PRELIMINARY TECHNICAL GUIDELINE
Adaptive Management of Coastal Forestry Buffers

Tāne's Tree Trust
NATIVE FORESTS FOR OUR FUTURE
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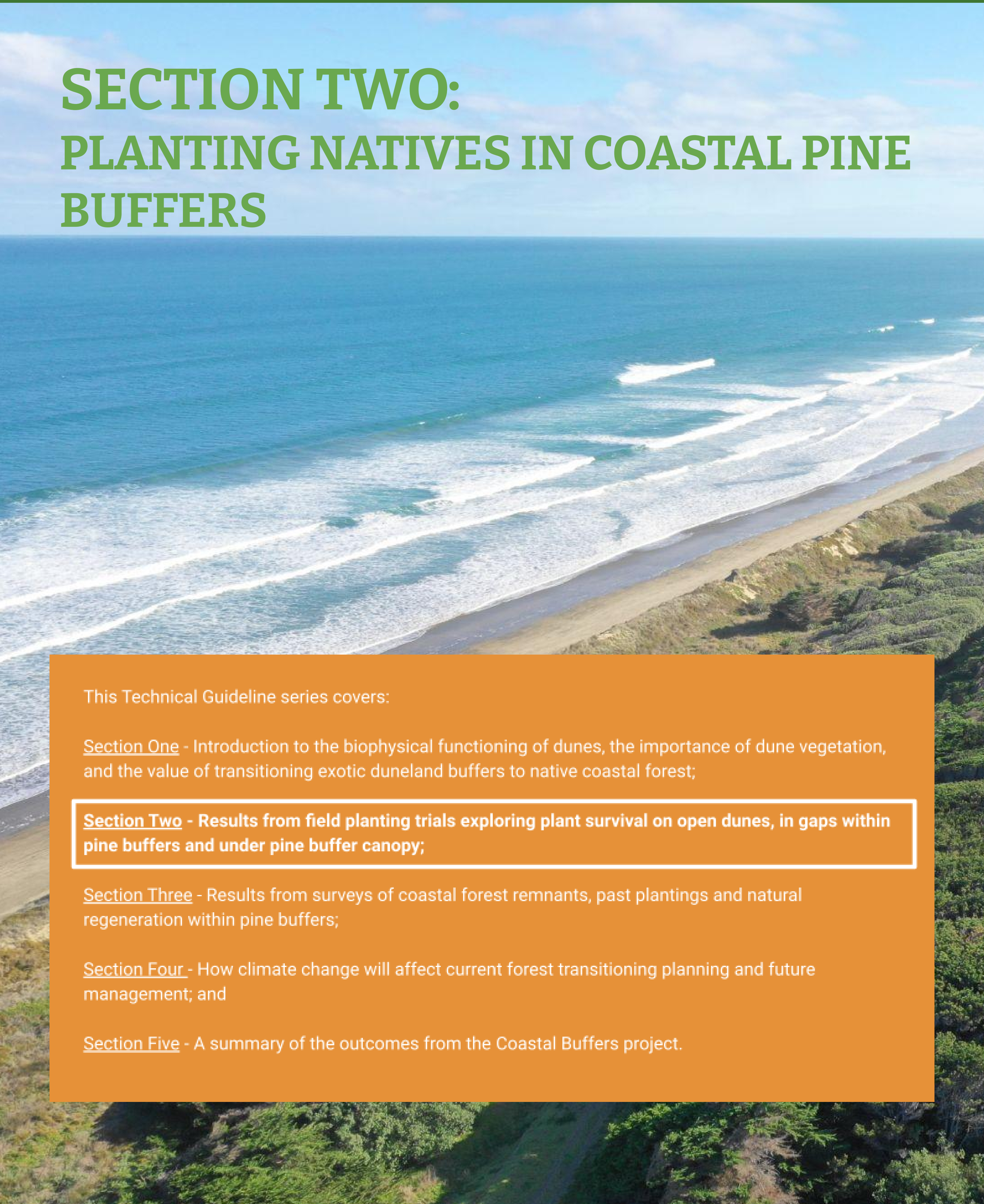

SECTION TWO:
PLANTING NATIVES IN COASTAL PINE BUFFERS

This Technical Guideline series covers:

Section One - Introduction to the biophysical functioning of dunes, the importance of dune vegetation, and the value of transitioning exotic duneland buffers to native coastal forest;

Section Two - Results from field planting trials exploring plant survival on open dunes, in gaps within pine buffers and under pine buffer canopy;

Section Three - Results from surveys of coastal forest remnants, past plantings and natural regeneration within pine buffers;

Section Four - How climate change will affect current forest transitioning planning and future management; and

Section Five - A summary of the outcomes from the Coastal Buffers project.

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2021

This Tāne's Tree Trust project has been partially funded by the Ministry for Primary Industries Sustainable Farming Fund (Project 405683) with support from project partners the Coastal Restoration Trust of NZ, Summit Forestry, Tainui Kāwhia Inc, Pārengarenga Inc, Hancock Forests, Rayonier Matariki Forests, Waikato Regional Council, Northland Regional Council, Auckland Council, Waikato/Coromandel DOC, Ngāti Tara Tokanui, Ngāti Whatua o Kaipara, Te Aupouri, Te Rarawa, Ngāti Kuri, Ngai Takoto, Kaitaia Intermediate, Bushlands Trust and Kāwhia and Opoutere Coastcare communities.

Introduction

This research assesses planting methods for transitioning exotic duneland buffers to native coastal forest buffers. In this technical article we summarise the planting trials to date, with preliminary recommendations on an adaptive management approach to transitioning exotics to permanent native coastal buffers.

Background

Extensive areas of exotic production forest occur on dunelands around the New Zealand coast. These forests typically have a sacrificial exotic forest buffer zone along their seaward margin to provide shelter to landward production stands from onshore salt-laden winds. These buffer zones, often extending up to 400 m inland of the coast, are critical to plantation survival, growth rates and timber quality. Current buffer zones are invariably composed of exotic species including radiata pine, macrocarpa and maritime pine, and they are often old (>50 years) and failing.

There is a significant opportunity to progressively replace these exotic forest buffer zones with more resilient long-lived indigenous coastal dune forest. The trials help inform the role of planting natives to complement any natural regeneration to establish a forest buffer dominated by native species. Planting trials were designed to evaluate effective and efficient methods for assisting the conversion from exotic coastal buffers.

Trial sites

The focus for the planting trials has been on sites within the upper North Island. This has involved planting a range of native coastal tree and shrub species and comparing performance of planted natives within pine shelter and on open nearby exposed dune sites.

Pilot planting trials were set up over three years at three coastal sites (see Figure 1) within typical northern North Island exotic forest buffers:

1. Te Hiku Forest, Te-Oneroa-a-Tōhē/Ninety Mile Beach, Northland west coast - within the pine buffer and on open seaward dunes;
2. Opoutere Beach, Coromandel east coast – within mature pines on dunes and adjacent open dunes; and
3. Kawhia, Waikato west coast – on the edge of Kawhia harbour in a recently clear-felled pine buffer area, and on the seaward open dune.

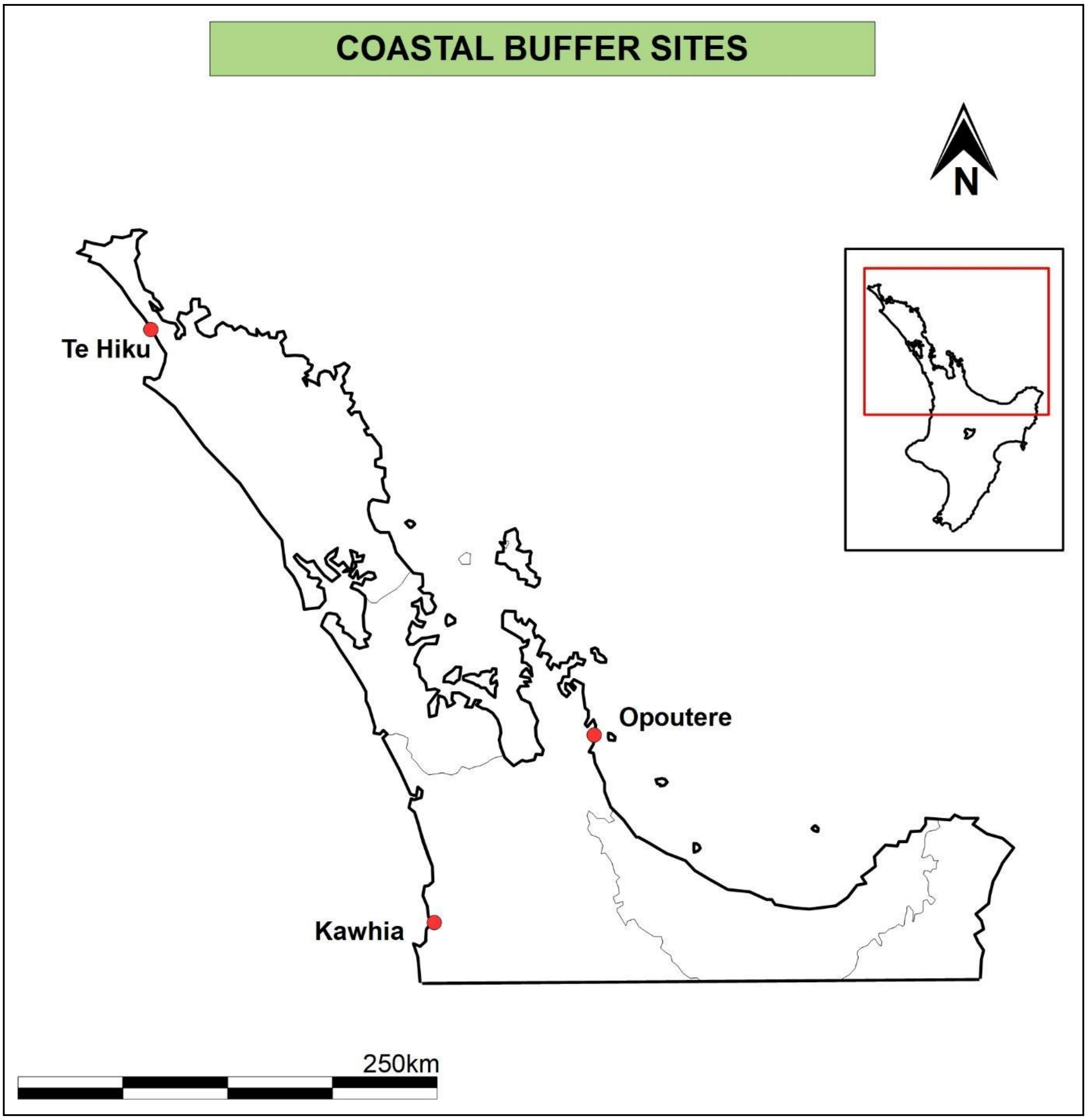


Figure 1: Location of the 3 planting trial sites within coastal exotic forest buffers in the upper half of the North Island.

Trial design, species and treatments

Experimental design

Planting and experimental design common to all sites involved planting mixed species' plots up to 20m in diameter with a central plot peg and a variety of treatments:

- Natural gaps in the exotic buffer canopy (Te Hiku/Opoutere);
- Under full canopy of exotic forest (Te Hiku/Opoutere);
- Open duneland sites with existing exotic and native ground cover vegetation (all sites);
- Proximity of plantings to the coast (all sites); and
- Recently clear-felled sites where the exotic buffer had been logged (Kāwhia).

Species and seedling grade

Species planted comprised a mixture of locally sourced coastal species including:

- ***Tree species*** – pōhutukawa/*Metrosideros excelsa*, karaka/*Corynocarpus laevigatus*, kauri/*Agathis australis*, kānuka/*Kunzea linearis (Northand) or K. robusta*, pūriri /*Vitex lucens*, kohekohe/*Didymocheton spectablilis*, tōtara/*Podocarpus totara*, tawāpou/*Planchonella costata*, titoki/*Alectryon excelsus subsp. excelsus,* porokaiwhiri/pigeonwood*/Hedycarya arborea*.
- ***Shrub hardwood species*** – akeake/*Dodonea viscosa*, houhere/*Hoheria populnea*, ngaio/*Myoporum laetum*, houpara/*Pseudopanax lessonii*, mānuka/*Leptospermum scoparium var. scoparium,* mahoe/*Melicytus ramiflorus*, karamū/*Coprosma robusta*, red matipo/*Myrsine australis*, wharangi/*Melicope ternata*, taupata/*Coprosma repens*, kohūhū/*Pittosporum tenuifolium*, whau/*Entelea arborescens*.
- ***Monocot species*** – tī kōuka/*Cordyline australis*, nīkau/*Rhopalostylis sapida*, harakeke/*Phormium tenax*, toetoe/*Austroderia splendens*.

Species were chosen based on historical records or known presence in the locality. Where existing plant trials had already provided information on species survival (e.g. Whitianga dune trial), this was incorporated into the species selection.

Container grades and plant size varied from small plants (30cm) raised in 7cm plugs to larger seedlings (>50cm high) raised in PB2 or PB3 Planter Bags or equivalent depending on stock availability.

A seed trial was also undertaken in Te Hiku forest to assess the benefits of sowing seed directly compared with planting. Seeds trials included the larger-seeded species - karaka, pūriri, taraire, tawapou and porokaiwhiri (pigeonwood).

Trial layout and treatments

Te Hiku - Replicated plots within Open/Gap/Canopy trial areas were established at different sites within the Te Hiku protection buffer over the three-year project. Small-scale seed trials were established under pine canopy.

Opoutere - Replicated plots within Gap/Canopy trial areas were established and open trials were established in a longshore grid. Replicate plots were established under pine canopy near the seaward edge and landward edge of the pine forest, together with planted lines of pōhutukawa, karaka and totara that extended from the high tide vegetation zone to the inland edge of the pine.

Kāwhia - Replicate plots were established at Te Aria o Te Wiwini and Takapuwhia, Kāwhia Harbour trialling different planting techniques including fertiliser, hydrogel, plant guards, planting depth. Replicate plots were also established in open sites at the ocean beach/Te Puia Springs based on zones running parallel to the shoreline.

Monitoring and data analysis

Trials were planted between 2019-2021. All planting sites were inspected soon after planting, and then 4-6 months later so that any issues with early performance, and in particular cause of dieback, browsing or mortality, could be noted. This allowed any management requirements to be addressed where practical and inform planning of future plantings. Monitoring was then undertaken annually during the project timeframe recording height, vigour and general observations.

Measuring a PSP plot

Survival and growth data was analysed to provide summary tables and graphs comparing sites, species and planting treatments.

Results

TE HIKU - NORTHLAND

The sacrificial pine buffer planted in the 1960s-1970s to protect the production forestry varies from 200-400m wide. Table 1 provides stand details. These stunted 40 years old pines reflect the harsh coastal conditions of the drought prone dunes and prevailing onshore westerly winds laden with salt during storms.

Table 1: Summary of the stem diameter plots (~120 m inland from toe of the frontal dune) established in the protective pine buffer at Te Hiku, Far North. Measured August 2018

	Plot size (radius m)	Average Height (m)	Average diameter (cm)	SPHA (alive only)	% of trees with multi leaders
Pine	11.28	13.4	27.3	700	37.9

Early performance of the coastal natives planted within the pine buffer zone at Te Hiku were significantly affected by the severe 2019/2020 drought. The average overall survival was 6.1% - with 1.5% in the open coast trial plots, 8.3% in the pine gaps and 8.6% in the plots under pine canopy. Ngaio had the best overall survival with 57% survival within gap plots, 37% under pine canopy and 6% survival out in open coast sites. Surprisingly tawāpou fared relatively well under pine canopy (40%) with other species of note surviving the 2019/2020 drought being pūriri under pine canopy (22%) and kānuka in pine gaps (27%).

The 2020 trial plants also had to contend with a continued (but less severe drought) and had an average overall survival of 36%. However, natives planted under the pine canopy or within a small gap had up to 50% survival compared to only 15% for natives planted in the open with no shelter (see Table 2). Height was also greater for seedlings planted in the pine buffer compared to open planting. Average plant vigour was greatest under the pine buffer compared to plantings in the pine gaps.

Table 2: Performance of natives 12 months after planting within the exotic pine buffer (under pine canopy and within pine gap) and adjacent open site in 2020, Te Hiku, Far North.

	Total number surviving seedlings	Survival %	Average height (cm)	Average vigour (0-5)
Canopy	141	42.7	39.0	3.1
Gap	164	49.7	32.6	2.3
Open	48	14.5	23.7	3.0

Figure 2 shows the performance of the individual species planted in the 2020 trials.

PINE CANOPY:

The main plant species that survived through the 2020-2021 summer drought included **houhere, tawāpou, tōtara, kohekohe, wharangi, pūriri, and pōhutukawa**. Of these houhere, tawapou, kohekohe, wharangi and pūriri showed the greatest vigour (growth).

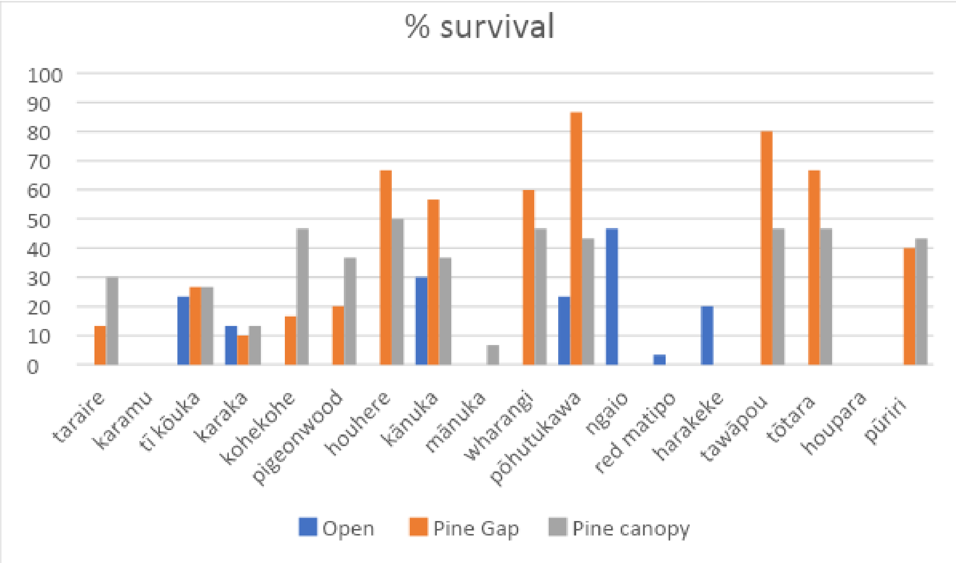
PINE GAPS:

The dominant surviving species were **pōhutukawa, tawāpou, tōtara, houhere, wharangi and kānuka**. Of these houhere, wharangi and kanuka displayed the most vigorous growth.

OPEN COAST SITES:

Very few plants survived in the open coast sites. Of the plants trialled in the open site, **ngaio** had the highest survival rate (47%) with much lower survival of tī kōuka/cabbage tree, kānuka, pōhutukawa, harakeke/flax and karaka.


Trial plantings in a pine buffer gap (left) and under pine canopy (right). Te Hiku, Northland



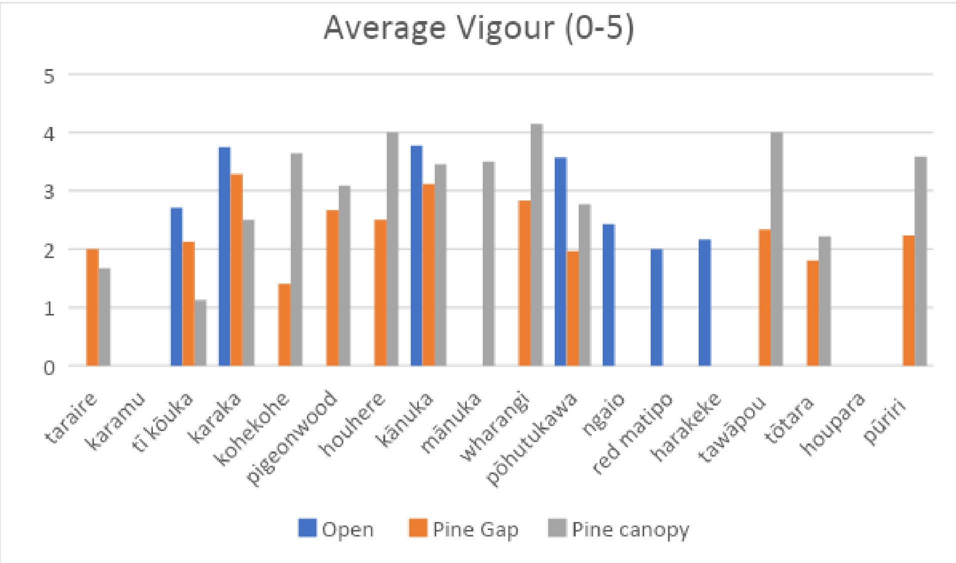


Figure 2: Performance of native shrub and tree species 12 months after planting (including % survival and average vigour) planted in different shelter treatments at Te Hiku forest(2020-2021).

Canopy trial plot before planting with dense carpet of needles and open understorey, Te Hiku Forest, Northland.

Browse by rabbit, hares and horses was an ongoing issue particularly reducing the performance of tī kōuka, karaka, taraire, tawāpou, pūriri, nīkau, māhoe and houpara. Pōhutukawa did not show much pressure from horse or rabbit/possum browse but was affected by insect browse. Taraire, tawāpou, porokaiwhiri /pigeonwood and pūriri also suffered from insect damage.

A planted line of pōhutukawa just inside the existing exotic buffer had very high plant loss from drought, except where pōhutukawa were located in a dune swale. Rushes were common in these swales indicating a higher water table.

A selection of better performing species planted under pine canopy at Te Hiku Forest, Northland – from left to right – wharangi, tawapou, kohekohe, and pūriri.

Seed trials

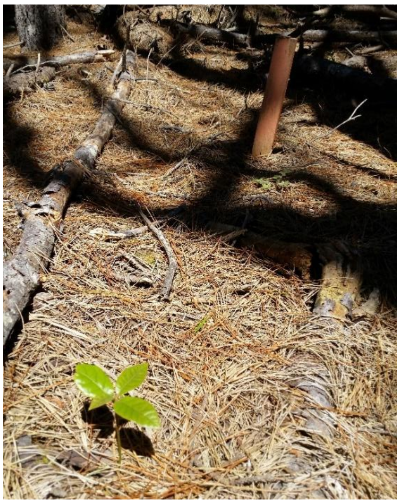
Early seed trials (Table 3) found that karaka germinated relatively well even with the drought but were heavily browsed by rabbits. Karaka seeds that were buried had a higher germination success (38%) than seeds that were scattered on the ground (14%).

Later trials found kohekohe and taraire had low germination rates and did not survive long term. Kohekohe may have been browsed but it appeared the few successful taraire seedlings succumbed to the effects of the drought. No germination of pūriri or pigeonwood was noted during the study. Pūriri germination may be delayed or affected by moisture content. Tawapou germination was low but the plants were healthy.

Table 3: Percent average survival after one year within seed trials at Te Hiku forest, Northland

	2019*	2020*	2021
karaka (scattered on surface)	9	n/a	n/a
karaka (buried)	19	18	65
pūriri	n/a	0	0
kohekohe	n/a	5	0
taraire	n/a	9	3
pigeonwood	n/a	n/a	0
tawapou	n/a	n/a	10

* 2019/20 severe summer drought



Left - Germinated taraire seed, and Right - germinated karaka seeds with a planted pūriri in foreground. Te Hiku Forest, Northland

OPOUTERE - WAIKATO

As with the other upper North Island sites, plantings at the Opoutere site were significantly affected by the 2019/2020 summer drought. Some species were also severely affected by rabbit/hare browsing.

OPEN COAST SITE

The open trial site was located on exposed low frontal dunes just landward of the dynamic envelope (i.e. the shoreline area subject to periodic erosion). Only a small selection of species were trialled at this site based on natural regeneration and previous planting and trials along this coast. For instance, previous large trials in similar exposed nearshore dune environments indicated karaka, kohekohe, tawapou and pūriri did not survive at all after 2 years, most dying within a few months. Pohutukawa in earlier trials had moderate survival but grew very slowly for the first 5 years.

Of the species trialled, karo was the hardiest and showed both high survival rates and vigour. Ngaio and akeake also had high survival rates but suffered greater salt/wind damage. Houpara and taupata survived the harsh nearshore dune conditions well but were severely browsed by rabbits/hares, resulting in very low (<2%) estimated survival rates. Manuka, mahoe and totara did not survive at all. Very small numbers of titoki and kanuka survived (<5%) but suffered severe salt and wind damage.

PINE BUFFER

The pine buffer sites under canopy were typically relatively devoid of vegetation (largely a mat of pine needles) in the seaward zone while native regeneration was more prevalent in the landward zone. The seaward zone had shorter, fatter trees with a lower density of pines per hectare compared with pines in the landward zone (Table 4).

Table 4: Summary of stem diameter plots in the coastal pine buffer at Opoutere, Waikato (Measured April 2022)

Site	Plot size (radius m)	Average Height (m)	Average diameter (cm)	SPHA (alive only)	% of trees with multi leaders
Pine – seaward front zone	11.28	21.2	44.4	275	0
Pine – landward back zone	11.28	26.1	36.8	525	0

The gap sites typically had dense rushland and vineland vegetation 0.6-1m high.

2020-2021 trials showed survival of various species was high where native seedlings were planted under a canopy of pines (average 87%) or were planted within a gap in the pine buffer (80%) (Table 5).

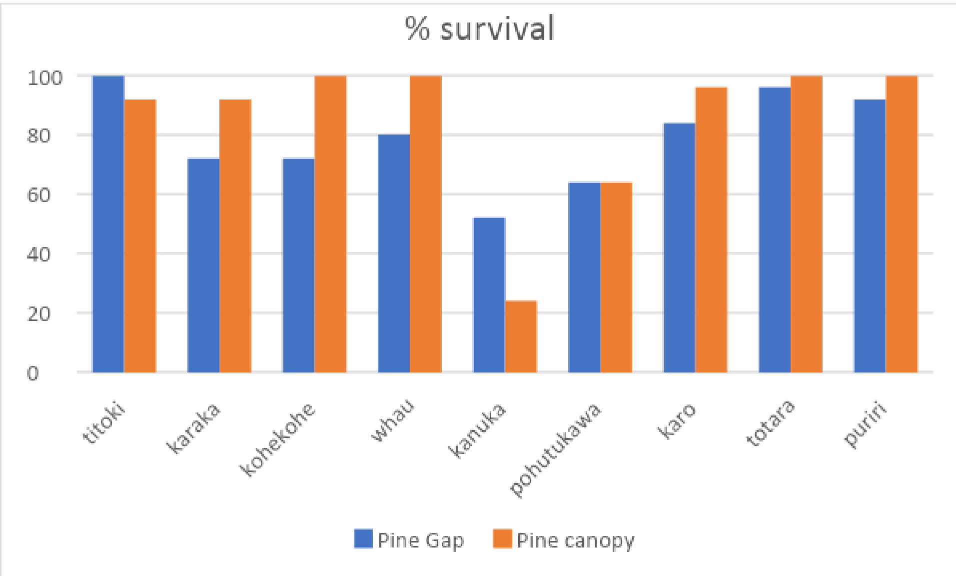
Table 5: Overall performance of seedlings a year after planting within pine canopy and gap planted plots (2020-2021) at Opoutere, Coromandel

Site	Species	Total seedlings	Average height (cm)	Average vigour (1-5)	Survival (%)
Canopy	All	195	54.9	3.6	86.7
Gap	All	179	58.9	3.8	79.6

Results from the plots after 1 year (Figure 3) show that:

Pine Canopy - Kohekohe, totara, pūriri, whau, titoki, karo and karaka had high survival and showed average-good vigour. Kanuka had low survival and poor vigour, while pōhutukawa had medium survival (64%) but good vigour.

Pine Gaps - Titoki, tōtara, pūriri, karo and whau had high survival and showed average-good vigour, while karaka, kohekohe, pohutukawa and kānuka had medium survival success (but more than 50%). They also showed good vigour except for kanuka.



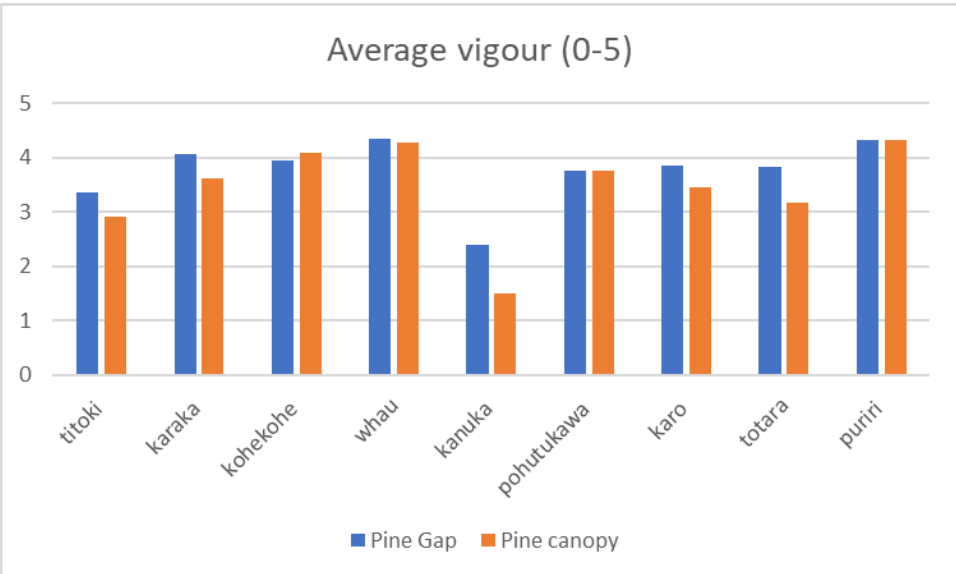
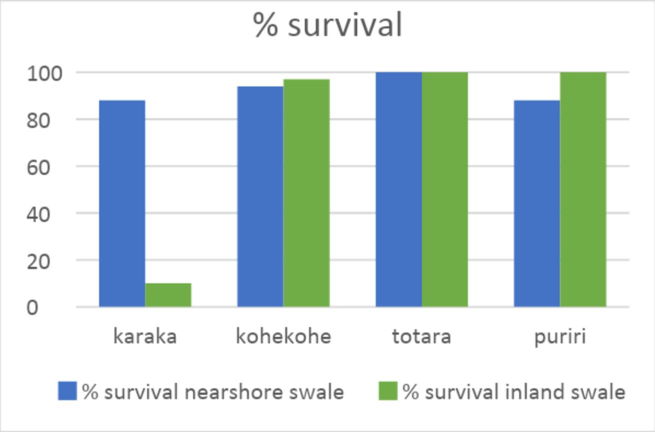


Figure 3: Survival and vigour of planted species within pine canopy and gap plots (2020-2021), Opoutere, Coromandel

Rabbit or hare browse was a particular issue for karaka, but also pūriri and karo. Insect damage was most notable on pōhutukawa and titoki, particularly in gap environments. Whau, pūriri and kohekohe suffered from wind burn in more exposed sites.

Figure 4 indicates good survival of kohekohe, tōtara and pūriri in the pine canopy distance-treatment plots. Results show **increased plant vigour for all species under pine canopy** further inland in the more sheltered site. Karaka would have also performed well except it was heavily browsed at the inland site.



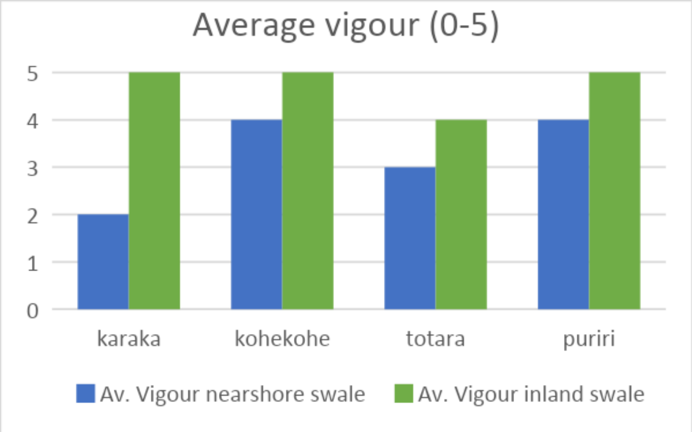


Figure 4: Percentage survival and average vigour of seedlings planted in non-bounded plots of single species located in a near-shore swale (70m inland with greater exposure to salt winds) and a swale further inland (100 m inland from frontal dune toe). Note the inland karaka plantings experienced heavy hare browse while kohekohe experienced some leaf burn and insect damage, and pūriri leaf burn, in the seaward swale.

Above - 1-year old Pūriri and karaka plots under pine canopy (70m inland from the dune toe and behind front dune ridge – nearshore swale within forest canopy). Opoutere, Coromandel

Right - Pūriri (vigour 1) with salt wind damage in contrast to a more sheltered and healthier pūriri (vigour 5) on the far right.

Further trial plantings of replicated plots seaward and landward were established, as well as planted transects of pōhutukawa, karaka and totara perpendicular to the shore, to test the effect of planting success under pine canopy relative to distance inland. Results however were not available by the time the project finished.

Plot under pine canopy near the seaward pine forest edge (left), and under pine canopy towards the landward pine forest edge (right). Opoutere, Coromandel

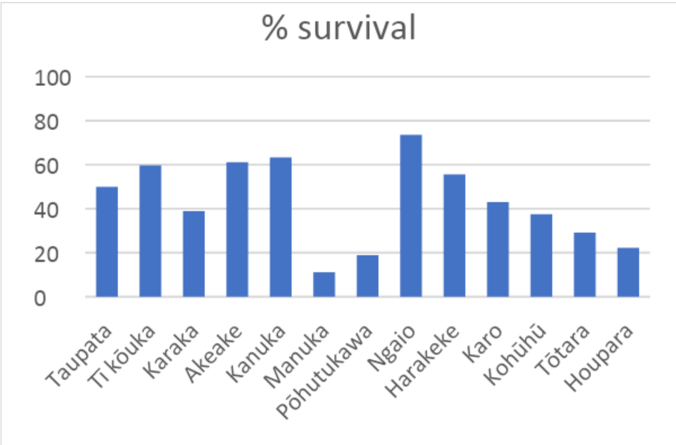
Kawhia Forest, Waikato

The initial planting at the Kawhia site evaluated a wide range of planting treatments across a recently clear-felled slope within the coastal exotic forest zone on the northern side of Kawhia Harbour. Only relatively hardy plant species were used in this trial. This provided some early indications of the tough site and climatic conditions within coastal buffers. This is despite the shelter provided by surrounding pines.

A major drought affected most species during the first year's trial planting. Overall survival was 38% one year after planting largely due to the drought. **Ngaio** was the best performing planted native with relatively good survival for **kanuka, akeake, tī kōuka and harakeke, and taupata** were the next best performers (Figure 5). Manuka, kohūhū and pōhutukawa performed poorly on upper drought prone slopes.

The best performing species one year after planting based on plant vigour included, kanuka, ngaio, harakeke and tōtara.

Plantings near the base of the slope performed best compared to plantings on drier upper dune slopes. Performance of native plants improved significantly when planted near existing shelter provided by regrowth of selected exotics such as lupin, or in the shelter of sprayed dead pampas or adjacent or within the shelter of logging slash. Of the tree species planted - totara, pohutukawa, rewarewa and karaka – the best survival and vigour was in sheltered microsites.



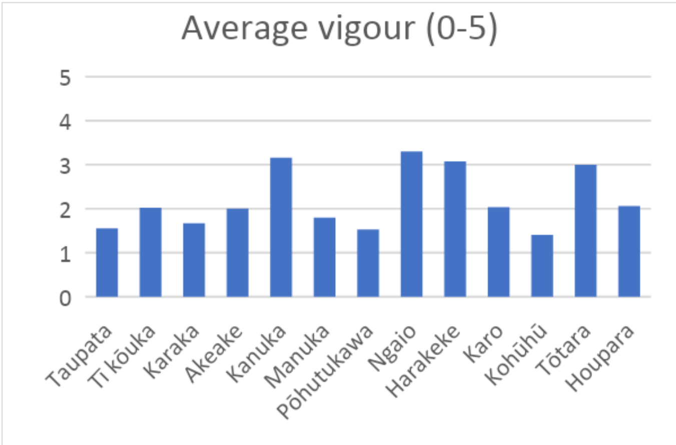
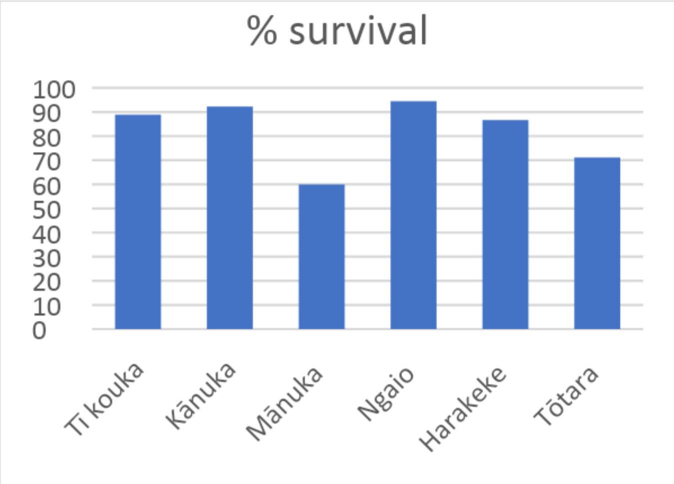


Figure 5: Performance of native shrub and tree species planted a year earlier on a clear felled pine site on Kāwhia dunes with an extended summer drought. (2019-2020)

The second summer's planting trials in 2020, also in a recently clear-felled coastal harbour edge site, did not have to contend with a drought and plant survival was 82%. Figure 6 shows the species with the greatest survival were **ngaio, kānuka, tī kouka and flax** with lower survival of tōtara (71%) and mānuka (60%). One year after planting kanuka averaged excellent (5) plant vigour, with ngaio and harakeke achieving on average good (4) vigour and manuka, tī kōuka and tōtara average-good (3-4) plant vigour.



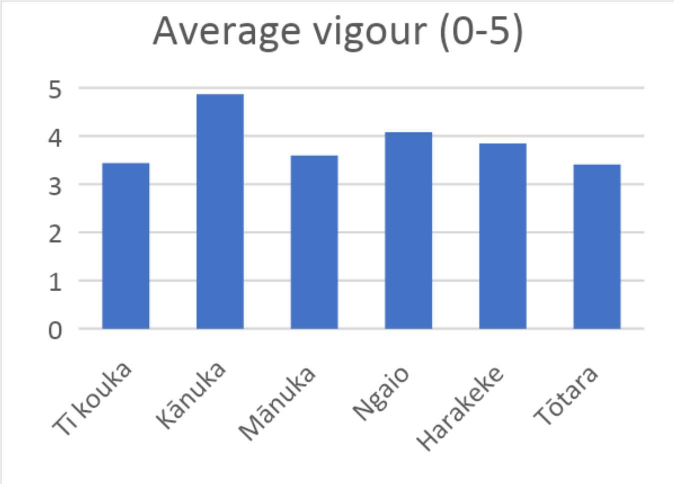


Figure 6: Percentage survival and average vigour of seedlings one year after planting (2020) at a clear-felled coastal edge site on the northern side of Kawhia Harbour.

Results from both a drought and non-drought year did not indicate any consistent benefits from fertiliser, hydrogel, planting depth or plant guard treatments. Planting in years where there is adequate rainfall is the single best driver of success where pines have been clear-felled. In contrast to the 30% survival in the drought affected year, overall plant survival during a non-drought year was 82% with plant vigour scoring high across all treatments.

Browsing by rabbits and hares and grazing by cattle reduce growth and survival of native plantings significantly. The plant protectors provided some initial shelter for planted natives and protection from browsers however broadleaved species in particular become overheated during the height of summer with resulting reduced vigour. The tall plastic corflute guards would have benefited from ventilation holes when installed to increase air circulation. Overall, the results did not indicate the plant protectors provided much of a benefit.

Results from the replicated plots in zones running parallel to the open coast shoreline were not available before the project finished.

Discussion

The work in this project suggests there is considerable potential to gradually transition existing exotic buffer zones to native coastal forest over many decades.

While further work is required to refine transition methods , the work conducted during this short project suggests the following factors are likely to be critical in establishment of native coastal forest buffers on exposed nearshore dunes of the upper North Island.

- **Capitalising on the benefits of existing pine shelter** –Despite difficulties with severe drought and animal browsing, the trials consistently showed higher survival and better vigour and growth rates for plantings sheltered by pines in the first critical year after natives are planted.

The trials indicate that transitioning existing exotic buffers by inter-planting native species and encouraging natural regeneration beneath the pines may be the most successful and quickest process to establish a native dune forest buffer. Clear felling and removal of the existing buffer zone trees is likely to be far less successful, with a reduced range of hardy and mainly shrub species suitable for these exposed conditions and increased weed and potentially browse issues.

While weed growth can be competitive and swamp planted natives if not maintained, exotic plants and logging slash can provide additional shelter on exposed coastal sites.

- **Species selection** – Results from these early trials indicate the best performing large tree species for planting under upper North Island pine buffer canopy or in pine buffer gaps include:
    - **kohekohe, pūriri, totara, karaka, titoki, tawapou, wharangi, houhere, whau and pōhutukawa;**
    - Some species such as kohekohe appear to establish best under a shaded pine canopy, whilst other more light-demanding/tolerant species such as kānuka grew better in the sheltered pine gaps. Some species had better survival in the pine gaps but more vigorous growth under the pine canopy.
    - NOTE: These trials only covered the early establishment of plantings. Longer term surveys are needed to help determine the ongoing health of these plantings with time. Also, other species may also be suitable that were not included in the trials. The use of any species at a site should be limited to those species which naturally occur in the relevant ecological district.

Where shelter such as a pine buffer is not available, the best performing species for planting on exposed upper North Island dunes include the shrubs/small trees **karo, ngaio and akeake**. Other species that also survived in our trials were harakeke, tī kōuka and kānuka, and to a lesser extent karaka. Houpara and taupata are also suitable for initial plantings, but only if well protected from animal browsing. In contrast, the trials and other work indicate almost no survival of forest canopy species in open sites on exposed nearshore dunes. Field inspections of various sites suggest pōhutukawa is the only large tree species that can successfully establish in these exposed areas. The trial results suggest that plantings in these areas should be limited to hardy shrub species (e.g. karo) until shelter is established.

The expected impacts of climate change including increasing severity of droughts will likely negatively affect the establishment of native vegetation on sand dunes and increase the importance of this transition work.

Other key factors suggested by the work include:

- **Planting microclimate** - It is important to read your landscape and target where you plant. Plantings generally established and grew better in swales where dune topography provided greater shelter and water tables were closer to the surface (an important consideration when drought are becoming more frequent). Forestry debris and existing shrubby vegetation in open situations also provided valuable shelter from sun, wind and salt. A field observation noted that the sand was usually damper under the shade of a pine canopy and pine duff was likely providing a mulch. Such benefits are going to become increasingly important for successful restoration activities with the increasing pressure of climate change.

- **Management of browsing by animal pests** - While we were not able to examine this aspect in detail, it was clear from both our trials and field inspections that browsing animal pests are a major factor controlling re-establishment of native vegetation on coastal dunes. Rabbits and hares are one of the most destructive causes of plant losses along with possums, deer, pigs and uncontrolled stock and horses.

Over the short period (3 years) of our trials, the problems were less notable under the cover of an existing pine canopy. The species most affected by browse in the trials were karaka, tī kōuka, nīkau, houpara, taupata, tawāpou, pūriri, māhoe and taraire. There was also evidence that insect damage might be an issue for some species, particularly in gaps in the pine forest where the forest floor is often covered by dense rushland/vineland vegetation. More detailed and longer-term work is required on these aspects.

- **Large-scale planting** - For large scale backdune restoration the concept of small-scale diverse plantings ('seed islands') may be worth investigating for gradual conversion of coastal pine buffers to coastal native forest. Seed islands can have multiple benefits – e.g. restoration plantings enhancing dune wetlands/lakes and riparian margins can also act as seed islands to the wider landscape.

A motorised planting auger provided consistently deep holes for planting of native seedlings and made planting easier and quicker for the planting crew.

- **Seed planting** - results suggest planting seed as opposed to broadcast spreading is more successful. Larger-seeded species including karaka and tawapou potentially germinated and grew well except results were conflicted by browse pressure. Seed trials with more detailed monitoring and browser control would be useful to explore the potential of seed planting.

Use of bamboo stakes saves considerable time relocating planted natives during maintenance and monitoring (far right).

Ensuring planters understand best planting practice is key to the plantings success (bottom left).