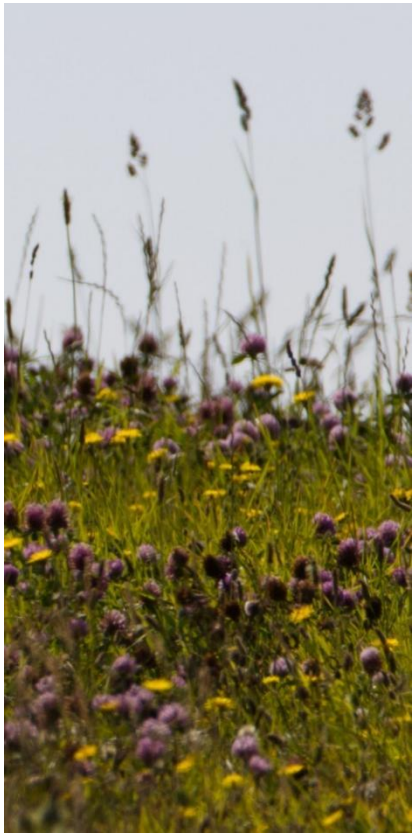
Environmental Enhancement at Tūmai Beach

A progress report and plans for 2024–2026.



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https://www.ecosystemsconsultants.co.nz/files/tumai-environmental-plan-2024-2026.pdf

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Executive Summary

The Tūmai Beach farm park is situated alongside Te Hakapupu (Pleasant River and estuary), 5 km north east of Waikouaiti and 45km north of Dunedin. It comprises of 16 private house lots surrounded by communally owned pasture and designated forest, tussock and estuary areas.

This report sets out the goals and general strategy for environmental restoration at Tūmai Beach for the coming two decades. It summarises successes and challenges to our restoration efforts to the end of 2023 to guide prioritisation of actions planned for the next three years.

The overarching goal of the Tūmai Environmental Enhancement Plan is to *create a self-sustaining coastal subdivision and ecological landscape.*

This will be achieved by *integrating ecosystem restoration and sustainable pasture production, while providing opportunity for people to enjoy their natural environment and contribute to its protection and enhancement*.

Tidal flows have been reinstated over 27 hectares of formerly reclaimed farmland and salt meadow communities are regrowing. At least 54,000 native woody plants and 13,000 native grasses, agaves and rushes have been established in communal areas since the farm park was established in 2009. At least 107 native plant species have been reinstated so far and native birds are appearing. Altogether we are around a third of the way to completing the re-establishment of a self-maintaining coastal native forest at Tūmai Beach farm park over half the communally owned ground in the farm park.

The Tūmai residents and all its helpers can justifiably feel very satisfied with the accelerated progress to enhance the Tūmai Beach farm park environment over the past three years. An adaptive management trial to learn how best to re-establish oioi (jointed wire rush) in South Arm of Te Hakapupu estuary has been established. Over 20,000 woody trees and shrubs have been planted in communal and private lots. Survival of the plants has been excellent over the last three years, averaging over 91%. Dense woody vegetation is in place to form a closed forest canopy over approximately 5 hectares in the coming 10-15 years. Sparser cover has been planted over all the remaining 12 hectares of retired pasture that is designated to become forest.

Despite encouraging progress, much work remains to be done. Each plant costs at least $10 to establish – this includes the cost of propagation, site preparation, planting and follow-up care. Our need for around 80,000 plants therefore requires an overall budget of at least $800,000 dollars, much more than 16 families that make up the Tūmai Beach farm park residents can muster on their own. Partnerships with external agencies and environmental restoration grants will be needed to help defray costs.

The main environmental enhancement priorities proposed for 2024-2026 are:

1. Secure establishment by releasing plants from smothering grass for at least their first three years.
2. If funding can be secured, start back-filling sparsely planted areas, first in the remaining estuarine margins, then further upslope.
3. Conduct an experiment to accelerate natural regeneration of native trees by supressing rank grass around the 'drip line' (canopy perimeter) of mature trees.
4. Erect signs and communicate the danger of fire to forest restoration, houses, and people.
5. Ongoing monitoring of oioi and woody plant survival, growth and spread.
6. Removal of invasive grasses encroaching on the farm pond.
7. Addition of walking tracks through newly planted forest areas.

Aside from these most urgent and important priorities, there are a series of ongoing actions that protect the investments already made and that will hasten success and deepen the value of our work, including:

- Maintaining farm stock exclusion.
- Introduced weed and pest animal control.
- Investing in connections and actions to support the wider catchment restoration efforts – a *Ki uta ki tai* (mountains to the sea) landscape ecology strategy.
- Increased education and precautions to avoid wild fire.
- Enriched pasture management and careful fertiliser management.
- Regular monitoring of the progress and success of our environmental care efforts and adaption of plans to reflect lessons learned.
- Increased scope and depth of research for improved environmental care.
- Vigilance regarding climate change impacts and evaluation of management interventions to mitigate them.
- Partnering with Kāti Huirapa Rūnaka ki Puketeraki to safeguard archaeological sites and restore the cultural values of the land.
- Provision of ecosystem services to support and restore the ecological integrity of the newly designated *Te Umu Kōau* Marine Reserve that includes the estuary surrounding the Tūmai Beach farm park.

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Environmental enhancement at Tūmai Beach

Tūmai Beach Farm Park

The Tūmai Beach farm park is situated 47 km north of Dunedin and about 5 km north-east of Waikouaiti (Fig. 1). "The land has outstanding rural and coastal views from a rolling hill landscape reaching 46m above *Te Hakapupu*, the Pleasant River, estuary and river margin"[1]. The eastern edge of the farm park is in a Coastal Landscape Preservation Area and there is a 20 metre esplanade strip bordering the estuary to maintain public access and conservation. *Te Umu Kōau*, a Marine Reserve, is being created between the Pleasant River Mouth and Stony Creek to protect the estuary flanking the Tūmai Beach farm park and inshore reefs along Tūmai Beach itself[2]. The marine reserve area extends into Te Hakapupu's estuary and includes the entire shoreline of the Tūmai Beach farm park, including the restoring South Arm. The Otago Regional Council, Kāti Huirapa ki Puketeraki Rūnaka, and local community embarked on a 5-year enhancement programme to improve the environmental and cultural health of the entire Te Hakapupu catchment, beginning in 2022[3]. Most of their actions to plant and manage the waterway are focused further upstream from the Tūmai Beach farm park, but their and our efforts nicely complement and will benefit each other.

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. Less than 10% of the original coastal zone vegetation of the Waikouaiti Ecological Area remains, so it is classified as an acutely threatened land environment[4]. Warm and fertile coastal sites where biodiversity will naturally flourish[5] are also important sites for recreation and environmental education. Re-insertion of woody vegetation in farming landscapes helps (i) stabilise land, (ii) reduce sedimentation and nutrient pollution of rivers, estuaries and near-shore ecosystems, (iii) slows the flow of water over the land, (iv) increases rainfall infiltration and improves resilience to drought and floods, and (v) protects the coast from seawater incursions and climate change. Complementary goals are to enhance both biodiversity and aesthetic value of the landscape.

Most of the building platforms and the mown pastures are on "undulating terrace tops"[6]. The farm park model designates parcels of productive land in communal ownership for hay or baleage, and steeper areas for planting of native forest and silver tussock (*Poa cita*)[7]. So far (January 2024) seven houses have been built on the 16 private lots (0.20 - 0.85 ha; average 0.5 ha). Private lots are surrounded by a 35.6 ha area that is co-owned in equal shares by all 16 lot holders. This communal land is managed by a 'Body Corporate' legal structure called *Tūmai Beach Services Ltd while the restoration programme is managed by Tūmai Beach Restoration Trust since July 2022 when it was*

[1] Moller & Moller (2012).
[2] South-East Marine Protection Forum (2018), DOC (2023).
[3] https://www.orc.govt.nz/our-council-our-region/projects-in-our-region/toitu-te-hakapupu-the-pleasant-catchment-river-restoration-project
[4] Walker et al. (2007).
[5] Moller et al. (2008).
[6] Robins, M.J. (2007).
[7] Moller & Moller, S. I. (2012).

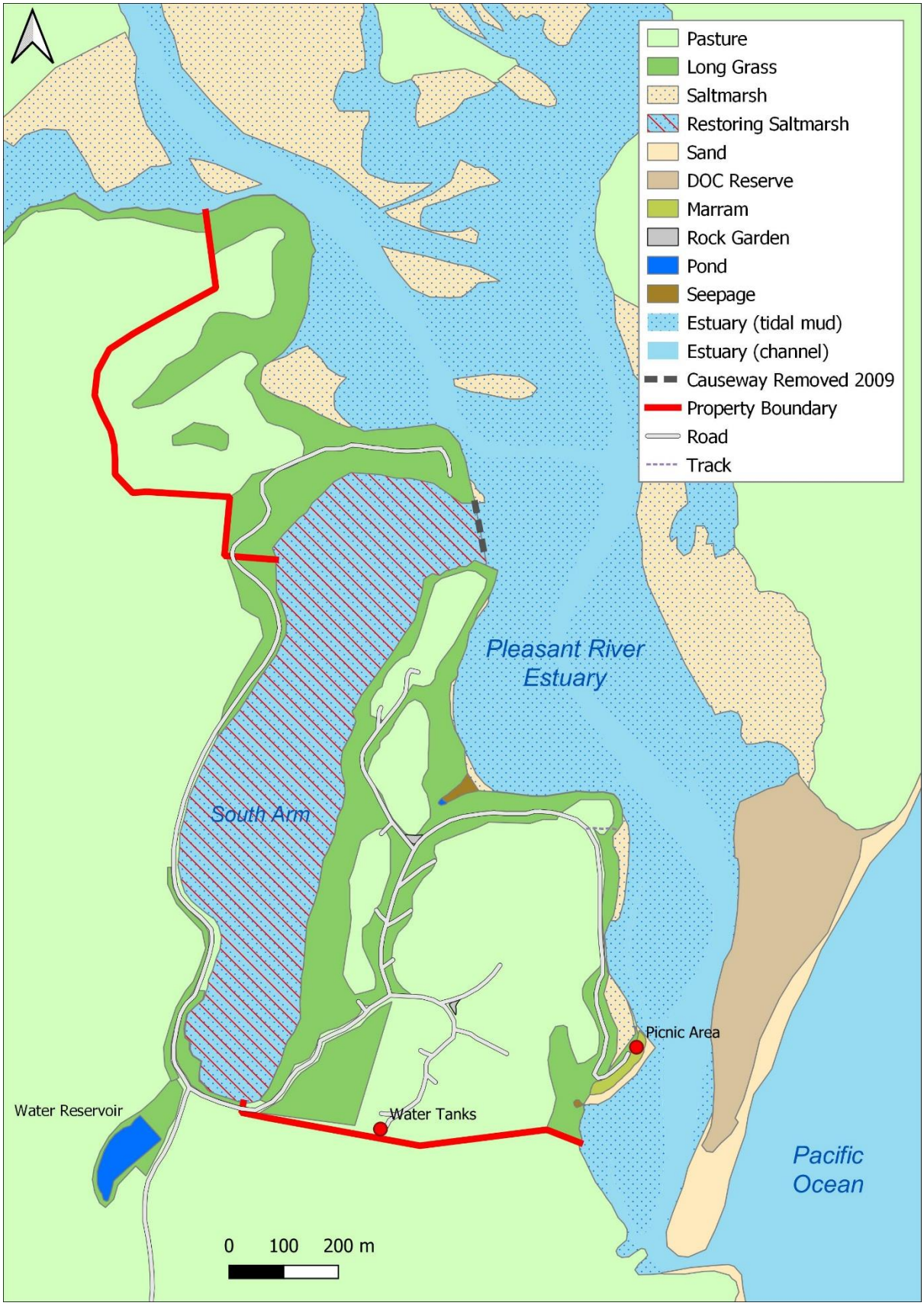

Figure 1: Overview of Tūmai Beach farm park at June 2021. Areas to the west of South Arm are no longer part of the Tūmai Beach farm park plans because Stage 3 of the original subdivision has been abandoned.

registered as a charitable trust. Restored forest and shrubland will be retained in perpetuity and public access to the esplanade strip on the estuary edge is legally guaranteed as part of the resource consent.

Planting of native species to cover approximately half of the farm park ground was a condition of the resource consent granted to develop the project in May 2008[8]. Removal of a causeway to reinstate tidal flows over 27 hectares of rough pasture at "South Arm" was also required and instigated in 2009 (Fig. 1). The relatively unmodified saltmarshes in the Otago Region have significant value in providing important habitat for indigenous invertebrates, fish, and birdlife[9]. Reinstatement of forest and the nearby estuary are expected to deliver a "net environmental gain" from the Tūmai coastal subdivision.

The Tūmai Beach farm park resource consent conditions effectively expired in January 2021. A Dunedin City Council planner & compliance officer and their Biodiversity Officer, who inspected the farm park on 2 August 2022, considered the restoration efforts to be exemplary. They concluded: "*In regards to the resource consent (SUB-2007-252 and subsequent variations), it is the opinion of the Council that the communal owners of Tūmai have satisfied enough of the conditions and proven future biodiversity investment at the site for the resource consent to be signed off*"[10].

Although no further restoration work is legally mandated, the Tūmai residents are resolved to fully restore an indigenous forest over around half of the communally owned land at Tūmai Beach farm park.

The *Tūmai Beach Restoration Trust* has been legally constituted to guide this ongoing environmental enhancement. The aims of the Trust are to (a) facilitate, oversee and manage the restoration of the ecological systems and native flora and fauna within the Tūmai Beach Farm Park; (b) benefit the community by maintaining facilities and providing access to the Tūmai Beach Farm Park; (c) benefit the community by promoting and encouraging conservation programs and values with the Tūmai Beach Farm Park; (d) promote pest management measures within the Tūmai Beach Farm Park; and (e) support and ensure the success of the Tūmai Beach Farm Park by assisting in the restoration of native flora and fauna in the surrounding areas (the 'halo') of the Tūmai Beach Farm Park.

Restoration plans are to be refreshed every three years to incorporate lessons learned, monitor progress and focus investment on the next most important priorities. This is the second such plan, to cover the 2024–2026 years. It was developed in consultation by all Tūmai owners and nearby farmers. This plan summarises progress to date and then sets the main priorities for environmental enhancement.

Enhancement goals

The overarching goal of the Tūmai Environmental Enhancement Plan is to ***create a self-sustaining coastal subdivision and ecological landscape***.

This will be achieved by ***integrating ecosystem restoration and sustainable pasture production, while providing opportunity for people to enjoy their natural environment and contribute to its protection and enhancement.***

[8] More detail of the history of the development and consenting process is provided by Moller et al. (2013).
[9] Otago Regional Council (1992, 2005); Patrick (1990, 1995).
[10] Email, 8 September 2022.

Environmental enhancement progress so far

Restoration of South Arm estuary

The causeway blocking tidal flows from South Arm was removed in 2009, immediately after the Tūmai Beach farm park development was consented. There were signs of a digger or tractor having been used to create deeper drainage channels in the inner reach of South Arm sometime between 2009 and late 2011. Occasional driving of four-wheeled motorbikes occurred in 2014, but driving vehicles on the soft sediments has since been actively discouraged by the Tūmai residents, in part by placement of large rocks at key access points. Therefore, only minor mechanical disturbance of the sediments has occurred since late 2009, and none whatever since 2014. Tracks of heavy farm machinery made at least 15 years ago remain evident in 2024. They are gradually fading by infilling and erosion of their margins by the tide, but they are a poignant reminder that estuarine substrates can take decades to heal after disturbance (Fig. 2).

Residents have noted a distinct increase in the water levels during high tides over the last decade, suggesting that some natural scouring of the outer reaches of South Arm has occurred and that more seawater is now flushing the ecosystem.

Although Tūmai is in a rain shadow cast by the surrounding ring of mountains, occasional heavy downpours cause flushes of freshwater (Fig. 3). Three streams drain into South Arm via outlet pipes laid under the access roads, two of which have a (partially effective) one-way valve to prevent much of the saltwater flowing into the surrounding paddock streams during high tide.

Glasswort (*Sarcocornea quinqueflora*) is naturally recolonising the disrupted soft substrate areas around the edges of South Arm, especially along its eastern flank. It is likely to cover most of the inner areas of South Arm in the next ten years without our help, but it is unknown how much of the more exposed outer reaches of South Arm will be colonised. A new raised road was constructed down the western flank of South Arm in 2009 to facilitate development of North Point, so much of that estuary edge is formed by imported and compacted rock spoil. Fragmented and narrow strips of glasswort beds are present there, but it is unknown if a natural substrate is forming and whether glasswort will prosper there.

Oioi (jointed wire rush)[11] is likely to have occurred in South Arm before being eliminated by cattle and sheep grazing following placement of the causeway in the 1950s. A first priority[12] identified in the 2021 – 2023 Tūmai Beach Environmental Enhancement Plan[13] was to re-establish small nursery areas of oioi scattered throughout the restoring South Arm from where natural spread would recreate extensive oioi beds to help improve water quality, trap sediments, provide fish spawning habitat, support invertebrate diversity and sequester carbon.

[11] Taxonomic, Māori, and common names of species planted at Tūmai farm park since 2009 are listed in Appendix 1.

[12] Priority settings in the 2021-2023 Environmental Enhancement Plan were referred to as 'stages' to reflect the relative urgency of each restoration aim. However, funding opportunities and practical constraints forced a more mixed strategy where work on some stages began before earlier priorities were completed.

[13] 'Stage 1' of TBEEG (2021).

Figure 2. A view of the mid-section of South Arm in October 2021. Wheel ruts from heavy machinery driving on the sediments in or before 2009 remain obvious during mid tide periods. Glasswort beds are gradually spreading from the margins. The green and yellow patches are drying mats of algae.

Figure 4. Flooding of the main road into Tūmai Beach farm park on 21 July 2017. The head of South Arm is to the right of the road. Rainwater flowing from neighbouring farms has accumulated to be approximately 4 m deep to the left of the road. Photograph by John Prescott.

Before planting oioi, we conducted a literature review and consulted 20 experts with experience in propagating oioi, and/or restoring estuaries and brackish wetlands with oioi[14]. The review predicted that oioi planted at lower elevations in glasswort beds would be stressed by more frequent and prolonged inundation by tidal flows and consequent hyper-saline soils. However, oioi may also escape competition by introduced plants that cannot cope as well with the more saline conditions at lower elevations. Conversely, survival and spread of oioi planted just within the terrestrial zone (just above the glasswort delineation of the estuary edge) may suffer increased competition from weeds, especially introduced grasses. Closer spacing of plants may increase survival and growth by reducing competition, but also reduce the rate of spread of oioi. Survival and growth of Oioi was predicted to increase where tidal flows were diluted with freshwater inflow.

The review emphasised that oioi was a particularly difficult plant to establish in estuarine systems and that predictions are tentative and outcomes site specific. Accordingly, we established two formal 'adaptive management' experiments to measure these potential trade-offs and to advise on the most cost-effective planting strategy to maximise establishment and rate of spread of oioi in Te Hakapupu.

The main experiment compares survival, growth and spread of 1,664 oioi planted in November 2022 in South Arm. Oioi were planted in 208 quadrats, each with 8 stems, at randomly chosen spots blocked within 4 zones of the estuary and an inflowing brackish stream (Fig. 5). Quadrats were randomly assigned between two elevations ('Upper' vs lower') and three spacings (0.25 m, 0.5 m or 1.0 m apart)[15]. The 2021-2023 environmental plan had envisioned just 200 oioi trial planting, but funding input from Otago Regional Council and support from Kāti Huirapa Rūnaka ki Puketeraki made this expanded trial possible.

A second experiment tests whether seasoning of 80 nursery-grown oioi with different concentrations of seawater could enhance their ability to withstand sudden salt shock when first transplanted into hyper-saline soils[16]. If so, restoration of oioi will be more cost effective and oioi might be planted in a much larger proportion of the degraded estuary sediments.

Survival, growth and spread of the experimental plantings will be monitored at six monthly intervals until winter 2025, when a report and recommendations for an adaptive management approach to re-establishing oioi in *Te Hakapupu* and other degraded estuaries will be published. Establishment of this experiment means that Priority #1 of the 2021-2023 Tūmai Environmental Enhancement Plan is complete, other than a requirement for continuous monitoring.

Fifty-nine 'Salt grass' (*Puccinella stricta*) clumps were planted in the upper reaches of the South Arm's saltmarsh meadow (Fig. 7). This is a native species that also occurs in Australia. It thrives in saline conditions and is common down the eastern coast of Te Wai Pounamu, as well as at some inland saline soils of Otago. These plants were a gift from the Puketeraki Native Plant Nursery, operated by Kāti Huirapa Rūnaka ki Puketeraki at Karitāne.

[14] Young et al. (2023).
[15] Moller et al. (2023).
[16] Moller et al. (2023).

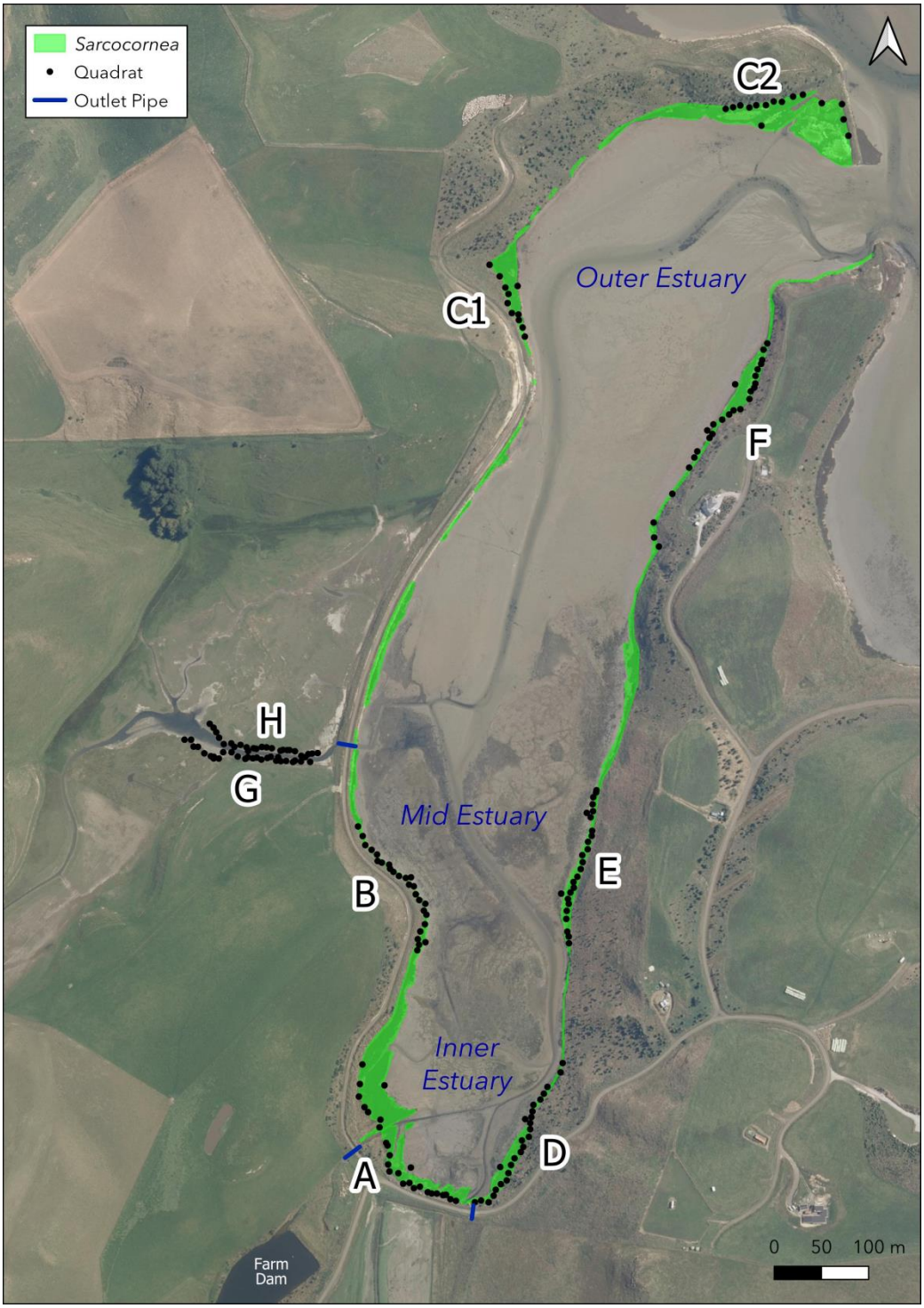

Figure 5: Arrangement of experimental oioi planting quadrats around South Arm, Te Hakapupu. Each quadrat received eight oioi plants, spread equally across eight zones (A-H). Two zones were placed along the margins of McWilliam Stream, and two zones in each of three strata ('Inner', 'Mid' and 'Outer' Estuary) to stretch the experiment across maximum tidal inundation frequencies. Matching zones were placed on opposite sides of the estuary and stream. Zone C was divided in two because a stretch of steep and rocky shoreline prevented establishment of glasswort there. A detailed description of the adaptive management trials is provided by Moller et al. (2023).

Figure 6. Locations of fourteen Puccinella stricta *clumps planted in the upper reaches of South Arm, November 2022. Each clump had 4-5 individual tussock whorls and were placed on the terrestrial side of the uppermost* Sarcocornea *bed (dark green zone).*

Restoration of ecological communities in wetter terrestrial zones

The second priority of the 2021-2023 environmental enhancement plan was to establish wet tolerant species around a small pond and associated wet drainage area, a small seep, and around the farm dam from which the residents draw water (Fig. 1). *Carex secta* was planted around the pond margin in 2022 and have flourished (Fig. 7). Planting of harakeke (*Phormium tenax*), Ti kouka (*Cordyline australis*) and Kahikatea (*Dacrycarpus dacrydioides*), all wet tolerant species, was completed in 2023 (Table 1)[17]. Assuming successful establishment, specialised planting of these wetter terrestrial areas is now complete. Grass will be removed from the margin of the pond and invasive algae suppressed in the 2024-2026 environmental interventions if possible.

Figure 7. Planting around the margin of the small pond within the Tūmai Beach farm park communal land, February 2024. The Carex secta *planted around the margin have reached 1 m tall. A thick mat of Lemna and green algae bloomed after a hay bale (now removed) rolled down into the pond from the nearby mown pasture. Pasture grasses are beginning to encroach from the edges.*

[17] Additional planting was conducted around the North Tūmai farm's dam from which the Tūmai residents draw water is not covered by this plan. This was a collaboration between the McWilliam farming family and Tūmai residents.

Table 1. Staging priorities for ecological restoration at Tūmai Beach farm park and their degree of completion by end of 2023.

Priority	Strategy	Approx. area (ha.)	% completed (December 2023)	Actions
1	Reintroduce saltmarsh species within South Arm estuary	NA	100%	Oioi review and planting trials established; monitoring now in progress for two more years before decision on whether to plant more or in different places; Seagrass planted.
2	Plant wet-loving species in freshwater seeps and around ponds	0.5	100%	Two wet areas planted with Kahikatea, Ti kouka, harakeke and toetoe; North Tūmai Farm dam margin planted; Barrier of dense vegetation still to be planted around the Tūmai Beach farm park pond for child safety.
3	Consolidate existing planting in estuarine margin zone	1.0	100%	Entire partially planted margin of inner and mid sections of South Arm completed; supplementary planting on outer South Arm and northern tip and eastern flank of "Airstrip Point" still needed.
4	New planting in estuarine margin zone	6.0	15%	All the remaining estuarine margin has been sparsely planted, but 75% of that area still only has approximately quarter of the target final stem density.
5	Consolidate existing forest planting on inland hillslopes	2.0	40%	Three quarters of early planting area has received targeted full stem density needed to achieve complete canopy closure.
6	New forest planting on inland hillslopes	7.5	15%	All areas designated for eventual forest have received sparse cover, but only at ca. 15% of the stem density required to achieve complete canopy closure.

Restoration of terrestrial communities along the estuarine margin

Tūmai Beach farm park has a long estuary edge. It stretches 1,245 m from the head of the restoring South Arm to its mouth (where a causeway was constructed in the 1950s to 'reclaim' the estuary for farming). Another 1,494 m of estuary edge stretches from the old causeway to the southern boundary of the farm park near where Te Hakapupu (Pleasant River) flows into the sea (Fig. 1).

This narrow strip is important ecologically for filtering nutrients and preventing sediment getting into the estuary. Estuarine margins also harbour a unique shrub community that changes over a short distance between the saltwater inundation zone to a fully terrestrial ecosystem. The boundaries between habitats ('ecotones') are usually more biodiverse and often harbour species that can exploit the in-between conditions of both habitats. The third and fourth priorities of the 2021-2023 Tūmai environmental plan were to plant ecologically appropriate species in this important 10-30 m wide strip that provides ecological transition between estuarine and terrestrial ecosystems[18].

One such species at Tūmai is the Saltmarsh Ribbonwood (*Plagianthus divaricatus*), a medium-sized shrub that copes with salty conditions and periodic flooding. It is amazingly resilient and grows fast. A few large specimens of the saltmarsh ribbonwoods persisted along the edge of South Arm before the farm park development, but Tūmai residents have accelerated its recovery by planting 350 stems of in clusters within a 3-5 m strip along the entire 2.7 km estuary edge around the farm park in 2022 and 2023[19] (Fig. 8).

Planting is targeted to be especially dense along the estuary margin to hasten ground coverage and scrub and forest establishment to prevent run-off and sedimentation of the estuary. Interplanting with harakeke, toetoe, native shrubs (*Veronica* [hebe] and *Coprosma* species) and saltmarsh ribbonwood was completed on all sections of the estuarine strip that had some surviving trees from the 2009 planting. Priority #3 of the 2021-2023 plan was therefore 100% achieved (Table 1).

We had hoped to prioritise planting in new sections of the estuarine margin (Priority #4), but our funders focus mainly on maximising carbon sequestration and therefore required our main emphasis to be planting tree species that reached at least 5 m tall at maturity. We were able to plant a sparse cover, mainly of saltmarsh ribbonwood, along new areas of the estuarine margin but we estimate that only 15% of our Priority #4 has so far been achieved (Table 1).

A gradual gradation from shrubs on the very edge of the estuary to forest trees further upslope is envisioned, partly for biodiversity, but also for aesthetic and recreational enjoyment. Public have a right to access this 20 m esplanade strip and residents often walk along the margin of the estuary to enjoy the light and impressive variety and abundance of birds that feed on the estuary's soft sediments. A walkway was formed along much of the eastern flank of South Arm in 2022.

[18] Stage # 3 was consolidation of estuarine margins already with some woody plants, Stage # 4 was first planting of the marginal stip.

[19] We thank Dylan King and Alice Raffilles ("For the Love of Trees", Hawkesbury Village) for donating some of the saltmarsh ribbonwoods to supplement those from The Queen's Platinum Jubilee gift provided by Trees that Count.

Figure 8. The estuary edge and adjacent terrestrial zone of scrub transitioning to forest further upslope in the upper reaches of South Arm. A mature saltmarsh ribbonwood is on the right. A continuous glasswort meadow (foreground) is maintained up to the high spring tide limit by periodic tidal inundation by saltwater and resulting hyper-saline soils. The highest oioi quadrats are planted at the very edge of the grass and shrub community flanking the flooded soft sediments (Fig. 5), but it is unknown whether competition will prevent them naturally spreading into more elevated and unsalted soils of the terrestrial strip.

Introduced broom (*Cytisus scoparius*) threatens to smother a remnant of coastal shrub at the northern tip of the Tūmai Beach farm park peninsula. The Tūmai residents have been cutting and removing the broom before seed shedding each year to gradually deplete the broom's seed bank. The volume of newly sprouted stems removed each year is steadily declining, so our goal to fully eradicate the weed is likely to be achievable in the next 10 years.

Restoration of coastal forest

The biggest and most time-consuming restoration priority set in 2021 was to re-establish indigenous forest over around half of the communal area of Tūmai Beach farm park. We concentrated first on restoring woody vegetation close to the estuarine margins, and then progressing upslope to abut the private lots where houses are built.

Within these zones, we are first infilling between the 2009 planting areas (2021-2023 Priority #5), partly because the scattered surviving trees, like those shown in Fig. 9, provide some shelter for small new plants. Also, existence of some woody vegetation means that more rapid canopy closure can be achieved there to trigger natural regeneration. Approximately 8,000 woody plants were planted amongst the scattered existing trees in May and July 2022. This completed the infilling of about 40% of area targeted for Priority #5.

The most challenging areas for afforestation are entirely abandoned pasture further upslope (Priority #6) where salt-ladened NE winds, drying warm north-westerlies, and exceptionally cold southerly winds, all can kill new plants and slow the growth needed to escape smothering by rank grass. We have learned that tall and strong plant protectors, anchored by two stakes, sheltering and also protecting against pests, are crucial to ensure the survival and establishment of most species in these areas.

Figure 9. Surviving tree cover in 2021 following initial planting in 2009. Poor survival of initial planting efforts in 2009 led to an incomplete and patchy spread of trees with rank grass in between. The dense grass sword is preventing natural regeneration to complete an ecological succession to form a fully functioning forest, so much of the effort since 2021 has been to plant the gaps between these first established trees.

A broad range of forest tree species were planted in 2022, initially at high planting density (1.3 – 1.5 m spacing between stems) to accelerate establishment of a reasonably representative forest composition and to allow for some plant failures. Our strategy was to create something close to the final multi-storied and species-rich forest structure from the outset i.e. an intensive and 'active' environmental management investment strategy to achieve a fast outcome.

A change to a more 'passive' strategy was adopted from the second half of the 2022 planting season in which we greatly increased spacing between plants and restricted the range of species planted as follows:

- 3,000 stems were planted in 'Rotary #1' and 'Rotary #2' patches at 1-5 m spacings in late October 2022 (shown in red in Fig. 10). Plants were more tightly spaced on the steeper bank margins of Rotary #1 that flank the main road leading into the Tūmai Beach farm park, but the overall average spacing was 3.1 m. This resulted in a stem density of 1,077 plants per hectare for the combined patch area of 2.4 hectares.
- 5,060 stems were planted at 2-5 m spacing (average 3.9 m) in September and October 2023 across 5.1 hectares (shown in green in Fig. 10).
- A full range of trees and understory shrubs were planted in October 2022, but only five main species were planted in 2023 i.e. Ngaio, Ribbonwood, Lemonwood, Tōtara and Broadleaf[20]. These were selected because they had proven to (i) survive well at Tūmai, (ii) be resistant to rabbit and hare browsing, (iii) grow fast to escape smothering by grass, and (iv) produce a spreading crown.

[20] See Appendix 1 for taxonomic, Māori, and common names of plants introduced to Tūmai farm park.

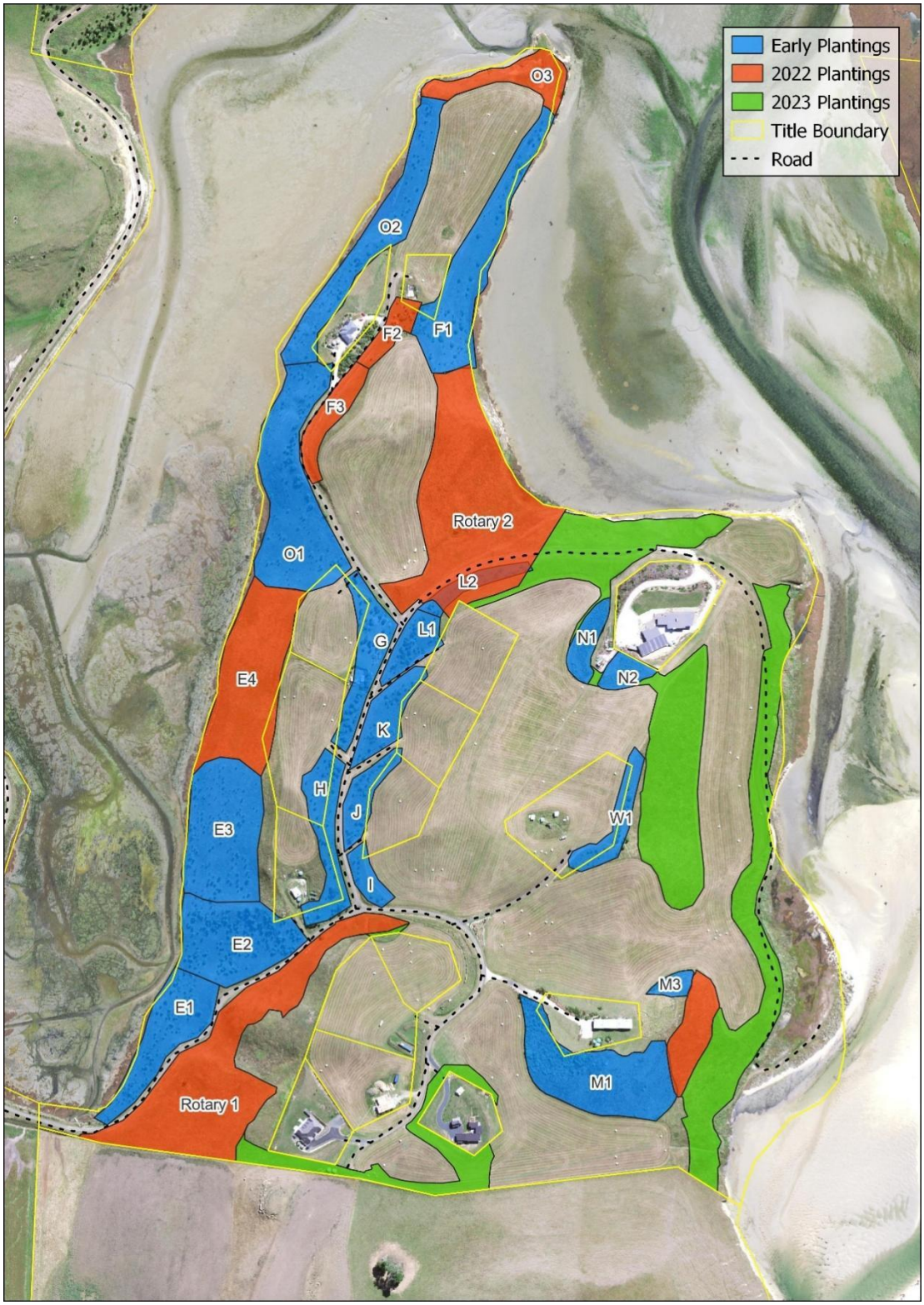

Figure 10: Forest areas planted by the end of 2023. 'Early plantings' (areas in blue) occurred mainly in 2009, 2013 and 2015, but have been continually enriched with more planting every year since. Thirteen thousand trees were planted at medium to high density in 2022 (mainly in areas coloured red). Five thousand trees were planted at medium to low density in 2023 (areas in green). The photo underlying the map was captured on 14 March 2021 by Landpro for Environment Canterbury and made available through the LINZ Data Service. Polygon labels were used to prioritise planting in the 2021-2023 plan which provides more detailed counts of species and stems for each area.

This new strategy for planting fewer species at lower density was reluctantly adopted because it had become apparent that closer planting of a wider range of species was going to be too immediately time consuming and too expensive to achieve our goals, even within 10-20 years[21]. Volunteers and residents were exhausted by the pace of planting and demands for aftercare. Complete coverage of the areas designated for forestry would require a further 80,000 plants if our original strategy of high initial plant density was pursued[22].

A sparser and more gradual planting strategy aims to reduce costs and labour requirements by capturing natural ecological forces of a slower and managed succession. We expect that the primary and sparse cover created will cradle subsequent "back-filling" and species enrichment in the coming years by creating shelter from persistent and salt ladened winds. Shelter will improve prospects for establishment of more vulnerable and slow growing species later. By initially choosing broadly crowning species, we seek to hasten canopy closure that naturally eliminates the rank grasses at Tūmai and thereby improves survival and growth of new plantings. Our ultimate goal is to enable natural regeneration of the forest driven mainly by seed dispersal by birds rather than our expensive and exhausting intervention. Our restoration goals will now take longer to achieve, but risk of burnout is reduced and the eventual total cost will be less if natural regeneration can be triggered.

The 2021-2023 plan estimated that 97,000 more plants would be needed from the end of 2020 to achieve the full canopy closure on communal areas designated for forestry and the shrub communities along the estuary margin[23]. Since then, at least 20,685 woody plants and more than 1,000 non-woody plants[24] have been added which equates to having achieved approximately 22% of the extra plants needed[25]. At least 12,454 woody plants and 500 non-woody plants had already been established on communal land before 2021[26]. Therefore, the target of 110,000 plants is now approximately 32% complete.

Wider spacing allowed the 8,276 stems planted since late 2022 to stretch over all remaining areas targeted for eventual forest cover at Tūmai Beach farm park. Although this represents a major milestone in reaching our final goals, much back-filling by interplanting remains to be done (Table 1). We estimate that only 15% of Priority #6 was achieved by the end of 2023 (Table 1).

[21] The cost and time required for releasing plants was underestimated and could not be covered despite receiving generous grants from 'Trees That Count', Rotary Forest Trust and Tūmai residents, The Kiwi Gaming Foundation and Bendigo Valley Sports and Charity Foundation.
[22] Sparse planting remains in polygons E3, E4, F1, F2 and F3, O2 which were planted in earlier years, as well as within the Rotary forests that were planted in 2022 and the remaining areas planted in 2023.
[23] Table 2, p15 of TBEEG (2021).
[24] Harakeke, toetoe, *Carex secta* planted along road and estuary margins are included; oioi and Saltgrass planted in South Arm estuary have not been included.
[25] Counts in Table 2 are underestimates because of incomplete records, especially in earlier years. Formal planning and reporting to grant awarding bodies in the last three years ensured that the 2021-2023 figures are accurate.
[26] Table 2 records the total of woody species planted in 2009 based on nursery receipts. However, a complete survey in 2013 showed that only 32% of theses successfully established (Moller et al. 2013). Over 8,000 native tussock grasses planted in viewing chutes are not included in these totals, but harakeke and toetoe and Carex secta planted along are included.

Table 2. Native species planted at Tūmai Beach farm park, 2009-2023.

	Woody species		Grasses, rushes, agaves	
Year	**Communal**	**Private**	**Communal**	**Private**
2009	13,248[1]	0	600[2]	0
2013	4,568[3]	NR	0	NR
2014	0	NR	4,500[3]	NR
2015	0	NR	3,500[3]	NR
2016	105	958[3]	316	230
2017	1,200[4]	238	0	255
2018	151	NR	274	NR
2019	998	NR	NR	NR
2020	1,193	74	NR	NR
2021	894	166	469	NR
2022	14,583	683	2,057[5]	71
2023	5,208	1707	339[6]	360
Total	**42,148**	**3,826**	**12,055**	**916**

[1] As reported from Nursery Receipts. An ecological survey in summer 2011/12 that showed that 4,568 (32%) successfully established Moller et al. (2013).

[2] Not recorded by developer. This is an approximate estimate from surviving toetoe at the head of the South Arm estuary.

[3] Counted as planted by residents.

[4] Planted by Developer. This estimate based on number surviving in a rapid survey in 2018.

[5] Includes 1,664 oioi and 59 Saltgrass clumps planted in South Arm estuary (Moller et al. 2023).

[6] Includes 80 oioi planted in South Arm estuary for a salt seasoning trial (Moller et al. 2023).

NR = Not Recorded.

Planting house gardens and road margins

The above review of progress has focussed entirely on the restoration efforts in the communally owned ground at Tūmai Beach farm park. Several families have also planted indigenous woody species and native grasses within their private house lots (Table 2). Ecological flows disregard legal ownership boundaries, so these private plantings provide important ecological connectivity between the ribbons of habitat being restored at Tūmai. We have logged planting of at least 12,055 native woody plants and 916 grasses and agaves[27] within the private sections so far[28].

Many residents are planting along the road margins that abut their property and they have planted a rock and tussock garden at the top junction of roads (Fig. 1). At least one other rock garden is envisioned at the road junction by polygons 'L' and 'G' shown in Fig. 10. These add biodiversity and habitat connectivity, as well as enhancing aesthetic appreciation of the landscape and screen the buildings for privacy. While these road margin plantings are encouraged, they are not included in the formal plan so far and will likely occur in an *ad hoc* manner to suit the plot owner's needs to protect views and break wind.

Obstruction of vision on a few sharp corners should be avoided by keeping the plantings further back and choosing low plants at these junctions.

Species diversity

At the time of the Tūmai Beach farm park subdivision, just four native woody species were known to be present, often represented by less than five stems. Now there are at least 97 woody native species and an additional 11 other types of native species (grasses, agaves, sedges and rushes) established at Tūmai (Appendix 1). Species richness has about doubled since restoration intensified in 2021. More diversity is present than enumerated here because some landowners did not record the formal species names of plants they planted. Also, some species source by residents for their gardens and margins of their lots included several cultivars.

Many of these new species are represented by fewer than 5 specimens, and some planted in house gardens and around the perimeter of private lots are not found naturally in north Otago. Forest composition predictions for the area identified 55 that have more than 0.5 probability of occurring in the original forest cover[29]. Many of these additional species will only survive when a fully formed and closed canopy is present and soil litter is being generated. Therefore, although a solid start in rebuilding native plant biodiversity is underway, much restoration remains to be done.

Many of the species that we have already planted are known to produce abundant fruit for birds (especially kererū) and lizards. We have also included a large number of nectar-producing species to attract honeyeater species (especially bellbird and tūī). Once the smothering grass cover is eliminated, natural seed dispersal by birds and lizards will begin to naturally build a representative and self-regenerating forest and shrub ecosystem.

[27] All *Phormium* (flax) species.
[28] Records from private lots are particularly incomplete, so these private planting totals are much underestimated.
[29] Moller et al. (2013).

Environmental enhancement plans for 2024-2026

Priority 1: Securing establishment of new plantings

The most urgent and important priority in the coming three years is to secure the establishment of the 18,000 trees planted in 2022 and 2023. Tūmai's semi-arid climate slows growth of the plants which must outgrow and successfully compete with the rank pasture grasses for water, nutrients and light. A fertiliser tablet[30] was placed just under the root zone of each newly planted tree to boost growth, but the grass sward reaches 1 m high in most places. Each tree or shrub therefore must be "released" by removing grass, thistles and other weeds from around their stem for the following 2-4 years.

Plant protectors[31] were placed around most species, primarily to prevent hare and rabbit browsing. The shields are also excellent for reducing the risk of wilting during strong winds, frost protection, shielding the tree from inadvertent spraying with herbicide, and for finding the trees in rank grass. A woollen biodegradable weed mat[32] is fitted around each stem to minimise the number of thistles and other weeds growing within each plant protector. Abundant seeding of the grasses and thistles mean that weeds sprout and grow from the gaps created where the tree stem and two stakes holding the plant protector in position pierce the weed mat. The mats disintegrate after a year, so most plants need to be released by hand-weeding inside the plant protectors in the second and third year after planting. There is also a need to remove the plant protector once the tree is well established. In around 95% of the cases the plastic protectors can be removed intact so they are sufficiently robust to be used for protecting a second new seedling. The wooden and bamboo stakes used to secure the protectors are sometimes broken or rotten, so we can only reuse around 80% of them for a second plant.

Kanuka, ribbonwood and lemonwood are relatively unsusceptible to rabbit and hare browse, so we reduced costs by spreading coffee sacks around the stems without guards when planted. These suppress weeds for 1-2 years over a much larger area than covered by the plant protectors, but spray releasing and some hand-weeding is still required.

Planting spots were sprayed with glyphosate prior to planting in autumn and winter, but a second spray around the plant is needed before the following autumn (year 1). Two rounds of spraying are needed for most plants in spring and autumn of year 2; and then 1 round in each of the next two years. Some plants therefore need to be spray released 5 times before they are considered secure. We therefore will require approximately 23,000, 18,000 and 5,000 releases in each successive year covered by this management plan (Table 3).

Hand-weeding is likely to be needed once per year per stem over the same establishment periods. The time required per stem varies a lot according to weediness, but averages about 90 seconds. Hand-weeding is estimated to require one person working thirteen working weeks in each of the next two years, and then four weeks in 2026 (Table 4).

[30] TerraPro slow-release tablets, supplied by Advance Landscapes.
[31] KBC TriGaurd 450x200mm Combo sets with additional Bamboo stakes, supplied by Advance Landscape Systems, Christchurch.
[32] EL EcoWool Mulch Mat 250mmSQ, 750gsm, supplied by Advance Landscape Systems, Christchurch.

Table 3. Estimated number of spray-releases required for trees and shrubs planted in communal areas of Tūmai Beach farm park 2022 and 2023.

Cohort		Releases per stem			Total stems to be released		
Year planted	Number planted	2024	2025	2026	2024	2025	2026
2022	13,000	1	1		13,000	13,000	
2023	5,000	2	1	1	10,000	5,000	5,000
Both					**23,000**	**18,000**	**5,000**

Table 4. Estimated time required to hand-weed trees and shrubs planted in communal areas of Tūmai Beach farm park 2022 and 2023. Totals assume that it takes 90 seconds to weed each stem, an 7-hour working day (allowing for breaks), and a 5-day working week.

Cohort		Releases per stem			Total releases, hours, days and weeks required		
Year planted	Number planted	2024	2025	2026	2024	2025	2026
2022	13,000	1	1		13,000	13,000	
2023	5,000	1	1	1	5,000	5,000	5,000
Both					**18,000**	**18,000**	**5,000**
Hours					**450**	**450**	**125**
Days					**64**	**64**	**18**
Weeks					**13**	**13**	**4**

Priority 2: Back-filling sparsely planted forest areas

If funding and voluntary contributions allow, the second priority for 2024-2026 will be to begin enrichment planting of those areas that were sparsely planted from late 2022. Some replacements of plants that died from the last two years of planting would be included.

The cost of spray releasing (Table 3) and time required from volunteers to hand-weed existing plants (Table 4) precludes any such enrichment planting in the next three years unless grants can be won to entirely fund (i) plant purchases, (ii) site preparation, (iii) planting, (iv) weed mats and replacement stakes for reused plant protectors, and (v) releasing the new plants over the following 3 years. It is therefore realistic to accept that no enrichment planting might happen, or that it occurs at a slow rate of perhaps no more than 1,000 new plants a year if external funding cannot be found.

Any enrichment planting should be concentrated in patches. Spatial aggregation was strongly recommended by Wildland Consultants[33] for the entire restoration programme because (i) it is how plants naturally establish and spread, (ii) birds are attracted to groves and will nest in them and distribute seeds, and (iii) the crowns of the trees grow outwards, shading out competing grasses and allowing seedlings to establish on the edge of a grove, enlarging it.

Planting within each patch should also take a clustered approach i.e. rather than simply mixing the target species in a random manor, some single species patches are recommended to encourage cross-pollination, especially in dioecious species (where there are separate male and female plants). Local tuning of some species assemblages is also advised i.e. some will be more successful than others in dry ridges and wetter southern faces that retain more moisture. It is also aesthetically more pleasing to have some patches of the same colour and texture rather than a uniform mix throughout the Tūmai landscape.

All plants should be eco-sourced where practical in order to maximise chances of establishment and growth and build ecological integrity of the restoration programme.

Wildland Consultants identified 34 species suitable for planting at Tūmai and matched them to four habitat zones[34]. They will form the bulk of our target species list, but we have augmented their list by applying a model to predict 54 species which were once present in the Tūmai forest before clearance for farming[35]. Forty-one of these "missing" species were not included in the Wildland Consultants planting plan. Using a somewhat arbitrary target of ensuring that at least 100 specimens of these formerly present species should be planted to encourage their spread, we recommend accelerated planting of 8 relatively large and erect species that were conspicuously missing: kahikatea, houhere, miro, mapou, *Coprosma rotundifolia*, mahoe, putapūtawētā and kōtukutuku. All these additional species were tried in 2021-2023, but mahoe and kōtukutuku often died, and mapou have hardly

[33] Wildland Consultants (2007c); see Table 1 of TBEEG (2021) for details.

[34] Their "Freshwater swamp" species will be chosen for the pond margin and seepage areas ('T' and 'U', Fig. 2); and "Margin of Estuary species" for planting in the soft sediments of South Arm if necessary (Wildland Consultants (2007a,b,c).

[35] The method used species lists from 86 forest remnants in East Otago which were then clustered into six 'Forest types' (Allen & Wilson 1991). 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 type stood at Tūmai and included 54 main species.

grown. We have recently taken particular care to plant them immediately alongside and slightly under existing well-grown trees of other species in the hope that shelter will enhance their survival and growth. It may be that many of the species identified by Allen & Wilson's model can only be established years or decades from now when a fully formed and closed canopy exists and a deeper forest litter layer forms.

All the restoration work is important and will be completed eventually – the prioritisation suggested here is merely to deliver maximum environmental enhancement as quickly as possible.

Seven threatened plant species have been identified by Wildland Consultants[36] and several understory plants requiring established forest micro-climates are identified by predictive modelling of original forest composition[37].

Care is needed to protect the views from the residents' houses on the margin of their lots. Selection of low species on the lip where the ground falls away westward and eastward will be needed, perhaps including a silver tussock 'viewing chute' as envisioned by the landscape architect who advised the Tūmai resource consent decision makers[38]. Significant sea and estuary viewing zones will also be protected. There is considerable opportunity to plant more native grasses and low divaricating shrubs in these edge spaces, not just to protect the views but also to nurture lizard and native invertebrate species.

Some Tūmai residents are 'adopting' areas of communal forest land adjacent to their individually owned lots. This gives them control of the local aesthetics and views enjoyed from their homes, but also facilitates releasing of the plants, weed control, and watering the growing plants when conditions are dry. We urge all residents to provide this added local care of adjacent communal forest and hope that such contributions to the communal effort accelerate in the coming years as more homes are built in the farm park.

Priority 3: An experiment to accelerate forest canopy closure

The full cost of planting at 1.25 - 1.5 m spacings and ensuring the protection and establishment of the plants is enormous (Tables 1, 3 & 4). Unless external funding can be found, we need to accept that full restoration of forests at Tūmai will take several decades, or we need to find a way of accelerating the natural regeneration and spread of the existing trees and shrubs at Tūmai.

Significant flowering and seeding by several canopy forming species is now in place throughout approximately a third of the target forest areas. Seed sources should develop in the next 10 years in the remaining areas that were sparsely planted since late 2022. Large numbers of seedlings are growing under mature trees that have a dense canopy, presumably because fertilised fruits have fallen from the parent tree, or because roosting birds have defaecated eaten seeds. Almost all these seedlings will die because they will be shaded by the parent tree. Lateral spread of forest cover

[36] Appendix 2 of Wildland Consultants (2007c).
[37] Appendix 3 of Moller et al. (2013).
[38] Moore (2007a,b; 2010).

requires establishment of seedlings next to, but not under the existing trees, so that the rank grass between widely spaced trees is eventually filled in.

An extraordinarily high density of introduced bird species live and feed in the existing scattered and half-formed forest and native bird species have also started to return. Thus a considerable force of seed dispersal is present, but blocked by the dense ground cover of rank grass.

We propose an experiment in the next three years to test whether herbicide applications to kill grass surrounding mature and isolated trees could reduce suppression of natural regeneration in a cost-effective way. Details of the experiment will require some refinement, survey and preliminary trials and field survey, but such an experiment is likely to incorporate the following general elements:

- *Aims:* Test the practicality, efficacy, optimum location, and cost of grass suppression by herbicide to accelerate lateral spread of native tree regeneration.
- *Treatment #1:* Apply herbicide[39] to an annulus 3 m wide around the outside of the 'drip line' of 10 isolated and mature trees of each of the five main canopy species[40] currently fruiting at Tūmai. Monitor seedling survival and growth at different distances from main trunk of these 50 trees over the following two years.
- *Non-treatment #1:* Monitor seedling survival and growth over the following 2 years at different distances from main trunk of 50 matched ("paired') trees where there has been non herbicide application in the annulus surrounding their canopy drip line.
- *Treatment #2:* Apply herbicide to 10 randomly chosen quadrats[41] to suppress the grass where there is no adjacent tree. Monitor seedling survival and growth in these quadrats over the following two years.
- *Non-treatment #2:* Monitor seedling survival and growth over the following two years in 10 matched quadrats where there is no herbicide application and no adjacent trees.
- *Cost-effectiveness:* Measure time and cost of the experimental treatment and compare the eventual cost of restoring a continuous forest canopy by interplanting compared to enhanced natural regeneration.
- *Recommendations:* optimal width of annuli and location of any future herbicide applications to maximise the rate of lateral spread of natural regeneration.

The experiment could be initiated as soon as summer 2024/2025 if resources allow. If sufficient funds and time are not secured, the experiment could be rolled out more slowly over several years, perhaps beginning with testing only one or two of the focal species.

[39] Review of literature and field experts' testimony would identify whether glyphosate, a low toxicity, relatively inexpensive and general herbicide could be used. It may be that a graminicide that only kills grasses is the better tool for the experimental test, at least later in the experiment when hopefully some of the wanted native tree seedlings are present.

[40] Ngaio, lemonwood, ribbonwood, totara, Ti Kouka.

[41] Probably squares of 16 square meter area.

Long-term land and community opportunities and threats

Ongoing maintenance and protection of environmental, social and cultural goals of the Tūmai restoration project require continuous vigilance and sometimes intervention. More general opportunities and threats that complement the intensive priority actions identified for 2024-2026 above are outlined in this next section of the plan.

Stock exclusion

The permanent exclusion of grazing stock from the Tūmai block is crucial for the restoration effort. Occasional stock incursions occur through the aging fence along the southern boundary of the Tūmai Beach farm park. The Tūmai Beach Services Ltd. will establish a budget for eventual upgrading of this fence.

Biosecurity management

Annual cutting (and poisoning of stumps) of Scotch broom has been undertaken by residents over the past 11 years because it threatens the remnants of indigenous scrub and silver tussock remaining there, and will hinder establishment of future forest species on the hill slopes[42]. There is sign of reducing infestation, but it may take another decade or two to fully flush the seed bank built up over many years. Introduction of a broom biocontrol agent is one option, but regular residents working bees have contained the threat so far. Occasional outliers (pioneering broom plants) are found well away from the main weed patches – it is imperative that these are killed immediately before they start a new seed bank in a new area on Tūmai. Outliers should be recorded, and the area inspected for the next year to ensure that other plants are not established.

Single mature trees of African boxthorn (*Lycium ferocissimum*), *Buddleja davidii*, and elderberry (*Sambucus nigra*) were removed in 2022 to prevent the risk of their spread once ground cover of grasses is eliminated by canopy closure.

Spartina, an invasive estuarine weed, was detected in South Arm and sprayed with Gallant in April 2021 by Otago Regional Council. New plants appear sporadically and are being removed by the residents. Tūmai residents will now systematically search the saltmarsh areas surrounding the farm park twice each year and any *Spartina* will be counted and mapped before being dug out or sprayed by ORC[43]. Regional scale “knock down”, then “mop-up”, and then "confirm absence" investments are required and are achievable if best practice is followed[44]. Until knock down has been achieved and mop-up is advanced, *Spartina* will probably continue to appear at Te Hakapupu because it spreads via seed carried by the tide and vegetatively once established in the salt meadow.

Survival and growth of the planted woody plants has been aided by ongoing control of hares (*Lepus europaeus*) and rabbits (*Oryctolagus cuniculus*) by the residents[45].

[42] Broom occurs in polygons O2, O3 and F1 (delineated in Fig. 10).
[43] Collaboration with ORC’s Biosecurity staff has been invited.
[44] Brown & Raal (2013).
[45] Approximately 300 shooting sessions have destroyed around 120 hares and 600 rabbits over the past seven years.

So far there has been no sign of common brushtail possum (*Trichosurus vulpecula*) within Tūmai Beach far park. This absence probably relates to the absence of large forest patches near the farm park and low density of possums in open farmland. Dispersing young possums, especially males initially, will eventually find the forest establishing at Tūmai. Vigilance and fast action will be required to kill these colonisers as soon as possible after they arrive to prevent the establishment of a breeding population. Possums reduce flowering and fruiting of trees and destroy some seedlings, so the rate of natural forest regeneration will be reduced, and the species composition of the forest will be changed if a breeding population of possums becomes established. It will be less costly and take less time to eradicate colonisers than suppress established populations.

Potential impact of Canada geese (*Branta canadensis*), both negative and positive[46], should be investigated. If on balance they are considered to be negatively impacting the environment at Tūmai at their current abundance, a formal and monitored Integrated Pest Management plan for geese should be implemented.

Animal species enrichment

Once natural succession is underway to restore habitats, attention should shift to trapping or poisoning of introduced small mammalian predators i.e. feral cats (*Felis catus*), stoats (*Mustela erminea*), rats (*Rattus rattus, R. norvegicus*), mice (*Mus domesticus*), and hedgehogs (*Erinaceus europaeus*). Predator control is expected to greatly increase the abundance and diversity of native bird, lizard and invertebrate species in the Tūmai forests once the quality of the habitat has been restored.

Rock refuges for lizards will also be considered.

Once a leaf litter is forming, inoculations of forest duff from nearby forest remnants should be trialled to accelerate establishment of invertebrates to aid forest ecosystem cycling at Tūmai. Nurseries may be able to inoculate seedling roots with appropriate mycorrhizal fungi from remnant native forests with similar plant compositions as Tūmai.

Taking an ecological landscape approach: *Ki uta ki tai*

Although restoration of our own land at Tūmai must take priority, collaboration with the neighbouring farm to seal off critical seepage areas (especially the water reservoir margins, and flat area adjacent to the road on the causeway flanking the southern margin of South Arm) should be the next priority.

Complementary restoration efforts to consolidate the 2009 planting west of South Arm would be particularly welcome to extend ecological and landscape connectivity for restoration of the whole Pleasant River estuary. Survival and growth of the original 2009 plants was particularly successful there, so interplanting to ensure canopy closure will be a smaller and less costly mission than on the Tūmai Beach farm park side.

[46] They are considered a pest by others, especially farmers, because they divert pasture production that might otherwise feed stock. Their droppings are considered to despoil pasture by some, but help build soil fertility. Feral geese droppings are acidic, causing a decline in water quality of estuaries and contributing to eutrophication. Geese frequently overgraze estuary edges, reducing plant species diversity, increasing erosion and sedimentation of estuaries. They could also be displacing native birds from their habitat and contributing to the spread of introduced weed species.

Guidance by manawhenua from the Kāti Huirapa Rūnaka ki Puketeraki will be sought to maximise the cultural value of the Tūmai Beach restoration project. The area includes Waahi tapu (sacred sites), Waahi tāoka (reinforcing the relationship Kāi Tahu have with Otago's water resources), mahika kai (food gathering places), kōhanga (nursery areas for Kāi Tahu's 'Taoka Species'[47]). Walking tracks and plants for weaving materials will also be established. We would like to adopt the use of the traditional Māori names for the landmarks within and surrounding Tūmai Beach farm park.

Collaboration with the Toitū Te Hakapupu project, and with the East Otago Catchment Group restoration efforts further up the Te Hakapupu catchment are the next priorities so that we contribute to a *Ki uta ki tai* ("Mountains to the sea") landscape restoration effort.

Public access and walking tracks

Tūmai residents have a right-of-way to drive over the metalled farm road to access their lots. They share the cost for maintaining this farm road in a safe condition. Signs stipulate authorised vehicles only, but the public has walking access down this road (a car parking area is established before the end of the sealed public road). The public also have a right to access a 20 m wide esplanade strip around the estuary on foot and to use the new causeway formed along the western edge of South Arm. These rights were stipulated as a condition of the resource consent for the Tūmai subdivision[48] and impose some safety restrictions on public visitors[49].

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[47] Their significance and the special role of Kāi Tahu in their care is legislated by the Ngai Tahu Settlement Act (1998). Examples of these species in the Te Hakapupu catchment include tuna (eels), inaka (whitebait), kanakana (lamprey), koukupu, waterfowl, wātakirihi (watercress)

[48] The consent (Dunedin City Council, 2008) states: "The farm flats, shown as Lot 26, are to be vested with the Crown as coastal marine area, and therefore will become available for public use and enjoyment. On subdivision, a 20 m wide esplanade strip is to be created along the estuary edge (including the new estuary edge defined by Lot 26), further providing for public access to and along the edge of the coastal marine area. The Committee considers this to be in accordance with the purpose of the Act, as it will meet section 6(d), 'the maintenance and enhancement of public access to and along the coastal marine area ...', a matter of national importance. The length of the esplanade strip created will be approximately 5km in length, a not insignificant amount. The new causeway will not have an esplanade strip but will have a right of way for public use, therefore also serving as public access along the estuary edge."

[49] The legal instrument states that:

2.1 The following acts are prohibited on the Strip:

(a) Wilfully endangering, disturbing, or annoying any lawful user of the Strip (including the owner or occupier of the Strip)

(b) Wilfully damaging or interfering with any structure adjoining or on the Strip, including any building, fence, gate, stile, marker, bridge or notice

(c) Wilfully interfering or disturbing any livestock lawfully permitted on the Strip

3. The prohibitions referred to in clause 2.1 (b) and (c) above do not apply to the Owner or Occupier of the Strip.

4. The following acts are prohibited on the Strip:

(a) Lighting any fire;

(b) Carrying any firearm;

(c) Discharging or shooting any firearm;

(d) Camping;

(e) Taking any animal onto or having charge of any animal on the Strip;

(f) Taking any vehicle onto, or driving or having charge or control of any vehicle on the land (whether the vehicle is motorised or non-motorised)

Authority to drive to the actual estuary edge via the private extension of Thorburn Road is at the discretion of the owners of North Tūmai Farm. The private roads around the farm park subdivision[50] are owned and maintained by the Tumai Residents.

The farmers and the Tūmai residents are willing to consider access by non-residents in vehicles on a case-by-case basis where appropriate and when risks are minimal. Recent visitors have driven over new plants and plant protectors, driven dangerously on the roads and paddocks ("burnouts"), lit fires in dry conditions, left their rubbish and excrement, and brought unleashed and poorly trained dogs onto the farm park.

Access requests will now be required in advance of a proposed visit, as with most farm access situations. An email (tumai.access@gmail.com) has been established and will be sign-posted at the end of the public section of Thorburn Road to inform people how to request access.

A 'Friends of Tūmai' Facebook Group has been established[51] to inform our neighbours of events and progress with environmental enhancement, and to say thanks for the wider community support for those efforts.

Walking tracks are being established through all the planting areas where practical. These will facilitate the site preparation, planting, after-planting care, and monitoring of restoration success. Tracks will also allow people to inspect the work and growth of the plants, watch birds, and enjoy the environment around the estuary. Progress in forming permanent tracks and gravelling (and stepping them) will follow as fast as funds allow.

The Tūmai residents have agreed not to drive on the soft sediments of the estuary unless required in an emergency or unless to launch a boat at a few launching spots. Boulders have been placed at spots where interlopers might gain access to the estuary. Past incursions by quad bikes, motorbikes and tractors have left ruts and mud patches, some of which last for years, and prevent re-establishment of saltmarsh species.

The salt marsh near the picnic area is degraded by introduced grass incursions and vehicles taking a short cut to reach the picnic area rather than traveling the full loop around to the road end. People will be discouraged from driving over the remaining *Sarcocornia* beds.

The salt marsh ecosystem is maintained by periodic flooding at high tides and pooled water. This natural flow and pooling should be uninterrupted if possible.

Fire risk management

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

(g) Wilful damaging or removal of any plant (unless acting in accordance with the Noxious Plants Act 1978 or the Biosecurity Act 1993)

(h) Laying any poison or setting any snare or trap (unless acting in accordance with the Biosecurity Act 1993).

[50] i.e. east of South Arm.

[51] https://www.facebook.com/groups/330442745799323

reasonably well known and many of the species planted in 2009 have high flammability ratings[52]. However, it is important to keep this risk in perspective: the expected fire risk in broad terms is by 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 is not expected to build up sufficient thatch to fuel a fire)[53].

The best overall strategy is to maintain a gap ("defensive zone") between the forest and houses at Tūmai by maintaining a broad mown perimeter or planting fire resistant plants. Fire risk will reduce as more rank pasture is replaced by forest. Vehicles must not be driven through rank grass in summer and the farmer cutting hay and baleage is contracted to mow the pasture areas just before the Christmas break when more of the owners are present. Use of chain saws and weed-eaters in long grass (for example to release plants) should be avoided in dry conditions. Weed-eaters should use nylon cord rather than a metal blade in order to reduce the risks of sparks starting a fire.

All residents are required to hold 20,000 litres of water in reserve and have a fire hose connection available to assist the fire brigade control any outbreaks.

People visiting the picnic area (Fig. 1) are prohibited from lighting fires. Signage will be erected at the picnic area in 2024 to remind people of this requirement. An onshore wind in dry conditions could start a grass fire that destroys a decade of ecological enhancement efforts and threaten the houses on Tūmai Beach farm park.

Pasture management

Baleage and hay is 'cut and carried' off the farm park. Periodic fertilisation is required to maintain production. Best practice is requested of the neighbouring farmer who is contracted to harvest the grass and manage the pasture i.e. minimum application rates, fertilising only when needed (as identified by prior soil testing), and precision application under calm wind conditions to avoid drift of fertiliser into the estuary. This is important to avoid eutrophication of the estuary which occurs when excess nutrients run into the estuary, resulting in algal blooms and low oxygen levels that can kill fish.

Exclusion of stock is causing a gradual shift in composition of the pasture sward, including a rampant growth of red and white clover. Their nitrogen fixation builds hay and baleage quality, but may also increase nutrification of the estuary – hence the need for the concentration of planting around the estuary margin and soil testing prior to fertiliser application.

Occasional ragwort (*Jacobaea vulgaris*) plants are encountered and wrenched. Burdock (*Arctium minus*) appeared in 2017. It is hard to kill, persists and spreads rapidly. It is a real nuisance for dogs in particular. Residents have gone to considerable effort to eradicate it by removing flowers before they seed, digging out their tap roots and spraying fresh leaves with glyphosate.

In the long-term there is considerable scope to create a diverse (multispecies) and colourful herbfield in the production spaces of Tūmai by over-sowing with herbs and different grasses. This in turn will attract and nurture beneficial insects which would assist in pollinating both pasture and forest species

[52] Fogarty (2001).

[53] In litt, Dr William Lee. Landcare Research. However, we have noticed moderate build-up of a thatch under dense planting of silver tussock at Tūmai and recommend that such silver tussock beds are planted well back from buildings.

while also providing a food source for insectivorous bird species returning to Tūmai. Introduction of native earthworms would be a New Zealand first – many species were driven extinct by intensive pasture farming. Such diverse approaches to pasture management[54] are becoming more common and a part of a more integrated 'multifunctional agriculture' approach[55]. A more diverse pasture would likely increase both the quantity and quality of baleage while requiring less fertilizer. It would improve soil structure biota and function due to diverse root structures and exudates, improving nutrient cycling and water infiltration. A diverse pasture would be more resilient to drought and flood. It would also help sequester carbon for climate change mitigation, so there could be an opportunity to earn an additional income through initiatives such as the NZ Climate Innovation market.

In the meantime, the restoration will concentrate on the forest and estuary margin habitats, but pasture enhancement could be considered in the longer run.

Monitoring, research, and environmental education

Restoration work at Tūmai can offer important lessons to share with other community-led restoration projects. Systematic and regular monitoring also will help the Tūmai residents adjust the pace and nature of investments, taking into account lessons learned, and measure progress towards reaching their goals.

The immediate priority is to monitor plant survival and growth in the establishment phase. Twelve permanently marked sampling quadrats have been established at randomly chosen sites (the 'M' series shown in Fig. 11)[56]. Measurement of plant survival and growth follows the protocol established by 'Trees That Count' and is reported to them annually until the forest is nearly fully grown[57].

Initial counts between one and four months[58] after planting detected just 2 dead amongst 274 stems (99.3% survival), so we can conclude that planting technique was excellent. The occasional early losses noted outside the quadrats were mainly due to desiccation, frost, hare or rabbit browse (when no plant protector had been fitted), and occasionally damage to the main stem when being planted.

Repeated measurement of at seven quadrats 17-19 months following planting were also excellent, but with two exceptions. Almost all of 500 kanuka planted in a 70 x 30 m patch on a western hillslope in May 2022 died[59]. Also, approximately 100 etiolated Ngaio stems spread throughout nearby multispecies stands died at this same time. Two heavy frosts just after planting damaged the ngaio in particular. The kanuka slope was hit by strong and prolonged warm north-west winds in the three weeks following planting. Emergency watering[60] was initiated during this dry period, but too late to

[54] https://regenerativeagriculturefoundation.org/regenerative-agriculture-alliance/
[55] Renting et al. (2009).
[56] Eight quadrats were established and measured in July 2022, and six more in December 2023 within areas planted subsequently. Unfortunately, one of the earliest quadrat marker pegs (M3) appears to have been shifted between measuring cycles, so the first year's survival data from that quadrat must be discarded. The original wooden stakes have now been replaced with steel waratah pegs to ensure this mishap does not recur.
[57] https://help.treesthatcount.co.nz/en/articles/8438231-advanced-monitoring-guide
[58] Average 2.7 months
[59] During replanting this area in October 2023, we estimated that 98% of the kanuka had died. The few survivors were stunted and defoliated.
[60] Water was transported from Palmerston and a nearby farm in 200L tanks to high points of the farm park from where gravity-fed flow delivered water through extended garden hoses. It took 3 weeks of exhausting work to hand water all the plants.

prevent desiccation of the kanuka. The stems were relatively tall when planted[61] and none had plant protectors fitted. Perhaps the high shoot-to-root-ratio contributed to them drying out? We recommend other planting projects to be wary of planting large ngaio and kanuka in particular.

The kanuka killed in our set back were replaced in October 2023 with small ngaio (within plant protectors), ribbonwood, tōtara and Pittosporum.

When data from the failure of the kanuka around plot M5 is excluded, overall survival of 170 stems planted at the remaining 6 quadrats was 91% when the second survey was conducted 17-19 months after planting. Survival was 100% at three of these quadrats, but 75% and 82% at two quadrats that had the large and etiolated ngaio plants.

The Rotary Forest Trust patches were planted early in October 2022 (Fig. 11). On 20 April 2023, we conducted a one-off check of the success of this project by scoring survival of the first 100 plants encountered 1m each side of a randomly chosen transect line in each of the forests. Both forest patches had 96% survival, nearly 7 months after planting.

We have also established 22 fixed 'PhotoPoints' for taking standardised photographs at two-yearly intervals (Fig. 12). Co-ordinates of each point is recorded by GPS. All photos are taken with a Tamron 18-400mm Zoom lens set at 50 mm, using an EOS90D camera mounted at 1.5m on a tripod. A first set of photos was taken in July 2022 following the main planting pulses; and a second set in December 2023 to record the 2023 planting cycle. The full set will be repeated in June or July 2024 when winter weather has flattened more of the rank grass around the woody plants. Thereafter the PhotoPoints will be repeated every two years in mid-winter.

Longitudinal measures of the strength of flowering and fruiting could be instigated to 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*) and grey warblers (*Gerygone igata*). Fantails have occasionally been seen since 2020 but are not yet conspicuous and grey warblers were first heard 2022 and again in 2023.

Arrival of frugivorous birds, especially silvereye (*Zosterops lateralis*), bellbird (*Anthornis melanura*) and tūī (*Prosthemadera novaeseelandiae*) 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. The key index of restoration success is the establishment of breeding populations so that Tūmai habitat is turned from being a 'sink' to being a 'source' area in a wider ecological meta-population.

[61] The 41 Kanuka planted in quadrat M5 averaged 786 mm (range 48 – 110mm); no separate measure of the tall batch of ngaio was taken, but they were definitely taller on average than the kanuka.

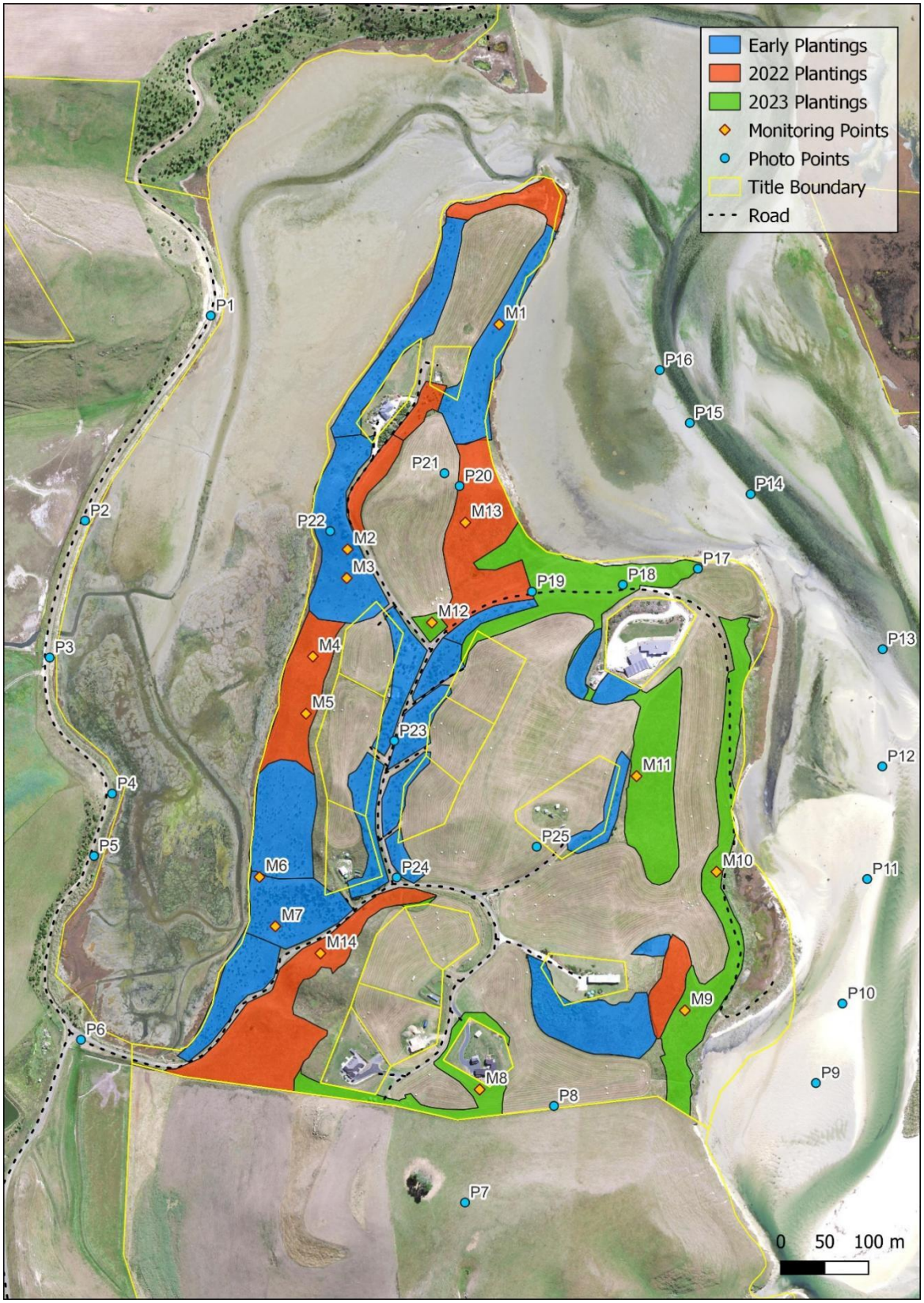

Figure 11. Locations of 14 fixed quadrats ('M' series) to measure tree survival and growth and 22 fixed PhotoPoints ('P' series) to monitor the success and speed of afforestation at Tūmai Beach farm park.

Full seed dispersal will only be attained when abundant populations of kererū frequent the farm park, but this is likely to require effective predator control and a year-round supply of fruit from a wide range of tree species. Kōwhai have already been planted throughout the farm park. They provide an important source of nitrogen in spring for kererū.

Periodic requests by researchers and bird counters to visit the farm park are received and encouraged.

Birds NZ now include the Te Hakapupu estuary in the national wader count (since 2023). *Birds NZ* have studied the distribution and abundance of waders in Aotearoa since 1939. In 1983, these counts were expanded to all major estuaries and harbours across the motu and are conducted around June/July and November each year. This survey provides information on the numbers of Arctic migrants that summer in Aotearoa and how many remain over the winter. It also counts native waders that form flocks in the winter.

Forty-two species of birds (including land and water birds) have been observed on and around the estuary so far by Birds NZ. Of these, 27 species are native, including 8 species which are endemic (found only in Aotearoa / New Zealand). Of these native species, one, the Taranui / Caspian Tern (*Hydroprogne caspia*) is nationally vulnerable, while 10 other species are at risk.

This includes Kuaka / Bar-tailed godwits (*Limosa lapponica*), a migratory wading bird which is declining primarily due to habitat changes in the Yellow Sea where they stopover on their migrations to and from their Arctic breeding grounds. 23 Kuaka were counted at Te Hakapupu in July, so a resident population is probably present over the winter, comprised of 1st to 3rd year birds that do not migrate. This population had swelled to 182 Kuaka by November with the return of the migratory birds.

A lone Hudsonian godwit (*Limosa haemastica*) was also spotted by the *Birds NZ* team in May. The Hudsonian godwit normally migrates from the Arctic to southern South America. However, a small number migrate in the wrong direction, reaching Australasia and the Pacific Islands in very small numbers where they are mainly found among large flocks of Kuaka. This particular bird had been in the Otago area for about a year and has been sighted at Warrington, Aramoana, Kaikorai and now Te Hakapupu. This sighting adds to our understanding that our Otago godwits do use many of our lagoons and estuaries, rather than staying just at one place.

Another exciting sighting in May was of a No Pohowera / Banded dotterel (*Charadrius bicinctus*) that carried a leg-band attached when she was on her nest at the Cass River delta in Canterbury on 19th October 2020 (this is part of a national study of migration within NZ, so the sighting is important).

These first observations already demonstrate the potential importance of Te Hakapupu for maintaining healthy bird populations at local, regional, national and international scales. The Tūmai residents also intend to work with *Birds NZ* to establish a transect count the open farmland and native bush birds.

The Tūmai Beach enhancement site will be registered as a site in *iNaturalist*[62] for recording biodiversity sightings and locations by residents, monitors and researchers.

[62] https://www.inaturalist.org/

Figure 13. Bar-tailed godwits (behind, left) and a Hudsonian godwit (front right) on Te Hakapupu estuary on 13 May 2023. Photograph by Kit Girling.

School visits and planting days, coupled with ecological lessons at school before and afterwards, are encouraged. Two school exercises in the 'Marine Metre Square' educational programme were conducted in 2021 and 2023.

Preliminary MSc studies of the estuary ecology by the University of Otago have been hosted and more are encouraged.

Climate change adaptation

There are several signs that Tūmai Beach farm park land is being eroded by the sea e.g. steep escarpments, fences and pipes that stretch from these banks (Fig. 14), and lines of old rotted and broken-off fence posts that extend out into what is now estuary surface.

The edge of the estuary was mapped using a hand-held GPS in August 2022. When compared with the original survey maps which were plotted sometime early last century or before, approximately 1 hectare of land has been washed away from the area close to Te Hakapupu entrance where impacts of direct wave action will be the strongest (Fig. 15).

Surveys or analysis of aerial or satellite imagery is needed to confirm rates of both accretion and erosion of the Sandspit Reserve that forms Tūmai Beach, but residents have observed rapid erosion of the inland (southern) margin of the dunes in the last 5 years, probably resulting in at least 25 m of sand being removed from back dunes. This erosion might relate to a recent shift of the main channel of the estuary from the true right to the true left bank of Te Hakapupu where it reaches the sandspit[63].

[63] Peter and Irene Walton report that this switch of sides happened soon after the causeway at the entrance to South Arm was removed in 2009.

Figure 14: Remnants of the boundary fence at the southeast corner of Tūmai Beach farm park, November 2022. This photograph was taken at the southern extreme of the map shown in Figure 15.

Figure 15. Changes in the position of the Te Hakapupu estuary edge around the current picnic area at the end of the Esplanade Track. The boundary surveyed sometime before 1929 for public cadastral mapping is shown in black , and the present boundary (2022) is shown in blue. Just over 1 hectare of land has been washed away and a much smaller area (approximately 250 m2) added at the tip of the beach front.

Sandspit Reserve vigilance and management

Intensification of research and management of the Tūmai sandspit Department of Conservation reserve would be valuable but remains a secondary priority for Tūmai residents while afforestation and restoration of South Arm take up all our time and funds. Collaboration with DoC and Kāti Huirapa Rūnaka ki Puketeraki to protect and enhance Tūmai Beach spit has been sought. If the proposed Te Umu Kōau Marine Reserve is established[64], restoration of the Tūmai Beach will be an important complement to complete a ki uta ki tai ('mountains to the sea') protection and enhancement strategy.

The structure and dynamics of sand dune systems are complex and require detailed study. Unique plant communities, including some threatened herbs, are associated with some dune slacks. Sometimes infilling of areas drives plant community succession, so careful management may be required to maintain dune plant diversity. Replacement of marram grass (*Ammophila arenaria*), the current dominant cover, with either *Spinifex sericeus* or pīkao (*Ficinia spiralis*, Golden sand sedge) could be considered if they are predicted to provide ecological resilience, climate adaptation and cultural benefits[65].

Climate change is expected to drive increase in sea levels, which when combined with more severe storm surges, could greatly accelerate land erosion along the eastern flank of the farm park. Much greater change will occur if the Sandspit reserve is breached, including a possibility that the sandbank is washed away entirely in the longer run. A detailed study of the soft sediment transfers in estuary and along the Tūmai Beach foreshore would be very useful for assessing the risks of climate change impacts, as well as any change in freshwater flows within the Te Hakapupu Catchment as a whole. Establishment of extensive exotic forestry in the upper reaches of the catchment can be expected to reduce the volume of freshwater flows in the lower catchment, while increasing the amount of sediment and slash during flooding events (if poorly managed). Downscaling of climate change models to take into consideration the impact of the surrounding mountains and their rain shadow effect would be needed to predict the long-term changes in the estuary, the sandspit and the Marine Reserve ecology.

Ongoing gorse (*Ulex europaeus*), broom and wilding pine (*Pinus radiata*) control on the sand spit DOC reserve is undertaken sporadically by Tūmai residents already. Two main patches of gorse are gradually spreading and should be destroyed as soon as practical.

Encouragement of little penguins (*Eudyptula minor*) and yellow-eyed penguins (*Megadyptes antipodes*) by providing nest boxes and acoustic attraction will be attempted once resources allow and sufficient habitat restoration and control of predators is proven.

New Zealand sealions (*Phocarctos hookeri*) haul-out on the sandspit and swim up the first reach of the estuary to catch fish. A maximum of four large males ('Beachmasters') have been seen on the main Tūmai Beach at one time over the past 8 years, and groups of up to five females and/or adolescent males are seen regularly play-fighting on the southern tip of the sandspit for hours on end. No small pups or birthing females have yet been seen there, but it seems likely that breeding will eventually occur on the reserve as the mainland population expands. Occasionally the sealions 'bluff-charge'

[64] South-East Marine Protection Forum (2018).

[65] Similar replacement of marram at the picnic area on the farm park side of the estuary should them be included because it could otherwise act as a source of propagules to reinfest the sandspit dune area.

people visiting the estuary and beach – this is often misunderstood as aggression, but it is actually an invitation to play[66]. There will be an increasing need to educate people of appropriate disturbance minimisation and safety tactics as sealion numbers increase. The Tūmai Sandspit reserve will make an increasingly important contribution to recovery of this endangered and charismatic marine mammal.

Systematic destruction of the Canada Goose nesting attempts on the Sandspit has been observed in the last two years. This is unpermitted intervention in a DoC reserve that will be altering the ecology of the adjacent estuary which is probably about to become a Marine Reserve[67].

Sheep and cattle from the farm flanking the base of the sandspit are frequently allowed to roam out onto the glasswort beds and sometimes wander as far as the southern tip of the marram grass. Disturbance of the sand surface invites woody weed establishment and spread, but impacts of the stock browsing are unknown.

A formal survey of the current ecological communities on the sandspit is recommended as a start towards a more formal and active management programme for the reserve.

[66] Jordina Whyte, chairperson of the NZ Sealion Trust, offered the following guidance on safety around sealions (September 2021).

- I have not heard of a single instance where someone on land has been bitten by a sea lion apart from researchers when catching and tagging them. It is even very rare in the water, with almost every case I've heard of where a sea lion makes biting contact with a human is because a diver or surfer has panicked and either intentionally or accidentally whacked or kicked the sea lion in the face.
- Sea lions do explore the world with their mouths, so experienced local divers and surfers have stories of being 'mouthed' by sea lions - usually on their diving flippers, or maybe a foot or ankle - but do not confuse this with biting.
- Paddlers also experience this mouthing of kayak paddles or fronts of boats from time to time. Occasionally a young sea lion will porpoise out of the water quite close to the paddler. Again, this can be intimidating if misinterpreted as aggression. Mostly they are just playing and seeing how you will react. I don't know of any circumstances where a paddler has been swamped or knocked out of their boats/off their boards.
- If you want to avoid unwanted attention, the best advice is to be boring - move quietly away and do not run. Running is exciting and may be seen as an invitation to chase - what a fun game! - just like with dogs.
- Don't make eye contact, and move away quietly, backing away if you can. Sea lions do sometimes bluff charge, and then stop 1.5m away from you. They want to let you know they're in charge of the situation, and to see how you will react. They are highly unlikely to make any physical contact whatsoever. Often if you hold something out, like a backpack, or even a pair of binoculars, they'll pull up just to the point where they can sniff and poke the object with their noses. They see it as an extension of you, and they're curious about you.
- The 'be boring' also applies to paddlers. Again, don't make eye contact or splash around, as this becomes interesting to them. Just move quietly to shore as quickly as you can without causing a ruckus, and get out. Surfers certainly routinely use this method if they don't want to cruise the waves with a sea lion friend.

[67] Canada geese and Greylag geese (*Anser answer*) are an introduced species that are considered a pest by some farmers and conservation organisations, but they are spectacular birds that are enjoyed by others. Culling of introduced species within a DoC nature reserve presents an ecological and philosophical choice about wildlife management policy of introduced and native fauna. Research and review may identify a need for an Integrated Pest Management programme for the geese in the future.

Safeguarding archaeological sites

The Te Hakapupu estuary contains numerous sites of archaeological significance, including the 'Pleasant River Mouth Site Complex'. Extensive excavations and survey of the area showed that there were multiples periods of Māori settlement for temporary campsites throughout the 14th-16th centuries AD. An archaeological assessment (that included a summary of the previous excavations and finds around the estuary) was undertaken by consultant archaeologist Amanda Symon as part of the original resource consent application for the development of the Tūmai Beach farm park subdivision.

No sign of archaeological remains has been found in the areas afforested or built on so far at Tūmai Beach farm park. However, moa bones were discovered in 2021 as they became exposed by erosion of around a 30m strip of the estuary margin[68]. The bones are mixed with the remnants of a buried forest and peat layer. Mana whenua were alerted, leading to a site inspection by the kaitiaki and two archaeologists. They concluded that the remains were coming from a natural rather than archaeological site because no artefacts, charcoal or bone injuries were found. The birds are presumed to have died in a landslide along with the forest. Accordingly, the site has been designated as a 'recovery site' from which ongoing surveillance and collection of the bones by residents is maintained.

Some of the bones have been lodged with the University of Otago. Studies using radiocarbon dating, ancient DNA, environmental DNA and wood species analysis techniques have been initiated by Dr Rebecca Kinaston (BioArch South) and Associate Professor Michael Knapp (University of Otago) to reconstruct past environments and understand the population history of Aotearoa's native birds. This would mean we could know what the environment was like, and what species were present, during the time the moa were walking around Tūmai. The moa bones had preserved ancient DNA inside them which showed two bones to be eastern moa[69], which appear to have elongated windpipes so were probably bugling on the forested slopes of Tūmai 2000 years ago. Preliminary radiocarbon dating of wood fragments shows that the birds died there between 80 and 220 cal[70] AD, suggesting that the moa remains are approximately 1800-2000 years old.

A collection of the moa bones is shown to visiting school parties, mana whenua and naturalists and once the formal research is completed will be offered for keeping by the Waikouaiti Primary school for their cultural education programme.

[68] Two other Moa bone fragments were found washed up on the edge of the main channel several hundreds of meters from the known deposit – we live in a remarkable part of the world where remains of extinct species that died more than 7,000 years BP are being washed up as flotsam!

[69] https://nzbirdsonline.org.nz/species/eastern-moa, a species with elongated windpipes that were thought to make a bugling sound.

[70] The radiocarbon dates are calibrated so they can match with the calendar years.

Summary: Progress so far and prospects for the future

More than 59,000 native plants have been planted since the Tūmai Beach farm park was established 14 years ago. We are a third of the way to completing the re-establishment of coastal native forest over half of the communally owned ground in the farm park. Tidal flows have been reinstated over 27 hectares of formerly reclaimed farmland and salt meadow communities are regrowing.

The Tūmai residents and all their helpers can feel particularly satisfied with the accelerated progress to enhance the Tūmai Beach farm park environment over the past three years. An adaptive management trial to learn how best to re-establish oioi in South Arm has been established. Over 20,000 woody trees and shrubs have been planted in communal and private lots. Survival of the plants has been excellent over the last three years, averaging over 91%[71]. Dense woody vegetation is in place to form a closed forest canopy over approximately 5 hectares in the coming 10-15 years. Sparser cover over all the remaining 12 hectares of retired pasture that is designated to become forest.

Despite encouraging progress, much work remains to be done. Each plant costs at least $10 to establish[72] – this includes the cost of propagation, site preparation, planting, and follow-up care. Our need for around 80,000 more plants therefore requires an overall budget of at least $800,000 dollars, much more than 16 families that make up the Tūmai Beach farm park residents can muster on their own. An application to register the forests into the 'Permanent Forest' category of the New Zealand Emissions Trading Scheme (ETS) is currently under consideration by the Ministry of Primary Industries. Successful registration would secure a modest income to help defray the remaining afforestation and forest maintenance costs. ETS registration will also help secure the ongoing presence of the forest for at least the next 50 or 70 years because it would legally bind the residents to maintain the forest unless they pay back the value of the carbon credits received. Even if the ETS registration is granted, partnerships with external agencies and environmental restoration grants will be needed to help defray costs.

This proposed plan was ratified by the Tūmai Beach Restoration Trust on 18 March 2024 after consultation with all Tūmai farm park owners. We now seek meetings, comments and suggestions for integrating our proposed environmental enhancement efforts with those being undertaken by other groups and individuals who are working towards shared goals[73]. Feedback from the neighbouring farmers is also sought to ensure that the farm park goals and procedures do not interfere with their practical farm operations. This plan will be modified if that feedback identifies significant new opportunities for collaboration with surrounding stakeholders to realise our shared goals.

[71] Except in one patch of kanuka that almost completely failed and which has subsequently been replanted.
[72] This estimate is provided by the Halo project which can capture cost savings from large scale activity and low labour costs.
[73] Feedback will be requested from the kaitiaki at Kāti Huirapa Rūnaka ki Puketeraki, the Toitū Te Hakapupu project directors and researchers, East Otago Catchment Group, Otago Regional Council's and Dunedin City Council's biosecurity and biodiversity staff, and the Department of Conservation.

The main environmental enhancement priorities proposed for 2024-2026 are:

1. Secure establishment by releasing plants from smothering grass for at least their first three years.
2. If funding can be secured, start back-filling sparsely planted areas, first in the remaining estuarine margins, then further upslope.
3. Conduct an experiment to accelerate natural regeneration of native trees by supressing rank grass around the 'drip line' (canopy perimeter) of mature trees.
4. Erect signs and communicate the danger of fire to forest restoration, houses, and people.
5. Ongoing monitoring of oioi and woody plant survival, growth and spread.
6. Removal of invasive grasses encroaching on the farm pond.
7. Addition of walking tracks through newly planted forest areas.

Aside from these most urgent and important priorities, there are a series of ongoing actions that protect the investments already made and that will hasten success and deepen the value of our work, including:

- Maintaining farm stock exclusion.
- Introduced weed and pest animal control.
- Investing in connections and actions to support the wider catchment restoration efforts – a *Ki uta ki tai* (mountains to the sea) landscape ecology strategy.
- Managing access risks.
- Incresaing education and precautions to avoid wild fire.
- Enriching pasture management and careful fertiliser management.
- Regular monitoring of the progress and success of our environmental care efforts and adaption of plans to reflect lessons learned.
- Increased scope and depth of research for improved environmental care.
- Vigilance regarding climate change impacts and evaluation of management interventions to mitigate them.
- Partnering with Kāti Huirapa Rūnaka ki Puketeraki to safeguard archaeological sites and restore the cultural values of the land.
- Provision of ecosystem services to support and restore the ecological integrity of the newly designated *Te Umu Koau* Marine Reserve that includes the estuary surrounding the Tūmai Beach farm park.

Acknowledgements

This plan was prepared by the Tūmai Environmental Restoration Group, a coalition of volunteers from the Tūmai Beach farm park residents' co. The working group includes Fiona Stirling, Henrik Moller, Juanita Meeuws, Rebecca Kinaston, Liana Seeto and Katherine Mitchell. They were assisted by several other residents and the plan was overseen by the Tūmai Beach Restoration Trust and Board members. The plan was peer reviewed by all Tūmai Beach farm park residents and the McWilliams family before being formally adopted by the Tūmai Beach Restoration Trust Board on 18 March 2024.

Chris Garden prepared the maps and calculated the areas of polygons. John Prescott and Kit Girling provided Figs 4 and 13. All other photographs are by Henrik Moller.

Andrew Stirling provided survey maps and advised on erosion of land on the estuary margin. Matt Thomson (Monowai Ecological), Angelina Young (Puketeraki Native Plant Nursery), David Sharp (Conservation Volunteers New Zealand), and Drs Mark Nixon and Megan Reynolds advised on plant selections, planting best practice and funding applications. Kerry Brown (formerly Threats Team, Department of Conservation) advised on *Spartina* eradication.

At least 20,000 native woody trees and shrubs, agaves, grasses and rushes were planted at Tūmai Beach farm park in the past three years to exceed the 2021-2023 targets set by the first environmental enhancement plan. This huge effort was only possible because of the help of many people and organisations.

Purchase of woody plants was funded by Trees That Count (including a Queen's Platinum Jubilee grant in 2022), the Rotary Trees Trust, and the Tūmai Beach farm park residents. High-quality eco-sourced plants were supplied by local nurseries i.e. Ribbonwood Nurseries (Dunedin), Saorsa (Hamish MacFarlane), Margaret MacFarlane, Puketeraki Native Plant Nursery (Karitāne), Smylers Peak (Amy & Adam Maw), For the Love of Trees (Dylan King and Alice Raffills). Other excellent plants were sourced from Matai Nurseries (Waimate), Riverside Horticulture (Rangiora), and Appletons Tree Nursery (Nelson). Many Tūmai residents contributed plants propagated in their own home nurseries.

Kraft Heinz provided used coffee bean sacks from their Dunedin factory to provide weed suppression mats. Plant protectors were funded in part by grants from the Kiwi Gaming Foundation and Bendigo Sports & Charity Foundation.

Over 200 volunteers have helped the Tūmai residents with planting, including the East Otago Catchment Group, Otago Regional Council staff, Centre for Sustainability of the University of Otago, McWilliam family, Salt Ecology and a group of Kindai University law students (from Japan). The East Otago Catchment Group co-hosted two planting days and mobilised their members to help with the mahi. The Tūmai residents and their families and friends have helped fund, plan, gather and distribute the plants, plant, feed and host the volunteers, monitor outcomes and release plants.

We are immensely grateful to Matt Thomson and Michelle Keating (Directors), and to Chris Hunter, Jordyn Ashcroft, John Hoskins and Kurt Trainor (a merry band of tireless field workers) from the Monowai Ecological team – they went well beyond normal expectations of contracted work to prepare spots, plant, protect and release plants, often on steep coastal slopes, all within budget and delivered on time.

The oioi restoration project emerged as a surprising and welcome opportunity in 2022. This research was mainly funded by the Ministry for Environment through *Toitū Te Hakapupu,* a collaboration directed by the Otago Regional Council and Kāti Huirapa Rūnaka ki Puketeraki. That project is managed by Melanie White (Otago Regional Council). Additional funding was received by the Bendigo Valley Sports and Charity Foundation and the residents of Tūmai Beach farm park and was generously supported by the McWilliam family who fenced off the margin of a stream flowing into South Arm for the trial. Volunteers from the Kāti Huirapa ki Puketeraki community helped plant and monitor the oioi experiments, including Angelina Young, Alice Raffills, Bernard Mullane, Elizabeth Vanderburg, George Meikle, Daniel Te Raki, Julia Rata-Te Raki, Shaunae Coombes and Ngahuia Wood. We are also grateful to the kaitiaki for opening our planting days with karakia and a welcome.

The collaboration, support and granting of access by the McWilliam family, who own and farm the North Tūmai farm, continues to be an important part of local partnership to put this environmental plan and associated research into action.

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Appendix 1: Species planted at Tūmai Beach farm park and South Arm of Te Hakapupu between 2009 and the end of 2023.

Lists include species planted in private lots and around the margins of the Te Hakapupu estuary. Names used follow the NZ Plant Conservation network guidelines and Wikipedia descriptions. All are native species except for Tree Lucerne which has been planted on some private lots as a nurse crop for inserting native species underneath.

Taxa	**Māori name(s)**	**Other name(s)**
Agathis australis	Kauri	
Alectryon excelsus	Tītoki	NZ Ash
Alsophila tricolor	Punga	Silver Tree-fern
Anemanthele lessoniana		Gossamer Grass
Apodasmia [Leptocarpus] similis	Oioi	Jointed Wire-rush
Aristotelia serrata	Makomako	Wineberry
Arthropodium cirratum	Rengarenga	NZ Rock Lily
Ascarina lucida	Hutu	
Astelia grandis		Swamp Astelia
Austrodera richardii	Toetoe	
Brachyglottis repanda	Rangiora	Bushman's Friend
Brackyglottis compacti		Castlepoint Daisy
Brackyglottis greyi		Daisy Bush
Carex secta	Purei	
Carex testacea		Speckled Sedge
Carpodetus serratus	Putaputāwētā	Marbleleaf
Chionochloa rubra		Red Tussock
Clematis paniculata	Puawānanga	
Clianthus puniceus	Kākābeak	
Coprosma crassifolia	Mingimingi	
Coprosma lucida	Karamū	
Coprosma parviflora		Leafy Coprosma
Coprosma propinqua	Mingimingi	
Coprosma pseudocuneata		
Coprosma repens	Taupata	
Coprosma rhamnoides		
Coprosma robusta	Karamū	
Coprosma rubra		
Coprosma rugosa		
Cordyline australis	Ti Kouka	Cabbage Tree
Cortaderia richardii		
Corynocarpus laevigatus	Karaka	NZ Laurel
Cytisus proliferus		Tree Lucerne
Dacrycarpus dacrydioides	Kahikatea	White Pine

Dacrydium cupressinum	Rimu	Red Pine
Dianella nigra	Turutu	NZ Blueberry
Dodonaea viscosa	Akeake	
Elaeocarpus hookerianus	Pōkākā	
Fuchsia excorticata	Kōtukutuku	
Fuscospora cliffortioides		Mountain Beech
Fuscospora fusca	Tawhai raunui	Red Beech
Fuscospora solandri	Tawhai rauriki	Black Beech
Griselinia littoralis	Kapuka	Broadleaf
Hoheria angustifolia		
Hoheria populnea	Houhere, ribbonwood	Lacebark, Ribbonwood
Hoheria sexstylosa		
Juncus pallidus		Giant Rush
Kunzea ericoides	Kanuka	
Kunzea robusta	Rawirinui, Kānuka	
Leptospermum scoparium	Manuka	Teatree
Libertia grandiflora	Mikoikoi	NZ Iris
Libocedrus bidwillii	Pāhautea	
Lobelia angulata	Pratia	
Lophomertus oncordata	Rōhutu	
Lophozonia menziesii	Tawhai, tahina	Silver Beech
Melicytus lanceolatus	Māhoe-wao	Narrow-leaved Mahoe
Melicytus ramiflorus	Mahoe	
Metrosideros excelsa	Pōhutukawa	NZ Christmas Tree
Metrosideros umbellata	Rātā	Southern Rātā
Meuhlenbeckia astonii		
Muehlenbeckia complexa	Pōhuehue	Small-leaved Pōhuehue, Wire Vine
Myoporum laetum	Ngaio	
Myrsine australis	Mapou	
Olearia adenocarpa		Small-leaved Tree Daisy
Olearia arborescens		Common Tree Daisy
Olearia avicenniifolia		Mountain Akeake
Olearia cheesmanii		Streamside Tree Daisy, Cheeseman's Tree Daisy
Olearia lineata v. dartoni		
Olearia nummulariifolia		
Olearia odorata		Scented Tree Daisy
Olearia paniculata	Akiraho	Golden Akeake
Olearia traversiorum	Hakapiri	Chatham Island Akeake
Ozothamnus leptophyllus	Tauhinu	
Ozothamnus vauvilliersii		Mountain Tauhinu
Parsonsia heterophylla	Kaihua	NZ Jasmine
Pennantia corymbosa	Kaikōmako	
Phormium cookianum	Whararikī	Mountain Flax
Phormium tenax	Harakeke	Flax

Pittosporum crassifolium	Karo	
Pittosporum eugeniodes	Tarata	Lemonwood
Pittosporum ralphii	Karo	
Pittosporum (Stephens Island)		
Pittosporum tenuifolium	Kōhūhū	Black Matipo
Plagianthus divaricatus	Makaka	Salt Marsh Ribbonwood
Plagianthus regius	Mānatu	Lowland Ribbonwood
Poa cita		Silver Tussock
Podocarpus totara	Tōtara	
Prumnopitys ferruginea	Miro	Brown Pine
Prumnopitys taxifolia	Mataī	Black Pine
Pseudopanax arboreus	Whauwhaupaku	Fivefinger
Pseudopanax crassifolius	Horoeka	Lancewood
Pseudopanax ferox		Fierce lancewood
Pseudopanax lessonii	Houpara	
Pseudowintera colorata	Horopito	Peppertree
Pterophylla racemosa	Kāmahi	
Puccinella stricta		Salt grass
Schefflera digitata	Pate	Seven Finger
Solanum laciniatum	Poroporo	Bullibulli
Sophora microphylla	Kowhai	Small-leaved Kōwhai
Sophora tetraptera	Kōwhai	Large-leaved Kōwhai
Veronica albicans		Hebe
Veronica buxifolia		Hebe
Veronica diosmifolia		Hebe
Veronica eliptica		Hebe
Veronica parviflora		Hebe
Veronica salicifolia	Koromiko	Willow-leaf Hebe
Veronica stricta		Hebe
Wahlenbergia violacea		Violet Harebell