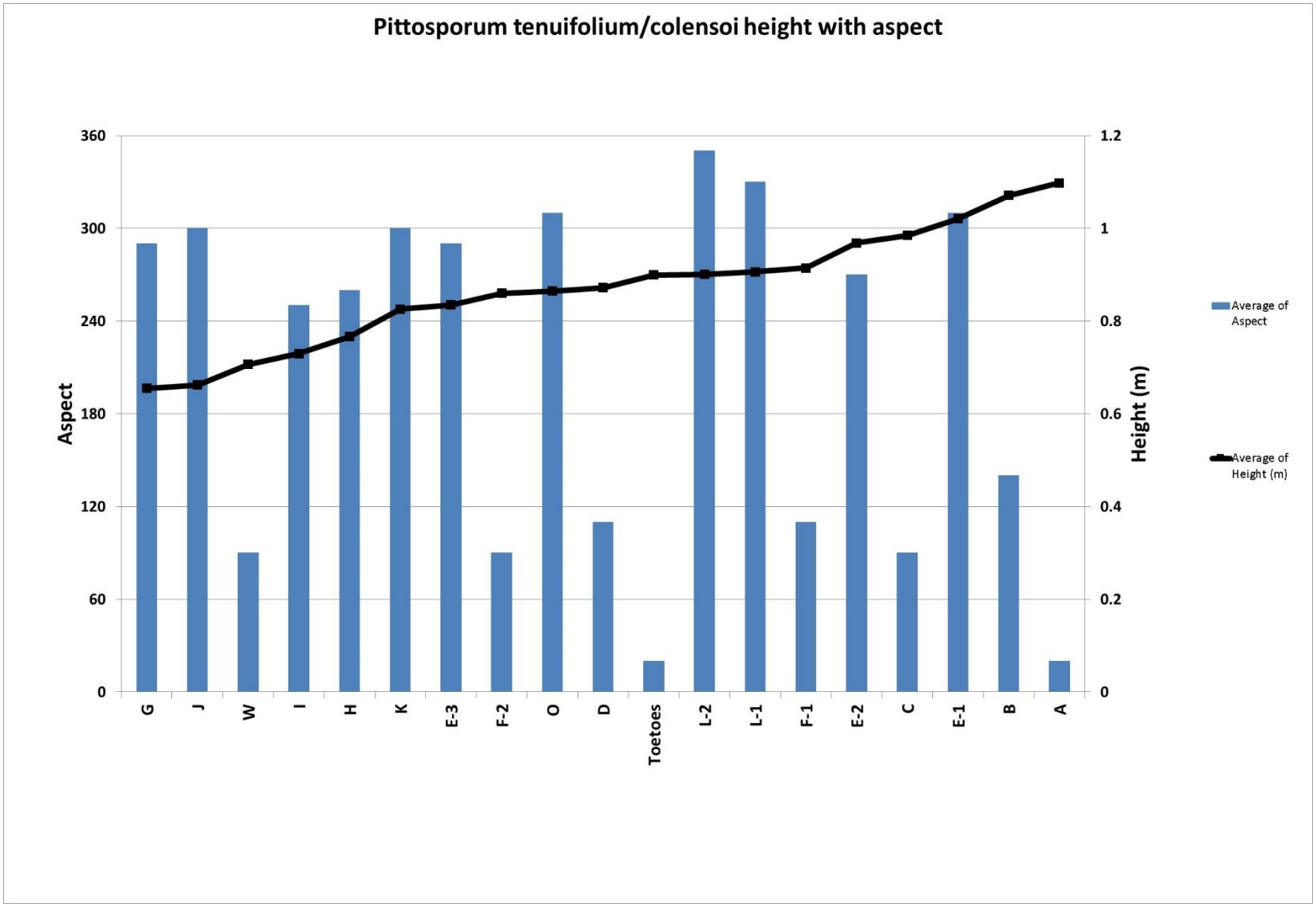

Figure 15: *Pittosporum tenuifolium/colensoi* height with aspect.

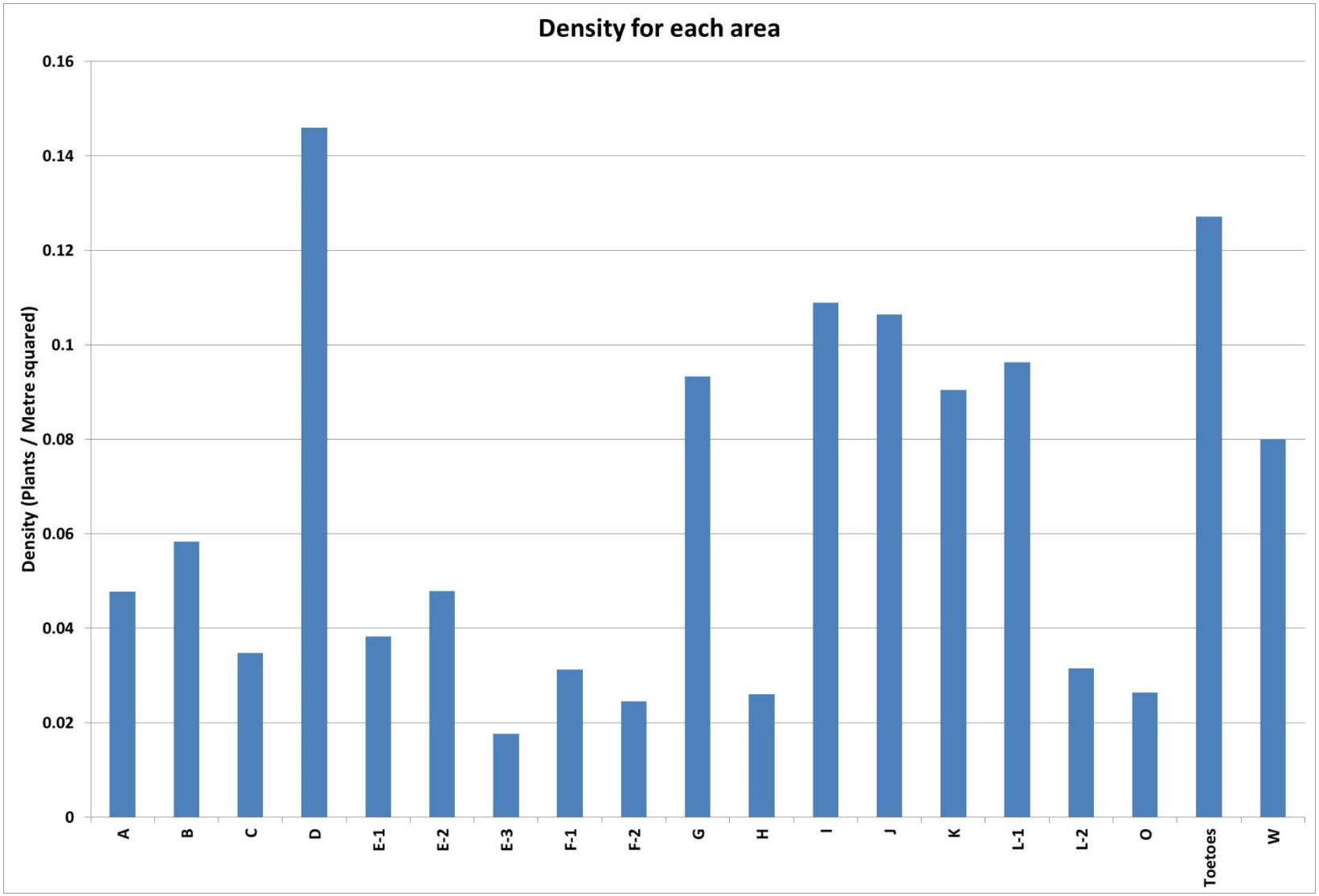

Figure 16: Native shrub density in each area.

Figure 17a: Regenerating forest at Tūmai Beach Sanctuary 2012. These sample photographs are some of over 122 photos taken during the survey in the summer of 2011-12. Top photo: Polygon K and L1, yellow in heat map (Figure 18). Middle photo: D and Toetoe hot spots in heat map. Bottom photo: Polygon B below the road, yellow in heat map.

Figure 17b: Close up photos of polygons K and L1 at Tūmai Beach Sanctuary 2012.

Figure 18: Heat map showing most dense areas of planting.

Discussion

Foundation plantings: a promising start but there is still a long way to go

Of the 14,148 seedling shrubs planted at Tūmai in 2009, 32% were still alive 3 years later when we did this survey. This has established (or re-established 4,568 plants of 36 different species where a mixed broadleaf and podocarp forest once stood. The 4,568 surviving plants are spread throughout 15.19 of the 29.24 ha that have been designated for regenerating forest to achieve the Resource Management Act permit target, so approximately 52% of the target area has been partially restored. Many of the faster growing species have now reached a size where they require little or no follow-up care. This can be a source of considerable pride for Peter and Irene Walton, directors of Waltons Ltd, and it represents a promising start for adding conservation value to coastal Otago as contracted by the Resource Management Act consent for the subdivision. There is every reason for optimism that forest regrowth will eventually be successful at Tūmai because of the (i) rich agricultural soils, (ii) absence of domestic stock, (iii) high growth rates and survival of some species already demonstrated at Tūmai, and (iv) presence of forest remnants at Goodwood and Tavora within 3 Km of Tūmai from where birds can carry seeds.

It is difficult to say how this rates in terms of expected efficiency of restoration investment because no other studies have reported survival and growth of native woody vegetation in pasture in coastal Otago. Considering the considerable effort invested by Waltons Ltd to prepare the site, do the actual planting and then follow-up with herbicide spraying to release plants, 32% survival may seem disappointing. Certainly many of the planted areas look rather sparse and do not meet the aesthetic and normal criteria by which most people would designate it as re-growing forest. The surviving woody plants are too far apart to have any prospect of closing a canopy to exclude pasture grasses, even after decades. Canopy closure and elimination of the thick cover of grasses is the key ecological 'tipping point' where natural regeneration of a range of forest species can naturally ensue. Canopy closure will naturally eliminate competition for light, water and nutrients from the vigorously growing pasture species[18] and allows a whole new array of native species to establish and grow. Elimination of the grasses allows seedling establishment, prolongs their survival and creates a whole new micro-environment where some less vigorous but low-light-tolerant species can persist. Arrival of forest birds will further accelerate restoration by distributing seed and colonization of bare areas under or between existing woody shrubs.

What determined the survival of the plants?

Survival probability was probably determined by fixed species characteristics and perhaps the size and quality of the shrubs provided by the nursery. Ability to withstand transplanting and cope with frost, browsing mammals (hares and rabbits), competition from grass, and having a fast growth rate to emerge from the grass sward are all potentially important. The more successful species in Figure 7 correspond closely with the tallest species in Figure 9 (Average height with grass comparison), suggesting that having a high (vertical) growth rate to escape smothering by grass is the most important criterion for success. For example:

- *Plagianthus regius*, (Lowland ribbonwood) has the most successful survival rate at 100% and is also the tallest species. Only 180 of this species were planted but they all survived.

[18] *Native Forest Restoration - A Practical Guide for Landowners* Tim Porteous.

- *Cordyline australis*, which had the second highest survival rate and fourth ranking in height, is such a species with a strong upward growth that is rapid.
- At the other extreme, the sprawling growth form of some *Coprosmas* make them vulnerable to smothering by grass and keep their succulent stems and leaves in the browsing zone of hares and rabbits for much longer.
- Similarly, *Pseudopanax arboreus* and *P. crassifolium*, were the 2nd and 4th shortest and clearly struggled to compete with the grass. *Pseudopanax arboreus* is described "as a pioneer in forest regrowth" "with a southern limit of Otago Peninsula", so it may be near it's climatic range even in the absence of competition with grass.
- *Nothofagus solandri* and *Nothofagus fusca* have a tall habit but are slow growing. Their natural habitat is forest and they have struggled at Tūmai as their low survival rate shows.

Dodonaea viscosa and cultivar *Dodonaea viscose 'purpurea'* (Akeake[19]) are outliers to the correlation between height and survival rate i.e. they ranked 4th and 5th in height, but survival rates were only 41% and 17% respectively. We often found plants of these species to be established but carrying a full load of dead or dying leaves. In *Going Native*[20] Dodonaea viscosa is described as "coastal"; "tolerant of most conditions although susceptible to heavy frosts; salt and wind-resistant; uses: hedge, shelter, nursery, stony and sandy sites." We therefore surmise that they were either hit by frost, or that they were particularly susceptible to the poison sprays used to release the plants from grass.

More of the southern variety of kowhai, *Sophora microphylla*, survived (56% cf. 13%) than its northern counterpart, *Sophora tetraptera*, yet both attained similar height (Figure 9). This may reflect adaptation of the southern species to colder climate.

Coprosma robusta had some healthy and large specimens, but towards the end of the survey in late summer we struck some that appeared sickly -hit by some blight. Its survival is 69% which seems low given its name and nature.

Next steps

Combating threats of smothering and browsing mammals: Smothering by grass is undoubtedly the biggest threat to the establishing plants at Tūmai, and Waltons Ltd have worked to address this threat with spraying programmes. The large area has meant this has been a huge task. The vulnerability of some species to becoming smothered by grass can be overcome in future by more effective releasing of the plants than occurred at Tūmai to support this first tranche of planting. We suspect the poison spray has adversely affected some of the plants, knocking them back for a period and maybe killing others. However, grass would have definitely killed them, so spraying was definitely the 'lesser of two evils'. Applying the spray using hoods over the nozzle and only in very calm conditions will reduce risk to the native plant, but prior weeding or trimming the surrounding long grass will also help by ensuring that the poisoned grass does not blow back onto and thereby contaminate the shrub. Mulching could be used as an alternative to spraying in smaller more manageable areas. Mulching can "greatly

[19] Akeake means 'poor' or 'infertile soil' in Māori and three species are known by this name: *Dodonaea viscosa*; *Olearia avicenniifolia*; and *Olearia traversii*.

[20] Ian Spellerberg and David Given (2009) *Going Native (Growing and using New Zealand native plants)* Canterbury University Press.

increase the rate of survival on dry open sites"[21]. This East Otago area can be dry. Drought resistant plants were selected for this location but Peter Walton reports the summer immediately after planting (when the seedlings were still vulnerable), was particularly dry and no doubt caused added fatalities.

With the exception of hares, there are relatively few browsing mammals to threaten seeding survival at Tūmai. Possums are virtually absent, but may eventually become a threat once forest cover gives them shelter for dens. Rabbits are a potential problem in a few patches, especially in freely draining and warmer sites and on the sandy fringes of the estuary. The hares may account for more damage than our survey could identify at this stage[22] and are likely to be a particular problem in winter and spring when they seek sugar from growing tips and stem bases.[23] Strategies to deal to the hares are needed. Poisoning with 1080 threatens the pet dogs that roam over Tūmai, and they are very difficult to trap. Inviting skilled hunters to shoot them is the first response, and encouraging the Tūmai residents to get a gun license and shoot them is the only practical option. It is impractical to erect wire mesh or plastic shields around all the plants to prevent hare and rabbit browse, except where residents wish to establish salient plants on margins or out in the open for aesthetic reasons.

Enrichment planting in patches: Further and more successful releasing or mulching around the small and currently smothered specimens (Figures 9-11) can recoup some of the investment already made in the planting. However, the most important next step to is to accelerate planting of new shrubs and couple this with much more effective follow-up releasing of the shrubs in their first three years. Wildland Consultants advocated[24] that indigenous vegetation be established in pockets rather than attempting broad scale planting over large areas. This strategy was recommended because:

- "it is how plants naturally establish and spread;
- birds are attracted to groves (rather than individual plants) and will nest in them and distribute seeds to them, fostering natural regeneration;
- the crowns of trees grow outwards, shading out competing grasses and allowing new seedlings to establish at the edge of the grove, enlarging it (Porteous 1993)."

We would add that planting patches of forest is also important for building confidence and an aesthetical appreciation for what is possible. This approach of focusing on patches can now be adapted by targeting consolidation of the denser areas that were established in the 2009 planting programme (Figures 17 & 18). Additional enrichment planting to consolidate the partially restored areas and speed up canopy closure is now needed.

Use nurse crops: Nurse crops may be worth exploring at Tūmai. Pasture is a challenging habitat for native seedlings and a nurse crop would create a more suitable habitat for more vulnerable seedlings. Tim Porteous recommends tauhinu (*Cassinia leptophylla* -also known as *Ozothamnus leptophyllus*) as a successful "nurse crop. It occurs naturally on fertile coastal land where it can grow as high as 5m. It does not live much beyond 15 years. Depending on the density of the tauhinu, appropriate coastal

[21] *Native Forest Restoration - A Practical Guide for Landowners* Tim Porteous.

[22] A later planting programme around Lot 4 in 2013 clearly identified hares as significant destroyers of new plants. This planting was into mown areas so it was easy to initially check plants before becoming obscured amongst tall grass. Hares clipped off the leading shoots, sometimes dropping them on the spot rather than ingesting them – a well-known irritation that is thought to help them wear down their teeth which grow continuously. Hares particularly targeted *Olearia odorata* and cabbage trees and sometimes gnawed them back to just leave a stump.

[23] Comments on hares from Valerie Fay at Orokonui Ecosanctuary.

[24] In their report no. 1839.

species such as akriaho (*Olearia paniculata*), coastal flax, taupata, cabbage tree and ngaio can be planted in between tauhinu, or planted in gaps or lines that have been cut."[25]

Which species should be planted next?

The first plantings departed markedly from that set out by Wildlands as part of the Resource Consent application for Tūmai (see Appendix B), and the survival rates of the species varied a lot (Figure 7). Accordingly, the current composition of the growing forest (Figure 8) is somewhat serendipitous. Next investments in planting should follow a more structured plan that maximises the rate of achieving canopy closure and starts to target the eventual species composition desired for Tūmai. One approach is to try to mimic the species composition and structure of the forest that is likely to have existed at Tūmai before it was cleared for farming. A preliminary predictive model using data on species composition within forest remnants in coastal Otago[26] identifies 54 species that probably grew at Tūmai, 41 of which are not included in the Wildland proposed planting plan (Appendix D, Table A3). Cross reference of a high probability that a given species was originally present with a goal to have at least 100 specimens present was used to identify the number of species for which there is adequate or inadequate representation at Tūmai (Column 7 of Table A3). This somewhat arbitrary division suggests that just 6 of the original species are already adequately represented somewhere on Tūmai, and that 32 of the original species are still absent or represented in too small numbers. Similarly, 12 of the 34 species recommended by Wildlands are now represented. There is no prospect that all these inadequately represented species can or should be planted immediately because many of them will not survive until a forest structure is in place to eliminate the understory of grasses, break the wind, and create new microhabitat conditions that are more typical of mature forest. Nevertheless, we suggest that some of the canopy species listed as inadequately represented so far in Appendix D are given priority in new planting schedules. In particular, kahikatea, houhere, miro, mapou, *Coprosma rotundifolia*, mahoe, putaputaweta and kotuktuku are relatively large and erect species that are conspicuously missing.

Twenty-four species have been established at Tūmai (at least one plant survived) that do not appear in the predicted original forest composition; and 21 species have been established that were not recommended in the Wildlands plan.

Fire resistance is an additional consideration when considering what to plant. Prolonged dry weather can make the long grass areas at Tūmai extremely flammable, so at least until forest is fully grown, there is a need for extreme care to observe fire bans. The fire risk from the different forest species is reasonably well known and many of the species planted in 2009 have high flammability ratings[27]. However, it is important to keep this risk in perspective: the expected fire risk in broad terms is expected to scale (highest fire risk first) as (1) rank introduced grasses; (2) some of the large native tussocks that build up considerable thatch; (3) native forest; (4) silver tussock (which does not build up a thatch to fuel a fire)[28]. The best overall strategy is to maintain a gap between the forest and houses at Tūmai by maintaining broad mown perimeter.

[25] *Native Forest Restoration A Practical Guide for Landowners* Tim Porteous p154.
[26] Wilson & Alan (1991).
[27] Liam G Fogarty NZ Fire Service Commisson Research Report (2001).
[28] In litt, William Lee.

Slow growing species with a tall habit are recommended for insertion only in a secondary tranche of planting once the grass is almost eliminated or reduced in vigour because of restricted light. Good examples of these second tier plants are the *Nothofagus* species.

The survey data gives clear information as to the most successful species at Tūmai (See Figure 7) and these are useful plants to consolidate the denser areas in future. Certain plant species can be targeted to attract birds to accelerate natural succession towards native forest. Some species for consideration are listed below, but this is by no means a complete list and a long-term plan is needed.

- One species that is noticeably scarce at this stage and which would be good to get established is flax: *Phormium tenax* (New Zealand flax, harakeke) and *Phormium cookianum* (mountain New Zealand flax, wharakriki). They are propagated by division and fans can be split off from established plants so if a source is available they can be acquired for free. They are fast growing, and can cope "with a wide range of open habitats, including standing water"[29]. They can compete with grass. Big plants would provide wind shelter for further planting and the flowering stalks would attract nectivorous birds.
- Ngaio are particularly suited to coastal sites and were planted on the most seaward ridge of Tūmai, so very exposed to wind and salt spray.
- *Plagianthus divaricatus* (Salt marsh ribbonwood) has a natural habitat of the estuary edge and can be seen growing at the water's edge around the Waikouaiti River and estuary near Karitane. It is a hardy plant and has a 64% survival at Tūmai, however it has been planted on the hillsides and will be out of place in the eventual forest setting. It is best suited to the estuary edge where most other species would struggle but it thrives.
- *Hebe buxifolia (odora)* and *Hebe elliptica* grow naturally on the East Otago coast in exposed places but despite this hardiness they have a low survival rate probably due to competition with grass for nutrients and light.
- *Kunzea ericoides* is ideally suited to the early stages of forest regeneration. Kanuka and Manuka are described as "important early colonisers of unmanaged pasture, [and] ideal nurse crops"[30]. Kanuka prefers drier and more fertile soils than Manuka. There were 1462 Kanuka seedlings planted at Tūmai, however its survival rate is only 15%. It is hard to be certain of what factors have contributed to this. There may be some misidentification with Manuka which had a 42% survival rate and prefers more moisture. There is a warning in *Go Wild - Guiding native restoration in Tasman District*, by Maggie Atkinson and Michael North that "Manuka and Kanuka must not have their roots disturbed". We recommend persistence to establish bands of Kanuka at Tūmai, but that special care may be needed to protect them from grass competition and nurture them to the rapid emergent growing stage.
- *Podocarpus totara* is described by John Dawson and Rob Lucas in *Field Guide to New Zealand Native Trees* to "behave like a coloniser. Young Trees are often seen on farmland owing to its pioneer behaviour (it grows in the open), unpalatability to stock and seed dispersal by birds." It can tolerate drought conditions. Its survival rate at Tūmai was relatively low in the first plantings at Tūmai, but it is just beginning to clear the grass height. Peter Walton reported

[29] *Going Native* Ian Spellerberg and David Given.
[30] *Native Forest Restoration* Tim Porteous.

that the first summer immediately after planting was particularly dry and East Otago can be very dry in summer so Totara is well suited to these conditions.

- Together *Pittosporum* species offer considerable opportunity to close the canopy and accelerate natural regeneration. *Pittosporum tenuifolium* with *Pittosporum tenuiflorium colensoi* are the most populous plant at Tūmai (Figure 8). As the 10th tallest species, they were already becoming visible above the grass at the time of our survey. *Pittosporum ralphii* has also proved to be hardy for Tūmai with a survival rate of 73% and is the 5th tallest species. It has thicker leaves with tomentum on the underside. *Pittosporum eugenioides* is usually hardy with vigorous growth but at Tūmai it appeared sickly and stunted. Its survival rate is 45% and it is 19th in height ranking. We suspect it was affected the poison so increased care when spraying and use of mulch may help it establish faster.
- *Olearia traversii*, (also *traversiorum*) (Chatham Island Akeake) is indigenous to the Chatham Islands where it is classed as a threatened species. It "forms pure stands on sand dunes and grows in mixed forests"[31] there. At Tūmai it is 3rd in height and has a survival rate of 68%. The Dunedin City Council plants this species in very exposed situations where it grows well.
- *Olearia lineata dartonii* was the 2nd tallest and had 3rd highest survival rate (85%). It has long and very narrow leaves that are needle-like with rolled edges, commonly known as the twiggy tree daisy. It is easy to grow and is tolerant to drought, cold and windy conditions. It is widely used in revegetation plantings.
- *Olearia avicenniifolia* (common name Akeake or Mountain Akeake) "is a rare hardy evergreen spreading, bushy shrub growing up to 3m high. It is endemic to the lowland/mountain scrubland throughout South Island and Stewart Island. The shiny, leathery, green, lance-shaped leaves are 5–10 cm long, with white tomentum beneath. In autumn this tree daisy produces sweetly white scented in much branched flower heads. *O. avicenniifolia* will tolerate dry conditions."[32] This plant proved a mystery to the survey team at Tūmai: we recorded no *O. avicenniifolia*, so either none of the 50 plants survived or maybe it was misidentified in the survey with *Pittosporum ralphii*, both having tomentum under the leaves.

Elimination of invasive weeds: The cost of restoration of forest at Tūmai is greatly reduced by absence of gorse (*Ulex europaeus*), and the restriction of broom (*Cytisus scoparius*) to the northern tip of the sanctuary. Elimination of the broom altogether, as soon as practicable, will reduce the seed source and slow the accumulation of a seedbank that might reinstate the plants after each control episode[33]. Control should be maintained every two years until no further regeneration is noted, and any plants found elsewhere on the estate should be immediately destroyed.

A communal nursery for community collaboration: Wildlands Consultants recommended establishing a nursery at Tūmai and this was listed in the Resource Consent as an intended step. Community effort can help speed the maturation of the forest once the basic forest canopy is established by the developers, as has been promised by 2018. Cuttings are an effective and fast way of propagating native plants. Cuttings could be taken from the successfully established plants at Tūmai, but collection of new species from the nearby Goodwood forest remnants and small patches of remnant vegetation

[31] From *Field Guide to New Zealand's Native Trees,* Dawson, J. and Lucas, R.

[32] T.E.R.R.A.I.N. Taranaki Education Resource Research Analysis and Information Network (http://www.terrain.net.nz/terrain/home.html).

in the seaward-facing gullies of the farm just south of Tūmai would help ensure local adaptation to coastal and semi-arid conditions.

The value of follow-up monitoring: this initial survey covered the entire area in order to find every surviving plant from the 14,148 supplied by the nursey. The records, GPS locations of each specimen, and the maps (Appendix C) now provide a firm baseline from which a subset of plants can be tracked in future. We suggest that a stratified random selection of plants be earmarked for re-measurement every 3-5 years. A minimum of 40 of each of the main species, and of some critical species for future ecological function of the ecosystem, should be monitored. Stratification of the sample for exposure to wind and distance from the sea would allow test of hypotheses for determinants of growth and plant vigour. Longitudinal measures of the strength of flowering and fruiting would help track the rate of reinstatement of forest ecosystem processes. Flowering and the arrival and abundance of pollinators are crucial next steps for natural plant propagation. We expect increases in the diversity and abundance of insects will be an early sign of restoration success and that this will trigger colonisation by insectivorous birds, especially early colonisers like fantails (*Rhipidura fuliginosa*). Arrival of frugivorous birds (especially silvereyes, bellbirds and tui) will herald accelerated natural seed dispersal and the beginnings of natural ecological selection of the most successful and suitable plants for Tūmai's forest. Deliberate planting of nectar plants will encourage the honeyeaters and provide the much needed energy sources to secure a resident population of birds throughout the year.

Measurement of reinstatement of these critical processes is of considerable interest for guiding selection of species in other coastal forest restoration efforts in Southern New Zealand. Re-establishment of the highly depleted coastal forests between Kaikoura and the Catlins regions is a conservation priority. The Tūmai Beach Sanctuary community-led conservation effort is a potentially important model for cost-effective and ecologically sensitive coastal development to help achieve a nationally important conservation goal[34]. It will also greatly increase the aesthetic appeal and land values[35] for the residents of Tūmai, as well as providing public good and ecosystem services to the surrounding ecological landscape.

[34] Moller & Moller (2012).

[35] Moller (2012) reviewed overseas studies that showed increased prices are paid for land (sometimes by as much as by 64%) where forest covers around half of the ground.

Conclusions & Recommendations

A great start has been made to restoring native forest at Tūmai. A first tranche of planting in 2009 has established 4,568 shrubs from 36 species. Some of the plants are growing very well and will need little care from now on. However, survival of the original plantings has been low, because of smothering and other possible factors, and the species selected did not follow a structured plan for restoration. The resulting density of native species is too low and very patchy, and large parts of the existing replanted zones now will need further enrichment planting to accelerate canopy closure. An additional 14 ha of the Tūmai grassland await first planting of native woody vegetation or native tussock grasses in the coming years in order to fulfil the Resource Management Act consent that created the farm park subdivision.

We recommend that future planting efforts include the following steps:

1. Establish and follow a designated plan designed to fasten and reduce the expense of attaining a fully functioning indigenous coastal forest ecosystem at Tūmai (this might be a reversion to the original plan provided by Wildlands or incorporate significant additions).
2. Consolidate the more dense areas identified in the heat map (Figure 18) to hasten canopy closure and create solid patches of vegetation that can then in turn shelter new plantings on their periphery.
3. Concentrate on smaller more manageable patches in new areas once the existing patches are fortified (as in 2 above).
4. Plant more of the proven successful species from this survey, but extend especial care to release and protect important additional species that have not done so well. Priority should be given to establishing canopy species that were identified as most likely to have been present at Tūmai before clearance for farming, but are not established in large numbers so far.
5. Wait until plants are more grown before planting them out so they will require less releasing before they outstrip the grass and also become less vulnerable to hare browsing.
6. Establish a second tier of forest species (ones not yet able to survive) to be planted only once the canopy has closed on several patches and the grasses eliminated.
7. Ensure that species which provide good nectar and fruit sources are included to attract birds.
8. In general, invest more in follow-up care of plants in the first 3-5 years after planting, including
    a. use mulching where possible to reduce grass as a competitor for nutrients and light and to help retain moisture in dry periods.
    b. use cone shields on the sprayer wand when poisoning around plants.
    c. use weed eaters to clear around established small shrubs to avoid herbicide applications being brushed onto the shrubs
    d. hand weed near the stem of plants to reduce competition and avoid accidentally ring barking a plant when using automated weed eaters
    e. instigate a vigorous hare and rabbit shooting program to reduce browsing damage
    f. protect plants with ‘cages’ if sufficient hare control cannot be achieved.
9. Eliminate the broom colonizing the northern most point of Tūmai Beach Sanctuary as soon as practicable and maintain two-yearly control efforts to flush the broom’s seed bank.

10. Keep records of future planting and follow-up measurements on a stratified random selection of the plants mapped and measured in this initial survey so that continuous learning from experiences at Tūmai can help guide cost-effective coastal forest restoration in the east coast of South Island.
11. Take photographs from the same GPS point intermittently to visually record changes.

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Appendix A: Field recording sheet

WayPoint and Photo Point log - Tumai vegetation survey					Page of
Date:		Observers			Camera Photo and direction.
	A - Clear B - 10-50% covered (little bit) C - 50-90% covered (mostly) D - Smothered				Polygon ID and Aspect
GPS	Plants				Comments/ Description
WayPoint No.	Species	% of plant alive	% of plant smothered	Height (cm)	

Appendix B: Suitable plants for Tūmai

Table of Indigenous plant species suitable for establishment on the Waltons Ltd property

Wildland Consultants

Ecological Assessment of the Waltons Ltd Property, Pleasant River Estuary, Otago . August 2007

Species	Common name	Plant type	Habitat			
			Freshwater swamp	Estuarine strip	Margin of estuary arm[1]	Hillslopes
Apodasmia similis	jointed wire rush, oioi	rush			•	
Carex geminatat		sedge	•			
Carex secta	pukio	sedge	•			
Carex virgata		sedge	•			
Coprosma crassifolia		shrub		•		•
Coprosma propinqua	mingimingi	shrub	•	•		•
Coprosma rubra		shrub		•		•
Cordyline australis	cabbage tree	tree		•		•
Cortaderia richardii	toetoe	grass	•			
Discaria toumatou	matagouri	shrub		•		
Elaeocarpus hookerianus	pokaka	tree				•
Ficinia nodosa	knobby clubrush, wiwi	sedge			•	
Griselinia littoralis	broadleaf	tree		•		•
Haloragis erecta		herb		•	•	
Helichrysum aggregatum		shrub		•		•
Hoheria angustifolia	narrow-leaved lacebark	tree		•		•
Isolepis cernua	slender clubrush	sedge			•	
Kunzea ericoides	kanuka	tree		•		•
Melicope simplex		shrub		•		•
Melicytus ramiflorus	mahoe	tree		•		•
Myoporum laetum	ngaio	tree		•		
Myrsine australis	mapou	tree		•		•
Olearia avicenniifolia		tree		•		•
Olearia fragrantissima		tree		•		•
Ozothamnus vauvilliersii	Cassinia leptophylla	shrub		•		
Phormium cookianum	mountain flax	herb		•		
Phormium tenax	flax	herb	•			
Pittosporum tenuifolium	kohuhu	tree		•		•
Plagianthus divaricata	saltmarsh ribbonwood	shrub			•	
Prumnopitys taxifolia	matai	tree		•		•
Podocarpus totara	Hall's totara	tree		•		•
Pseudopanax crassifolius	lancewood	tree		•		•
Schoenoplectus pungens	three-square	sedge			•	
Sophora microphylla	kowhai	tree		•		•

Appendix C: Baseline Maps

This section presents the location and number of plants in map form. A dot records the location of a plant but does not indicate its size or health. Different styles of dots are used to represent different species in the maps that need to differentiate species. There is an element of distortion in the scale, as the dots representing the plants are as small as possible, but are still disproportionally large in comparison to the area of the polygon that is reduced to fit an A4 page. Therefore, when distribution over all areas is shown in one A4 map it gives a false impression of density. For a truer impression of density we have produced higher scale maps of adjacent polygons, but still restricted to an A4 page.

The groupings of polygons in these maps are: (A B C), (D E Toetoe), (F O) and (G H I J K L and W). This means each map subject is covered in a series of 5 maps (1 overall map of all areas and 4 close up maps of the different polygon groupings). These maps give more accurate information on numbers and location than photographs which cannot capture all angles and do not show plants obscured by grass.

The maps record the following subjects:

- All plants (Figs. 19, 20, 21, 22, 23)
- *Pittosporum* -the most populous plant at Tūmai (Figs.24 - 28)
- *Podocarpus totara* and *Cordyline australis* -2nd and 3rd highest survival rates, 3rd and 4th most populous plants at Tūmai (Figs. 29 - 33)
- *Olearia* species -*O. dartonii* and *O. traversii* have strong survival rates (Figs. 34- 38)
- *Kunzea ercoioides* and *Leptospermum scoparium* (Figs. 39- 44)

Plagiantus regius (Lowland ribbonwood) is not covered in a map despite its outstanding survival rate of 100% as only 180 plants were purchased.

The area of Toetoe planting stands out on this map as densely red where it is planted several deep although curiously, where it is planted in a single row along the narrow strip between estuary and road to the east, it does not show as dense despite being an impenetrable wall of large Toetoes. This is due to the waypoint readings not taking account of size. These Toetoe plants are large –about 2 metres wide by 2 metres high with flowering stalks even higher, but the waypoint reading identifies only one plant at that location.

Figure 19: All plants all areas.

Figure 20: All plants A B C.

Figure 21: All plants D E Toetoe.

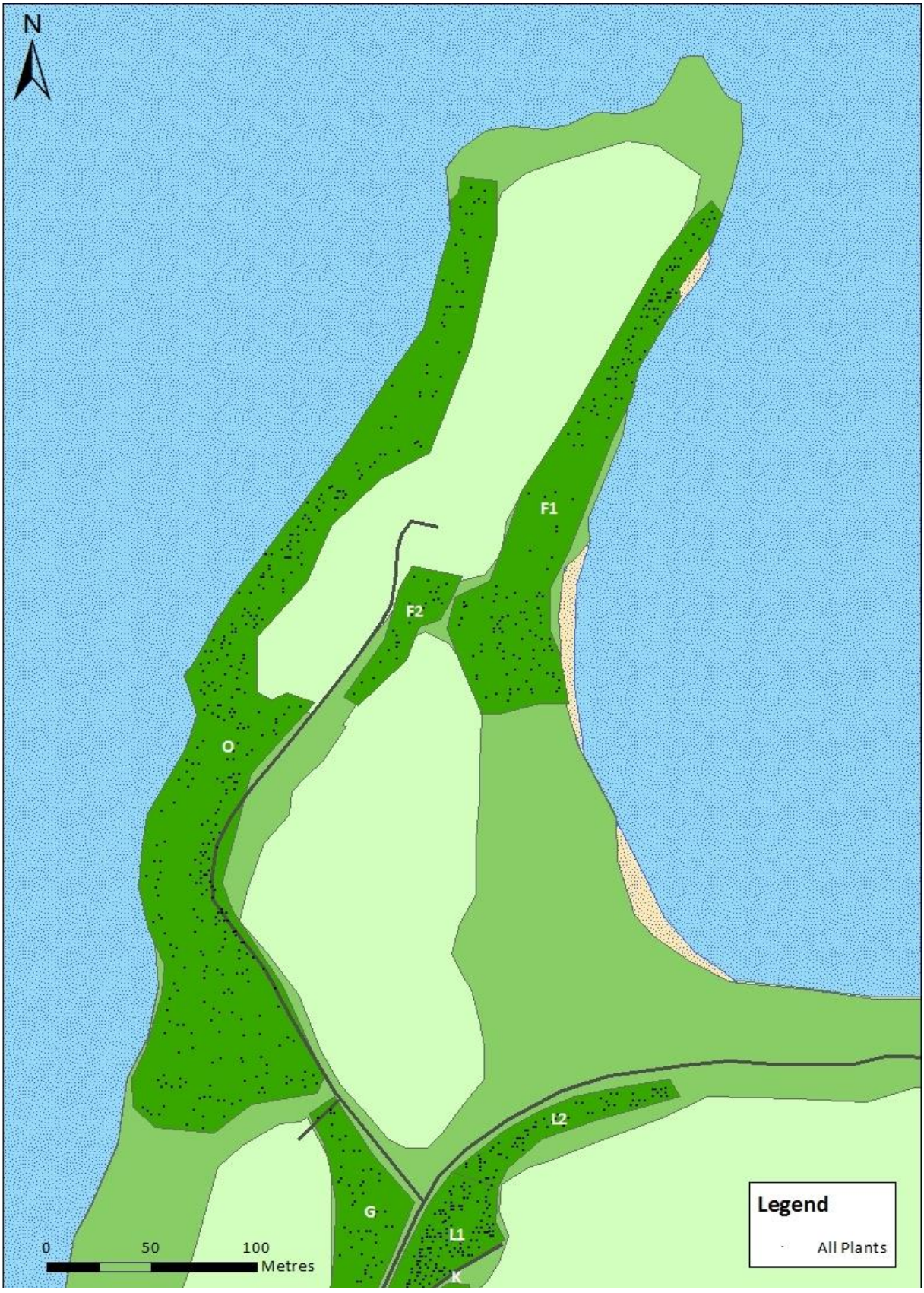

Figure 22: All plants F O.

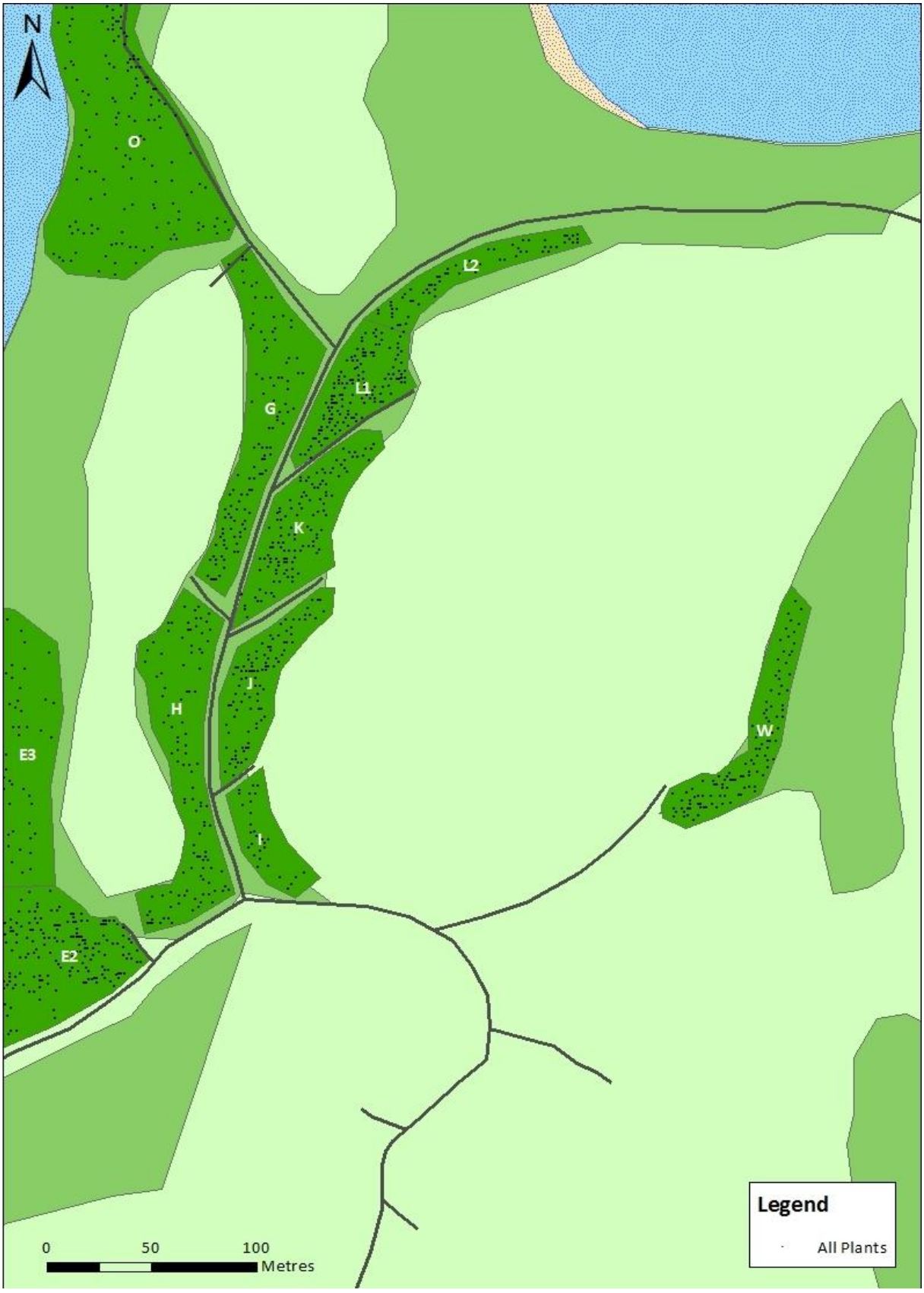

Figure 23: All Plants G H I J K L and W.

Figure 24: *Pittosporum* all areas.

Figure 25: *Pittosporum* A B C.

Figure 26: *Pittosporum* D E Toetoe.

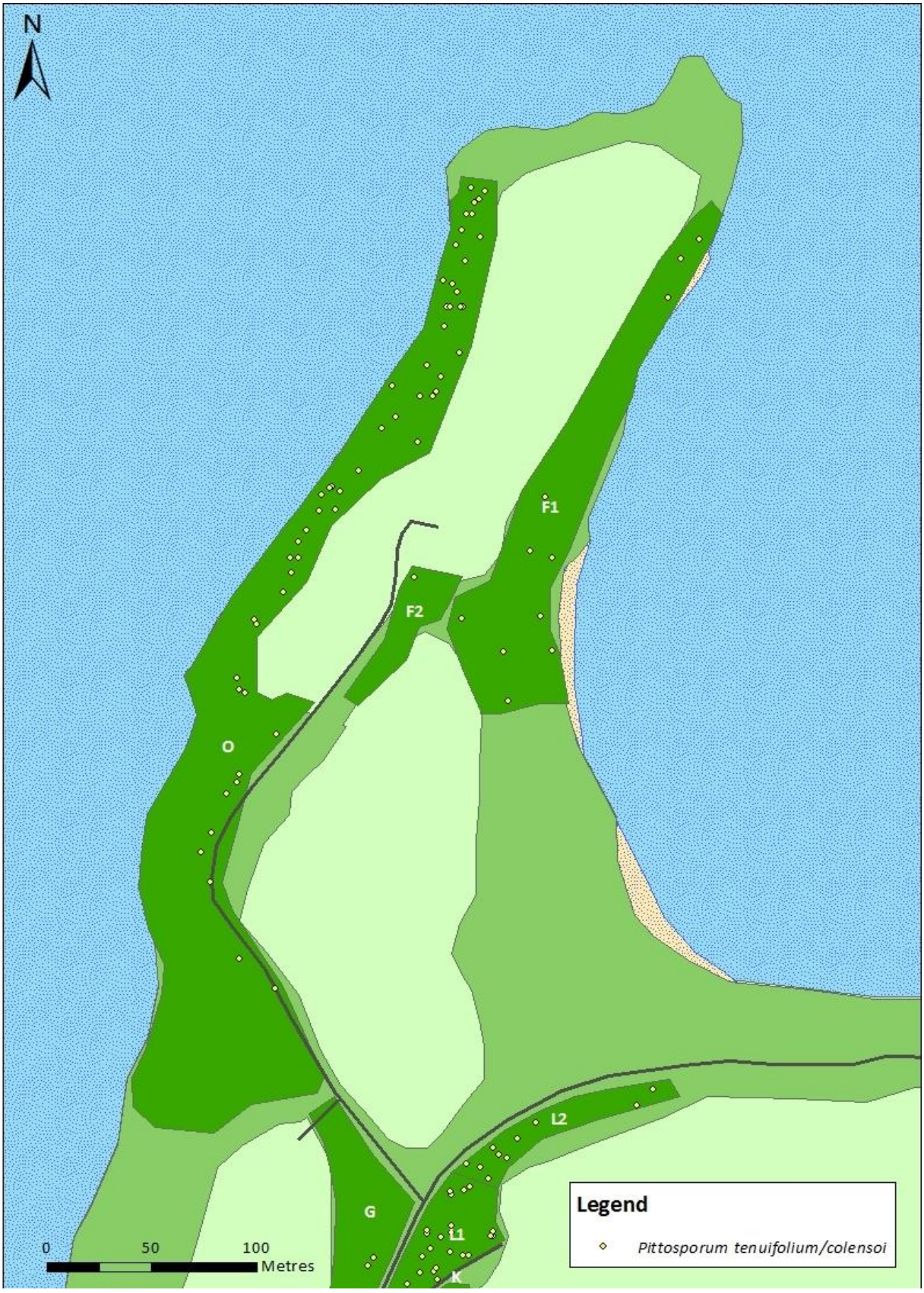

Figure 27: *Pittosporum* F O.

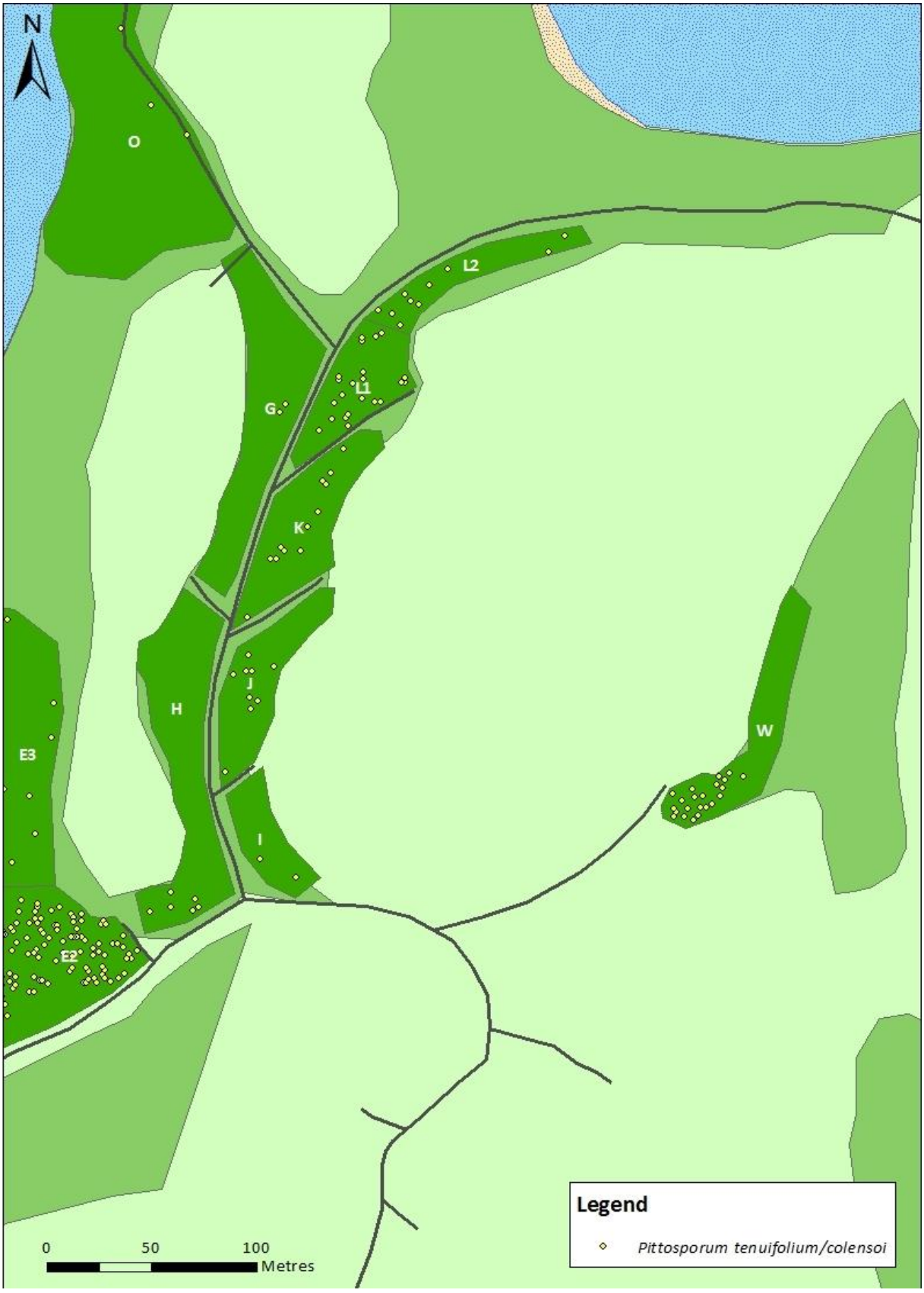

Figure 28: *Pittosporum* G H I J K L and W.

Figure 29: *Podocarpus totara* and *Cordyline australis* all areas.

Figure 30: *Podocarpus totara* and *Cordyline australis* A B C.

Figure 31: *Podocarpus totara* and *Cordyline australis* D E Toetoe.

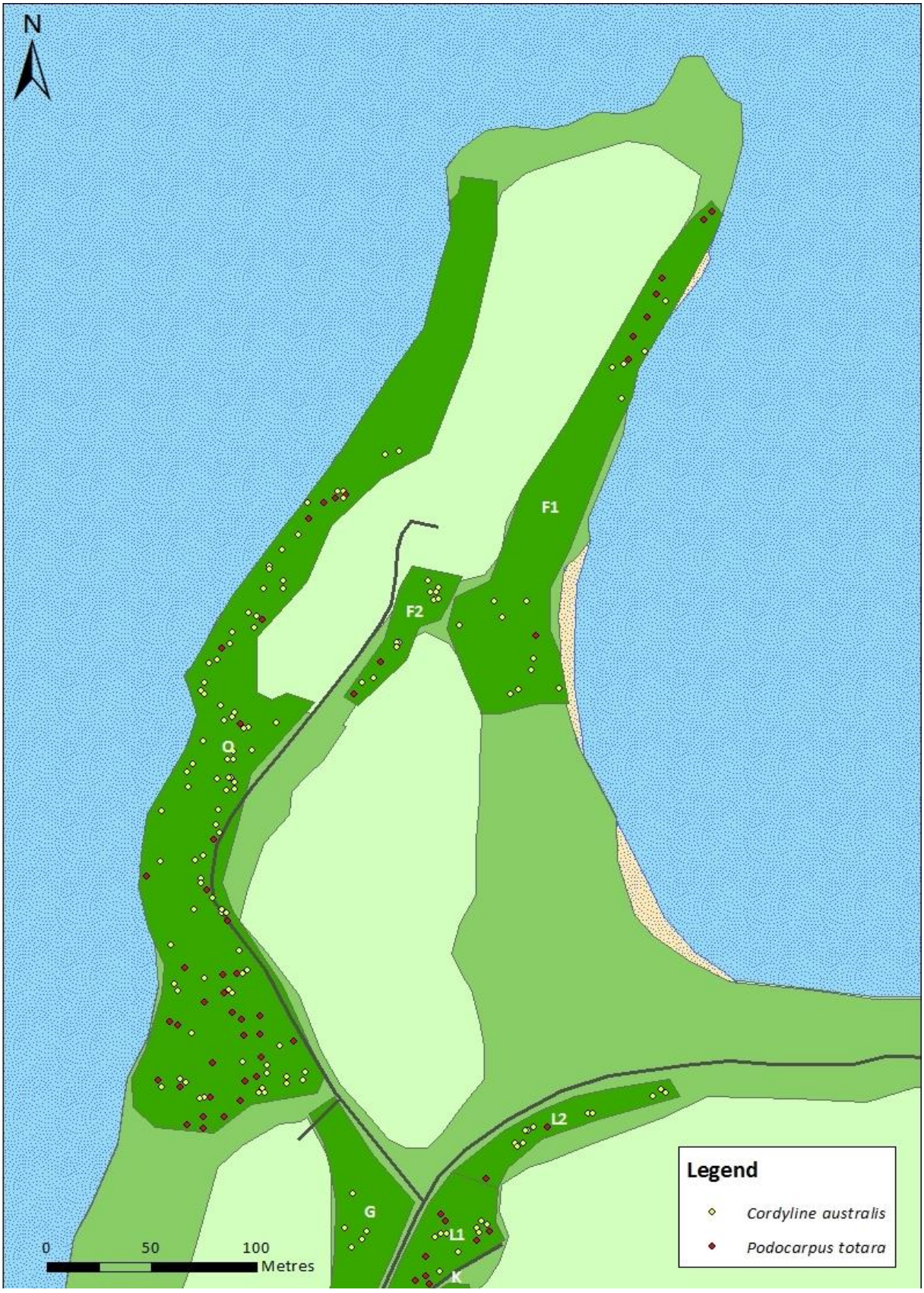

Figure 32: *Podocarpus totara* and *Cordyline australis* F O.

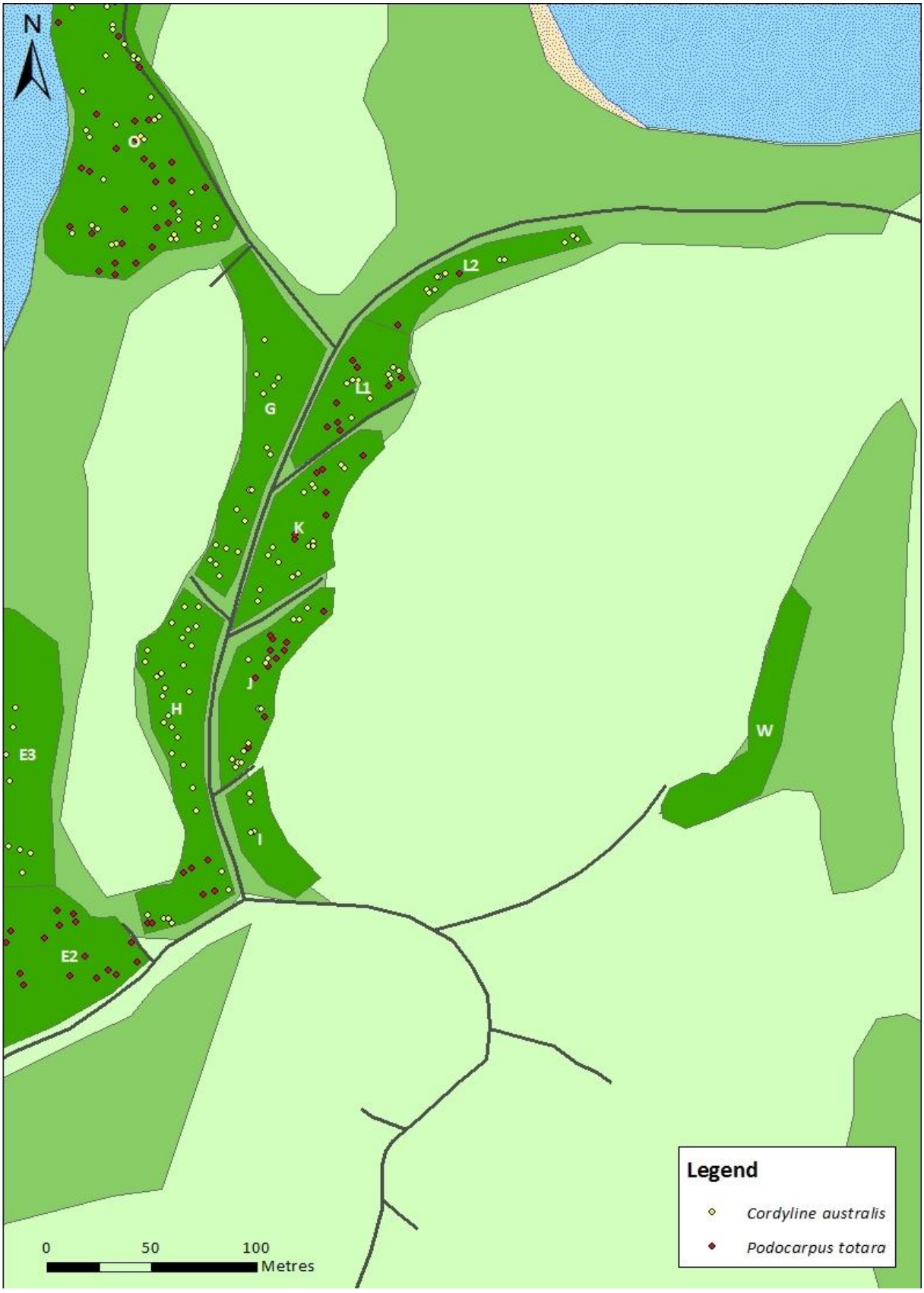

Figure 33: *Podocarpus totara* and *Cordyline australis* G H I J K L and W.

Figure 34: *Olearia dartonii, Olearia paniculata, Olearia traversii* all areas.

Figure 35: ***Olearia dartonii, Olearia paniculata, Olearia traversii*** **A B C.**

Figure 36: *Olearia dartonii, Olearia paniculata, Olearia traversii* D E Toetoe.

Figure 37: ***Olearia dartonii, Olearia paniculata, Olearia traversii*** **F O.**

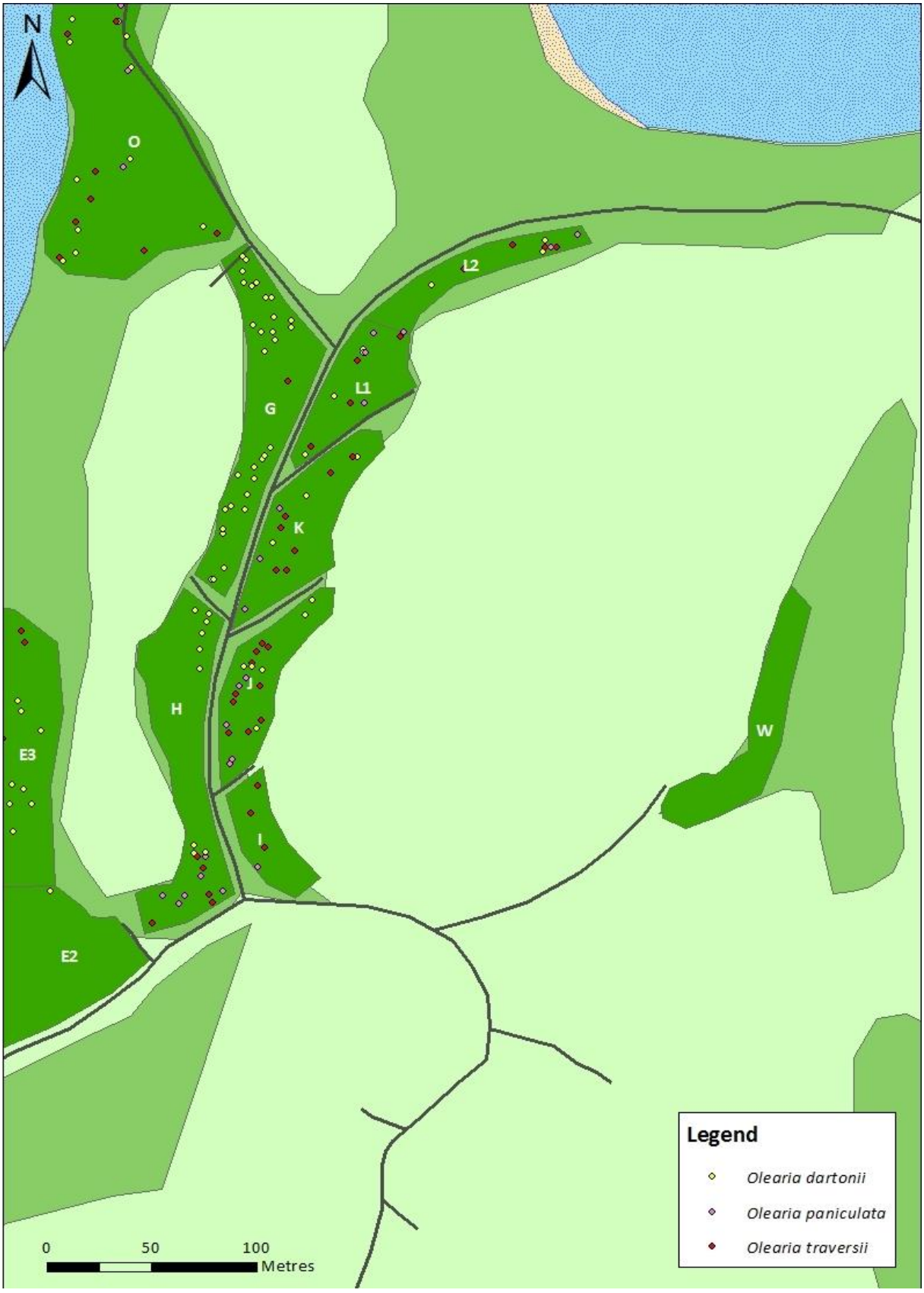

Figure 38: ***Olearia dartonii, Olearia paniculata, Olearia traversii*** **G H I J K L and W.**

Figure 39: *Kunzea ericoides* and *Leptospermum scoparium* all areas.

Figure 40: *Kunzea ericoides* and *Leptospermum scoparium* A B C.

Figure 41: *Kunzea ericoides* and *Leptospermum scoparium* D E Toetoe.

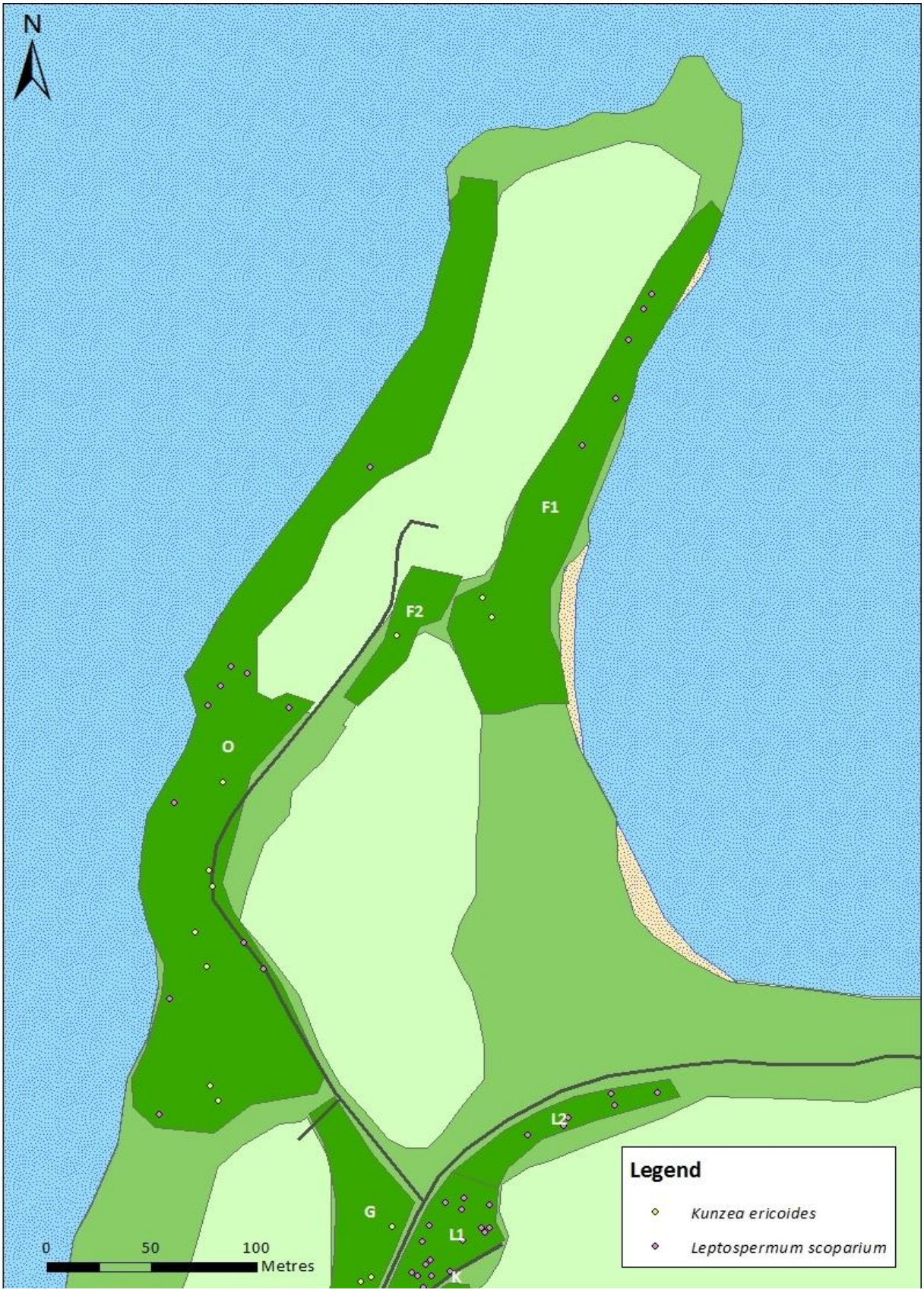

Figure 42: *Kunzea ericoides* and *Leptospermum scoparium* F O.

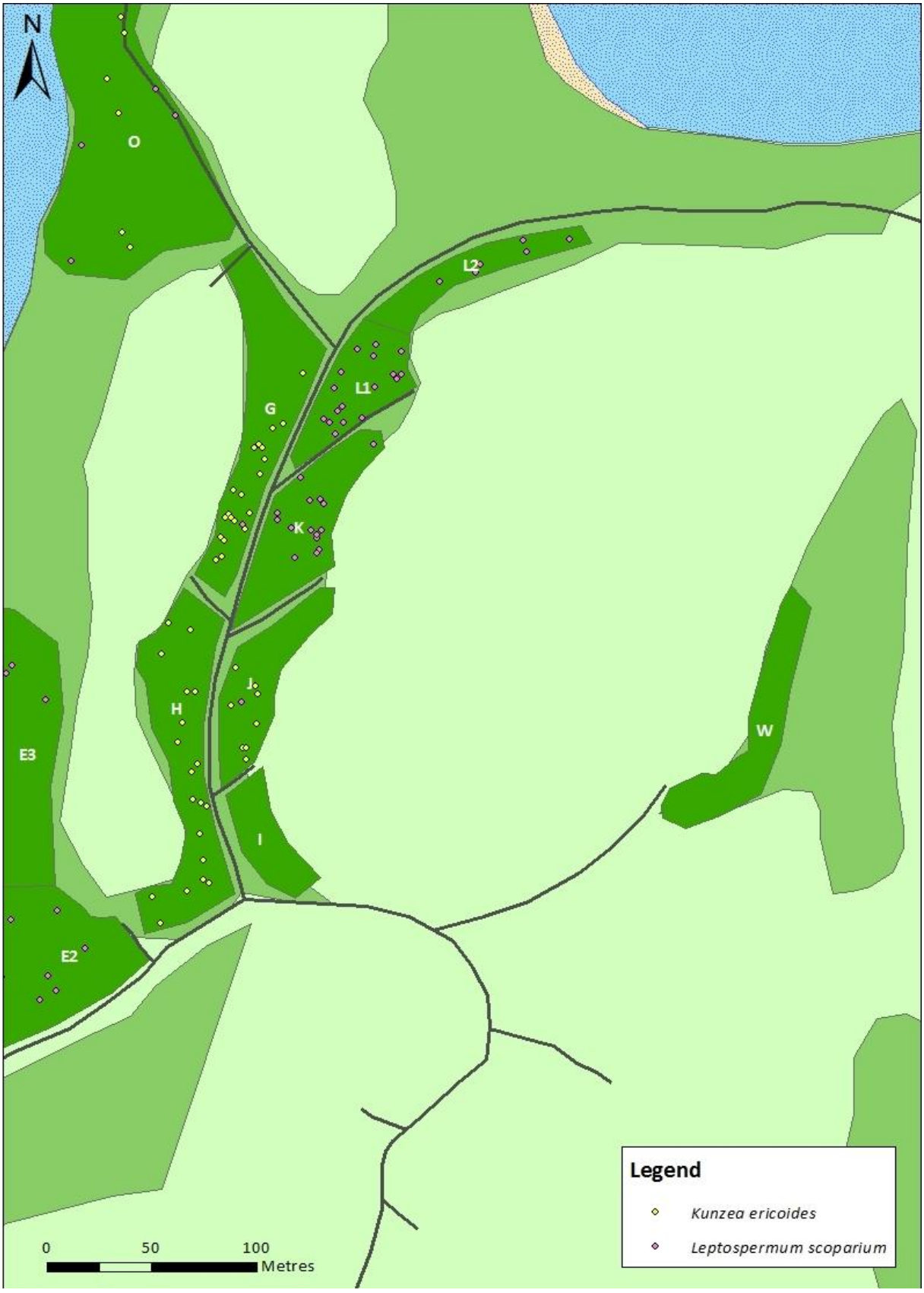

Figure 43: *Kunzea ericoides* and *Leptospermum scoparium* G H I J K L and W.

Appendix D: Predicted plant community composition of the original forest at Tūmai.

The predictive tool created by Allen & Wilson (1991) has been used to predict the probability that the following species were once present in the Tūmai forest before clearance for farming. The method used species lists from 86 forest remnants in East Otago which were then clustered into six 'Forest types'. Selection of the appropriate forest type for a given site was identified from (i) distance from the sea, (ii) exposure to onshore wind, (iii) rainfall, and (iv) geology (measured on a coarse scale).

When these predictors were applied for Tūmai, the model predicts that a 'Henley' coastal forest stood at Tūmai and that the probability of each of 54 main species is as shown in Column 4 of the Table A3 below. Column 5 shows whether the species is already present at Tūmai, based on the results of this survey. Column 6 shows whether that species was nominated in Wildlands' proposed restoration plan for Tūmai. The last column indicates the species currently missing from the restoration efforts so far which have a greater than 0.7 probability of having been present based on the Allen & Wilson model. These missing species could now become priority targets for future introductions, starting with those that can be expected to form part of the original forest canopy.

Table A3: Predicted original species composition at Tūmai and their planned and current presence at Tūmai.

Species	Māori names	Common names	Probability of having been present	Number of specimens detected in the survey described in this report	Proposed in Wildlands Plan	Adequate representation[†]
Clematis paniculata	Puawhananga	Native Clematis	0.91		No	X
Coprosma crassifolia			0.91		Yes	X
Dacrycarpus dacrydioides	kahikatea		0.87		No	X
Hoheria angustifolia	Houhere	Lacebark, Ribbonwood	0.87		Yes	X
Podicarpus totara	Totara		0.91	375	Yes	+
Prumnopitys ferruginea	Miro		0.91		No	X
Pseudowintera colorata	Horopito	Pepper Tree	1.00	54	No	X
Cordyline australis	Ti kouka	Cabbage Tree	1.00	371	No	+
Myrsine australis	Red Matipo, Mapou		1.00		Yes	X
Pseudopanax crassifolius	Horoeka	Lancewood	1.00	23	Yes	X
Asplenium bulbiferum	Manamana	Hen and Chicken Fern	1.00		No	X
Asplenium flabellatum		Necklace Fern	0.52		No	
Blechnum fluviatile	Kiwakiwa		0.96		No	X
Coprosma rotundifolia			1.00		No	X
Coprosma propinqua	Mingimingi		0.96	23	Yes	X
Coprosma linariifolia			0.96		No	X
Kunzea ericoides	Kanuka		0.83	223	Yes	+

Sophora microphylla	Kowhai	South Island Kowhai	0.74	92	Yes	X
Uncinia uncinata		Sedge	0.74		No	X
Pittosporum eugenioides	Tarata	Lemonwood	0.96	88	No	X
Aristotelia serrata	Nakomako	Wineberry	0.83		No	X
Muehlenbeckia australis			0.78		No	X
Parsonsia heterophylla	Kaihua	NZ Jasmine	0.96		No	X
Phymatosorus diversifolius	Kowaowao	Hound's Tongue fern	0.96		No	X
Pittosporum tenuifolium	Kohuhu		0.96	830¥	Yes	+
Polystichum vestitum	Puniu	Prickly Shield Fern	0.96		No	X
Blechnum discolor	Petipeti, piupiu	Crown Fern	0.87		No	X
Astelia fragrans	Kakaha	Silver Spear	0.74		No	X
Blechnum capense	Swamp Kiokio		0.57		No	
Blechnum minus	Swamp Kiokio		0.65		No	
Coprosma parviflora	Mingimingi		0.65		No	
Coprosma rhamnoides		Red Fruited Karamu	0.83		No	X
Hebe salicifolia	Koromiko		0.70		No	
Hymenophyllum multifidum		Filmy Fern	0.00		No	
Leptospermum scoparium	Manuka	Tea Tree	0.74	85	No	+
Microlaena avenacea		Bushy Rice Grass	0.43		No	
Podocarpus cunninghamii		Hall's Totara	0.63		No	

Pseudopanax colensoi	Orihou	Three Finger	0.48		No	
Hebe elliptica			0.00	36[£]	No	
Myoporum laetum		Ngaio	0.13	91	Yes	
Acaena novae-zealandiae		Bidi-bid	0.43		No	
Acaena juvenca			0.13		No	
Asplenium falcatum		Epiphyte, Sickle Spleenwort	0.70		No	X
Blechnum lanceolatum	Nini, Rereti	Lance fern	0.70		No	X
Cardamine debilis		NZ Bitter Cress	0.74		No	X
Coprosma areolata			0.63		No	
Hydrocotyle americana		Pennywort	0.83		No	X
Polystichum richardii	Pikopiko	Common Shield Fern	0.78		No	X
Ripogonum scandens	Kareao, Karewao, Pirita	Supplejack	0.30		No	
Rubus cissoides	Tataramoa	Bush Lawyer	0.91		No	X
Melicytus ramiflorus	Mahoe	Whitey Wood	0.91		Yes	X
Carpodetus serratus	Putputaweta		1.00	0	No	X
Fuchsia excorticata	Kotukutuku	Fuchsia	0.96		No	X
Griselinia littoralis	Kapuka	Broad Leaf	1.00	335[µ]	Yes	+

[†] 'Adequate representation' is scored where a species has a higher than 0.7 probability of having been present originally at Tūmai (Column 4) and currently having less than 100 specimens surviving from the first tranche of planting (Column 5).

[¥] This total includes 41 *P. colensoi* which were purchased, but potentially not distinguished from *P. tenuifolium* in the survey.

[µ]Includes 80 specimens of a variegated cultivar.

[£] This potentially includes a mix of *H. eliptica* and *H. buxifolia.*