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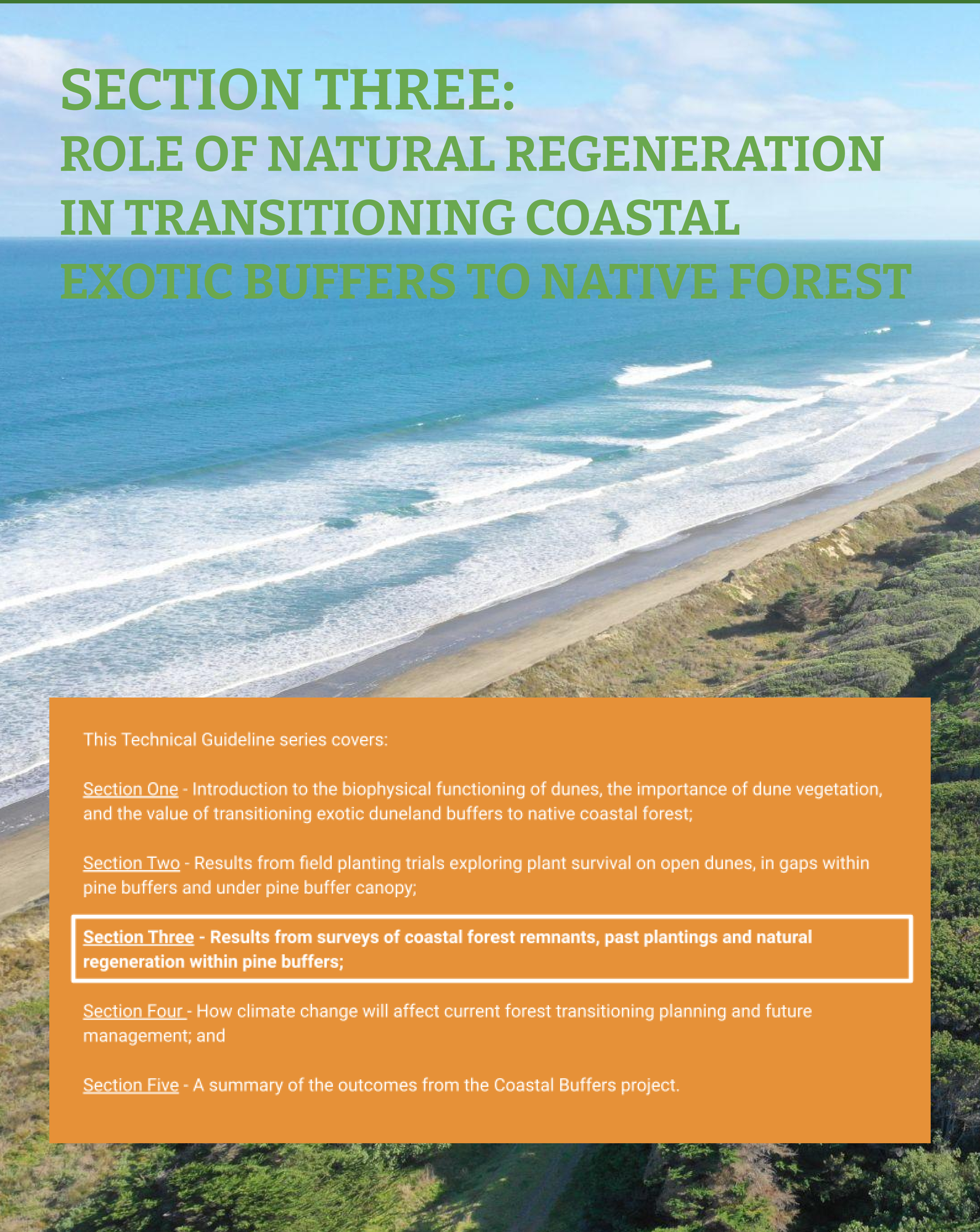

SECTION THREE:
ROLE OF NATURAL REGENERATION IN TRANSITIONING COASTAL EXOTIC BUFFERS TO NATIVE FOREST

This Technical Guideline series covers:

Contents

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Introduction

This research assesses methods for transitioning exotic duneland buffers to native coastal forest buffers.

In this technical article we provide a summary of surveys of natural regeneration within existing exotic buffers, native coastal forest remnants and past native plantings. The results help inform recommendations on an adaptive management approach to transitioning exotics to permanent native coastal buffers.

Historical information

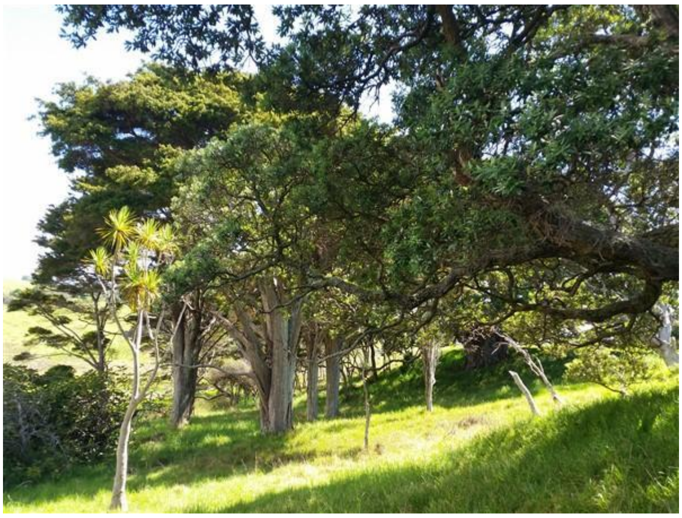
Prehuman forest cover

As discussed in the first technical article, several studies and early observations indicate that coastal dunes were dominated by tall native forest. Conifers and broadleaved forest characterised the dunelands of northern New Zealand including conifers such as tanekaha, kauri, rimu, kahikatea as well as pōhutukawa, karaka, kowhai, pūriri, titoki, kohekohe, tawāpou, kanuka and a wide range of small broadleaved trees and shrubs.

Modified dunelands

By the beginning of the twentieth century Cockayne (1911) noted there were few true duneland forests left including a lack of historical duneland botanical information. Schnachenberg (1935) records the existence of an extensive pōhutukawa forest covering the back dunes between Kawhia and Aotea Harbour entrances. The pōhutukawa forest was likely typical of vegetation found on stable dunes along much of the upper North Island's west coast before the land was cleared for farming.

Kanuka dune forest is now extremely rare in the North Island outside of the Far North where the best remaining examples are found on the south Kaipara spit (Smale 1994). Kanuka forests on dunes are essentially seral, and with the absence of further disturbance (e.g., browsing) are merely a stage in a primary successional pathway from open dune vegetation to tall forest.



Remnant pōhutukawa and tōtara trees on the landward side of dunes at Pakiri, Auckland Region

Survey of existing coastal vegetation

The aim of the field surveys was to collate information on native trees and shrubs successfully establishing or remnant along the coastal zone. The sites visited provided a broad overview of the conditions of natural regeneration under exotic plantation canopy, within native forest remnants and on open exposed dunes. These surveys highlighted site-specific issues that needed to be factored into any successful restoration project.

Methodology

The presence of native shrub and tree species and their height were sampled. Site factors that could be affecting successful natural regeneration or planting success were also noted – including distance from the beach, proximity to native forest seed sources, presence of browsing mammals, and noting past and present management history of each site.

The characteristics of exotic buffer forests were also recorded including RECCE plots, average height and diameter of the canopy trees and density of planting. Also of interest was the current status of the buffer stands such as age, incidence of dieback and windfalls, and the size and number of any canopy gaps and associated understorey and gap vegetation, both exotic and native regeneration.

At each site forestry managers and landowners including local iwi assisted in identifying sites for surveying, helping undertake the surveys, as well as providing background to past and current management of the land.

Survey sites

Coastal sites with exotic or native buffer zones were selected across the Waikato, Bay of Plenty, Auckland and Northland regions for surveying (Figure 1). These included:

- Te Kao Forest, eastern Northland
- Te Arai, Te Oneroa-a-Tōhē, western Northland
- The Gap, Te Hiku Forest, western Northland
- Pakari, eastern Northland
- Woodhill, west Auckland
- Muriwai, west Auckland
- Piha, west Auckland
- Opoutere/Ohui, eastern Coromandel Peninsula
- Bowentown, western Bay of Plenty
- Waihi Beach, western Bay of Plenty

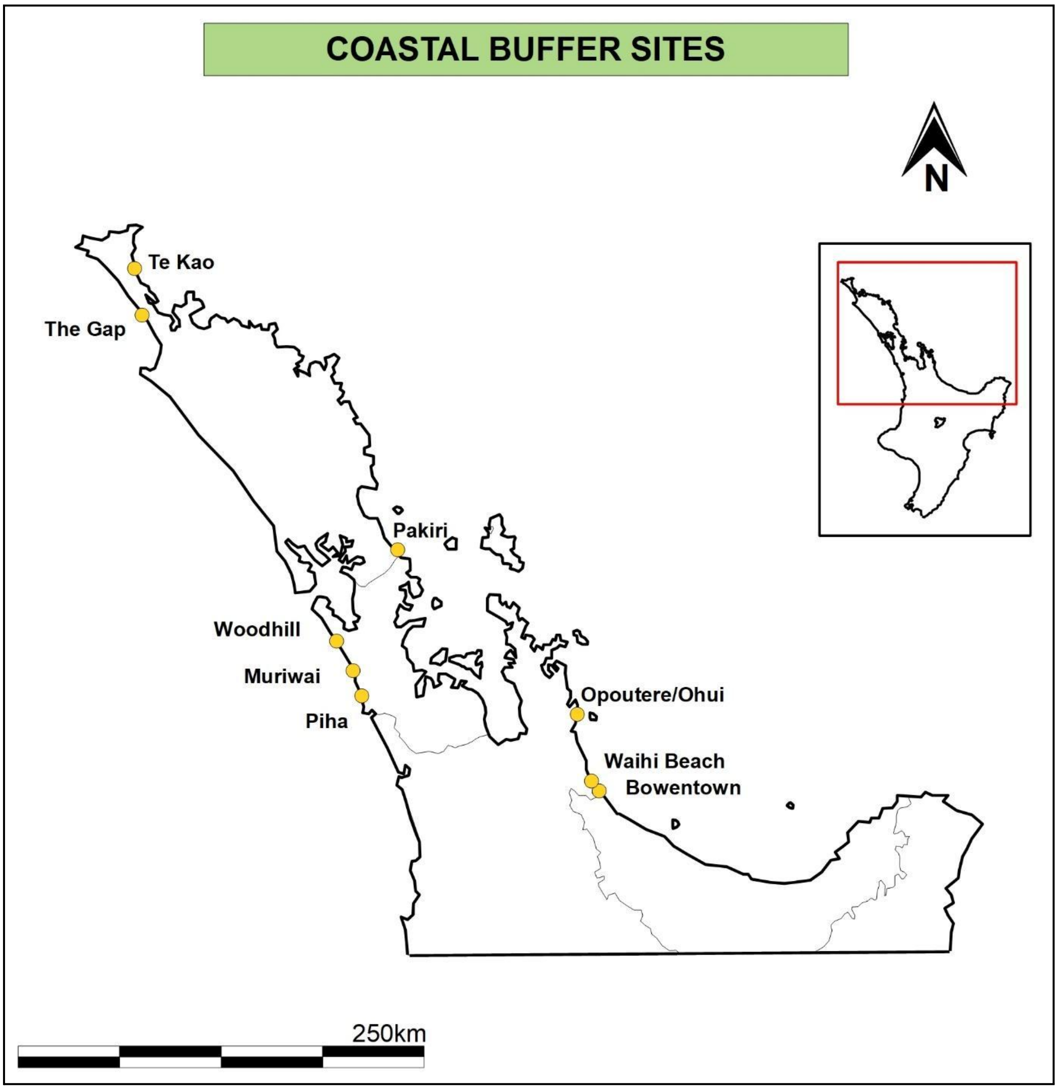


Figure 1: Location of the coastal vegetation survey sites in the upper half of the North Island.

Results

Remnant coastal forest is uncommon, and diverse coastal forest sequences a rarity in northern New Zealand.

Diversity of species

The main native species found as scattered mature remnants, planted or regenerating at the survey sites included pōhutukawa, houpara, karo, pūriri and kānuka (Table 1). Remnant or planted pohutukawa were found at all sites and were usually the most dominant species. Houpara and karo were also commonly planted and naturally regenerating, however pūriri were predominantly remnant trees. Exotic planted and wilding species included pines, macrocarpa, Norfolk Island pine and wattle.

Table 1: Numbers of trees and shrubs surveyed at each site.

Site	Pōhutukawa	Houpara	Karo	Pūriri	Kānuka	Other native	Exotic	Total
Te Hiku	29	0	1	0	23	0	12	65
Muriwai	9	1	29	0	1	3	3	46
Piha	13	2	10	0	0	6	0	31
Te Kao	57	0	0	0	6	0	0	63
Te Arai	114	4	0	18	8	14	0	158
Pakiri	16	0	0	2	0	5	0	23
Opoutere	55	20	9	19	0	24	0	127
Bowentown	36	38	3	0	0	6	0	83
TOTAL	**329**	**65**	**52**	**39**	**38**	**58**	**15**	**596**

Sampled measurements of each species indicated a substantial range in height for the most common tree and shrub species (Figure 2).

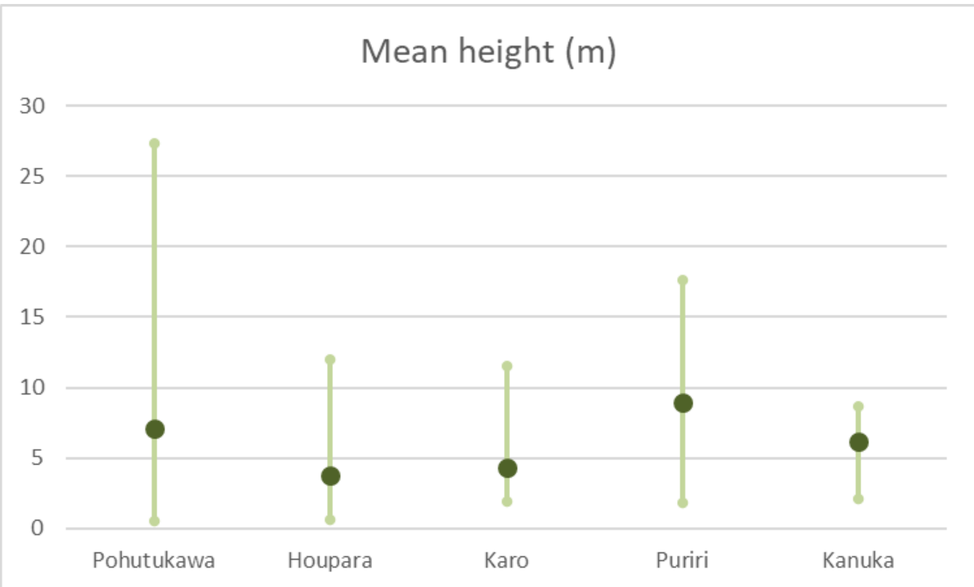


Figure 2: Mean heights of species with 10 or more individuals measured with minimum and maximum height extent shown.

Left - Kānuka, pōhutukawa, karo and flax on dunes at Te Hiku (Far North). Right - Pōhutukawa dune forest remnant at Pakari (northern Auckland).

Proximity to sea

Height of the main tree and shrub species measured across all surveyed sites shows a clear 'wedge' effect when data is aggregated using a logarithmic scale (Figure 3). Upper height was just over 5 m within 10m of the high-water mark and increased to over 15 m at 100m from the sea, and to over 25m at sites 1km from the coast. Pōhutukawa was the major species influencing upper height growth (Figure 4).

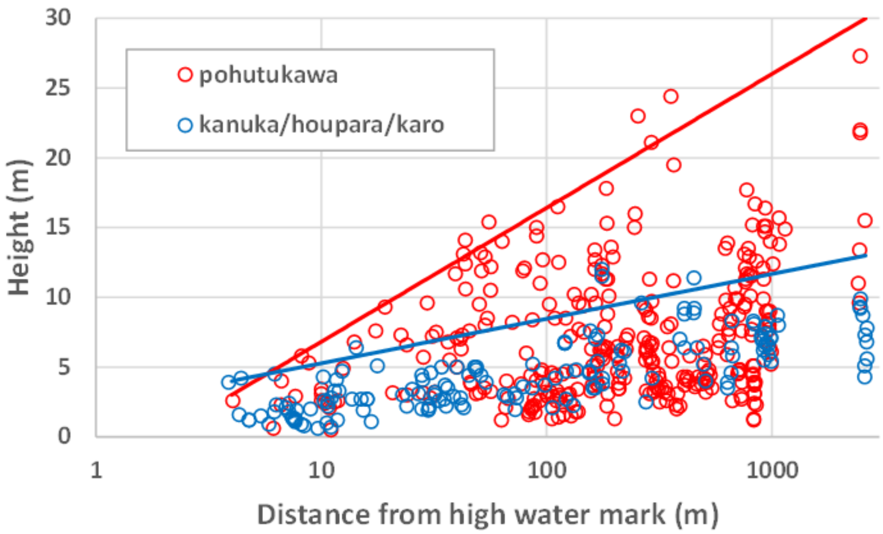


Figure 3. Heights of pōhutukawa (red) and other species (blue) measured at all sites versus distance from high water mark and orange line indicating upper height trend.

Large pohutukawa clumps in duneland, Parengarenga, Far North

Figure 4 shows houpara and karo can grow closer to the high tide mark than kānuka and pūriri. Maximum height of sampled small trees and shrubs including houpara, karo and kanuka was under 15m whereas pūriri exceeds this (Figure 5).

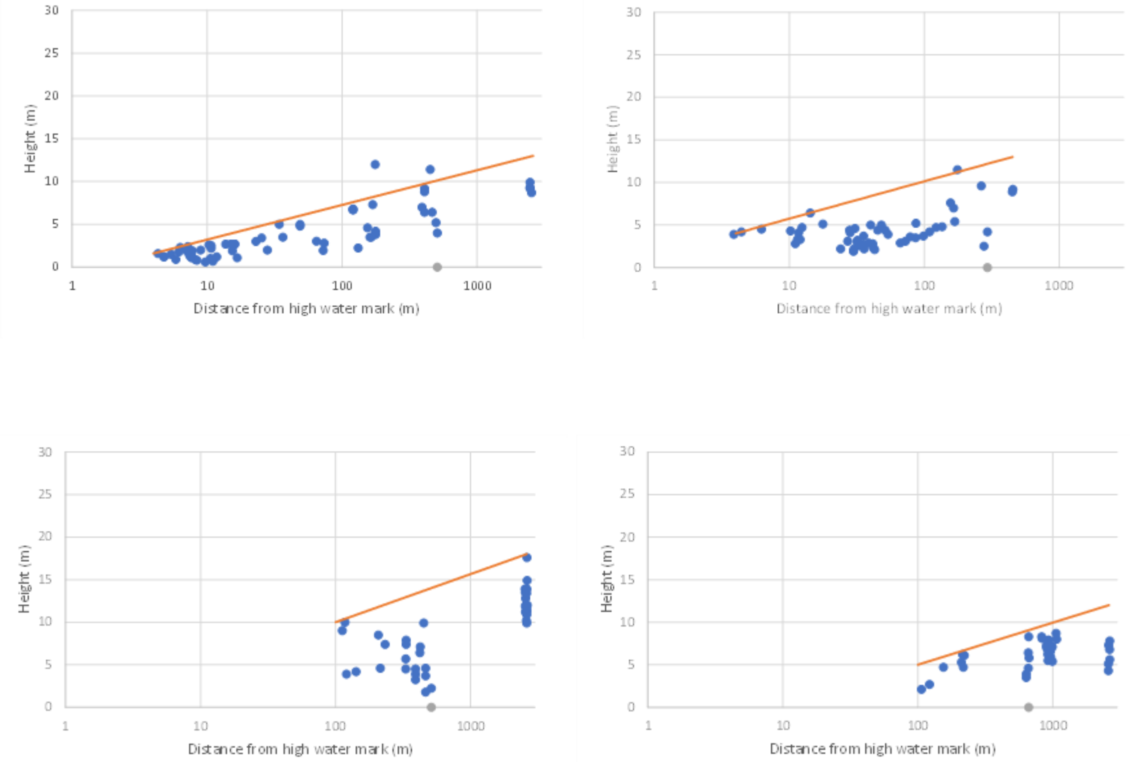


Figure 4: Height of houpara (top left), karo (top right), pūriri (bottom left) and kanuka (bottom right) versus distance from high water mark with orange lines showing upper height trends for each species from east and west northern coasts.

When height of all stems measured is plotted against distance from high water mark separately for east and west coast sites, top height of trees is significantly higher at east coast sites compared to west coast sites (Figure 5). The wedge effect on the dynamic west coast sites characterised by prevailing westerly onshore winds results in tree heights under 20m, whereas top height of trees on the east coast are 5m higher. Of interest, tree height of west coast sites plateaus at 5m height for 100m from high water mark whereas height of trees on east coast sites exceed 15m at 100m from the coast.

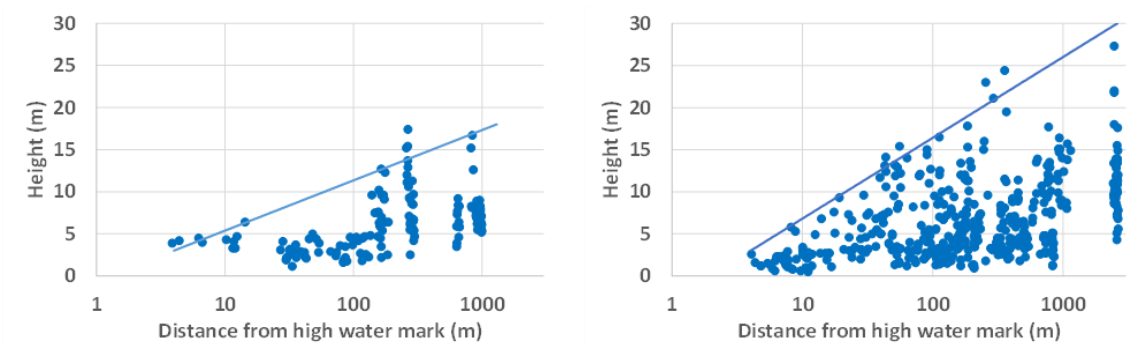


Figure 5: Height of all stems measured versus distance from high water mark for west coast sites (left) and east coast sites (right) with upper height trend shown.

As shown in Figure 3, pōhutukawa is the dominant northern coastal tree that determines maximum canopy height. Trendlines for pōhutukawa forest on the east coast of the Far North indicate that height increases quickly inland. Pōhutukawa trees reaching ~18m height were found within 200m of the high tide mark. Surveyed trees however on the west coast of the Far North did not reach ~18m height until >800m of the high tide mark.

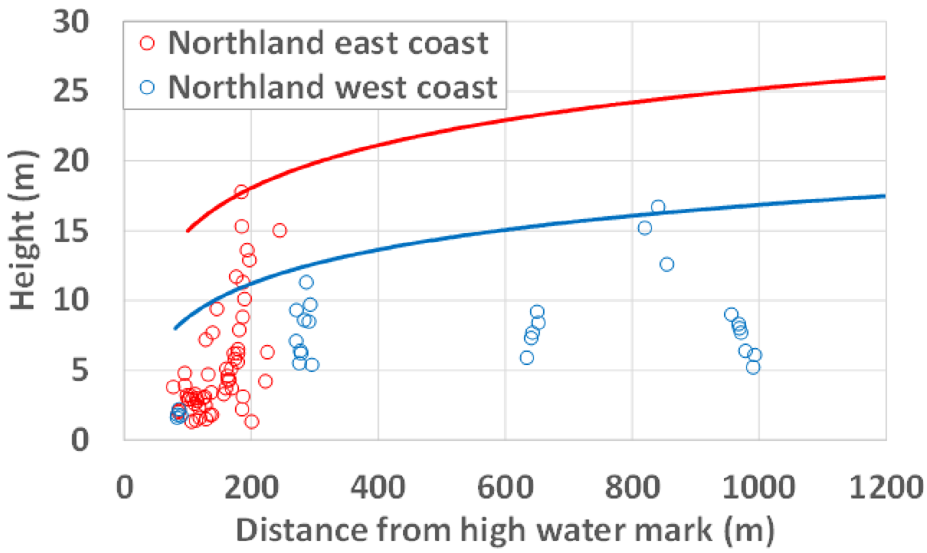


Figure 6: Height of pōhutukawa-dominant coastal forest with increasing distance from mean high water for survey sites on the east and west coast of the Far North.

Width of coastal forest

Assessment of mature coastal pōhutukawa-dominant forest remnants surveyed in the Far North illustrate that pōhutukawa may have dominated on the west coast up to one kilometre inland. This compares to most east coast pōhutukawa-dominated remnants only being dominant to just over 200m inland (Figure 2). This likely reflects the harsher environment on the west coast resulting in greater inland influence of salty winds but the results also reflect an artifact of past land clearance and development where more intense land development has occurred on the east coast compared to on the more exposed west coast. The lack of remnant coastal forest sequences doesn't provide a clear answer.

Regeneration within exotic buffers

Most of the exotic coastal buffers are dominated by radiata pine with macrocarpa often planted along the seaward edge. The width of exotic buffers varies from 50-400 m and most are 40-60 years old, indicating they were established as part of earlier pine rotations.

All exotic coastal buffers exhibit the classic wedge shape of lower crowns for those trees closest to the sea with increasing height for pines landward.

At the exposed west coast Te Hiku Forest site in Northland, the average height of the pines 120 m inland of the seaward edge was 13.4m, less than one-third height of pines further inland (~45 m tall). The stocking after some 50+ years remains very high at 700 stems/ha. This is however reduced from the original planting density of at least 1,000 stems/ha due to loss of trees from intense competition. Despite the current high stocking, nearly 40% of the trees had poor form with multiple leaders (Table 1). Failure of ageing gnarled pines was more evident along the exposed seaward edges reflecting the strong onshore west coast wind environment.

Macrocarpa planted as single lines ranged in height on west coast sites from 10.6 to 17.4m within 250m of the high-water mark. The common weedy Acacia longifolia ranged from 5.3 to 10.6m in height up to 900m from high water mark on west coast sites.

Measuring a PSP plot at Te Hiku (Far North)

At Te Hiku on the west coast, the dominant native understory species were karo and houpara estimated to be up to 750 stems per ha for both species ranging from <15cm to 125cm in height (Table 2).

Where larger pine gaps occur, natives such as karo, toetoe, houpara, mingimingi, and pohuehue are found but exotic wattle, pampas, and exotic grass and exotic herbaceous species are also present. It was noted that there was a lack of local native seed source to potentially allow more diverse species regeneration.

The pine undergrowth species were similar to that found under the planted Te Hiku pōhutukawa buffer (Table 2 and Table 3 - and see Case Study at end). There were less karo and houpara seedlings under the pine than the pōhutukawa plantings. However, while there were also less tall houpara saplings under the pine, there were more karo saplings compared to under the pōhutukawa. Both understory species were more sturdy (greater diameter) under the pine (Figure 5). However, there were half as many saplings under the pine canopy as under the pōhutukawa canopy. It is possible that wild horses were not able to access the pōhutukawa understory as easily as under the pine, hence the greater houpara seedling density.

At Opoutere on the east coast, the seedlings under the frontal pines contained a more diverse range of species than that found under the back pines but the density of seedlings was much higher under the back pines (Figure 4). However, unlike the west coast pine understory, larger saplings were either absent under the front pines and at a low density under the back pines (Figure 5). It was not clear if this was potentially due to the canopy density of the Opoutere pines or differences in exposure/soil moisture.

Table 2: The tally of seedlings counted by height class that are naturally regenerating under planted pine (700 stems/ha) and planted pōhutukawa (~950 stems/ha) at Te Hiku Forest, Northland - Measured August 2018; and Opoutere, Waikato (~300 stems/ha front zone and ~550 stems/ha back zone) - Measured April 2022.

Site	**Zone**	**Species**	**0-15cm**	**16-45**	**46-75**	**76-105**	**106-135**	**135cm-diam <1cm**	**Total seedlings/ha**
Te Hiku	Pine front	Houpara	5	2	2	3	1	2	375
	Pine front	Karo		2		2	3	8	375
Te Hiku	Pōhutukawa front	Houpara	49	72	33	20	21	27	8724
	Pōhutukawa front	Karo	5	6	8	9	3	13	1729
Opoutere	Pine front	Mingimingi			2				255
	Pine front	Shining karamū	2	8	2		2		1783
	Pine front	Houpara	5	8	1				1783
	Pine front	Karo		2			2		509
	Pine front	Red mapou				1			127
	Pine front	Pine	17						2165
Opoutere	Pine Back	Mingimingi					3		382
	Pine back	Shining karamū	9	38	10	9	13		10059

Table 3: Number and average stem diameter of saplings with a diameter greater than 1cm at 1.4m above ground level found naturally regenerating in planted pine and pohutukawa plots at Te Hiku Forest, Far North and Opoutere, Waikato.

Site	Zone	Species	Count	Average diameter (cm)	Total saplings per ha
Te Hiku	Pine front	Karo	18	3	450
	Pine front	Houpara	6	2.7	150
Te Hiku	Pōhutukawa front	Karo	10	1.8	393
	Pōhutukawa front	Houpara	19	1.5	747
Opoutere	Pine front				0
Opoutere	Pine back	Shining karamu	3	3.0	75
	Pine back	Wharangi	1	3.5	25
	Pine back	Mingimingi	1	4.8	25

On east coast sites, density of pines was highly variable and likely to be a combination of planted and some wilding pines. Pines tended to be taller and in better condition on east coast dunes reflecting the less dynamic wind conditions compared to west coast sites.

Where there is a high density of healthy pines within buffers the understorey is often relatively open. However, where the canopy is more open, usually due to windfall or dieback, there is often a limited range of naturally regenerating natives such as houpara/coastal five finger, karo, mingimingi, and the ground fern Asplenium oblongifolium and. This lack of native diversity is likely due to a lack of seed source and/or browsing animal pressure rather than suppression from the pines. Understory growth also increased further landward under pine canopy indicating the effect of increasing shelter provided by the dune topography and pines.

Browsers

Observations from our surveys found rabbits and possums remain a universal issue, particularly along forest edges and in larger canopy gaps. Browsing by cattle in the Kawhia forest, horses in the Te Hiku Forest and deer in Woodhill Forest negatively affect the success of native regeneration in those areas.

Wild horses on dunes at Te Hiku (Far North)

Drought

The drought of 2019/2020 caused widespread loss of small plantings and natural seedlings but also larger established plants. Isolated plants and small plantings with large edges were more susceptible to drying winds. Observations found that soil moisture appeared to be retained for longer under vegetated canopy (including pine).

Lack of native seed sources and loss of suitable establishment conditions

Many sites visited had no or limited nearby native seed sources. Field observations noted a correlation between adult tree and seedling presence. However, even where seed sources were nearby (e.g. pōhutukawa), the lack of suitable substrate and microclimates for seed germination (see Pōhutukawa feature box in the Introduction (Technical Guideline 1), together with competition with exotic vegetation cover and browse pressure, reduced the likelihood of natural regeneration occurring.

Conclusions

Zonation
The most common remnant northern coastal forest species found during this project was pōhutukawa. Pōhutukawa and a few hardy shrubs such as houpara and karo were found close to the frontal dune. Diversity of remnant and regenerating coastal forest species increased further inland and included tōtara, pūriri, kānuka, karaka, taraire, tī kōuka, porokaiwhiri/pigeonwood, haekaro/Pittosporum umbellatum, mahoe, rangiora, red matipo, ngaio, kawakawa, mingimingi/Leucopogon fasciculatus and various Coprosma species.

Veg wedge
The degree of exposure to harsh salty winds determines the steepness of the coastal vegetation wedge. As the hardiest and tallest northern native coastal tree, pōhutukawa growth is key to determining the veg wedge shape in Northern New Zealand.

Generally, the west coast is buffeted by stronger storm winds than experienced on the east coast. This results in the vegetation increasing inland at a flatter angle in height and a resultant wider buffer needed to protect tall plantation trees inland. Correspondingly, the east coast dune vegetation increases in height much more rapidly inland.

Old plantings of pōhutukawa and macrocarpa seaward of the pine buffer, Te Hiku Forest (Far North).

The suitable width to establish a coastal forest buffer on the east coast will be less determined by the physical coastal conditions than by the width required to support a diverse and sustainable coastal forest, with long term climate change effects an additional consideration (see Technical Guideline 4).

Height of vegetation
Due to past land uses, the presence of remnant mature coastal forest is severely limited. However, a number of mature pōhutukawa found in the nearshore zone indicate that pōhutukawa can achieve heights at least as tall as 30-year-old radiata pine.

At Bowentown in the Bay of Plenty a pōhutukawa 40 m back from the frontal dune was measured at 11.7 m high; a tree 55m inland at Pakari was over 15m high; and a 24m high tree was measured at Opoutere 350m inland. A pōhutukawa clump within the Te Hiku exotic coastal buffer was measured at 12.7-15.4m high equivalent to the surrounding pine canopy (11.3-14.9m high). The tallest pōhutukawa was measured at Te Arai at over 27 m tall (2.4km inland).

A 11.7 m high remnant pōhutukawa 40 m from the toe of the frontal dune, Bowentown (Bay of Plenty).

Loss of the natural coastal buffer
Although there is evidence that mobile dunefields occurred naturally in some areas (Hesp 2000), it is almost certain that sand behind the foredune would have supported a more vigorous and diverse flora before land clearance and grazing and browsing animals were introduced. There would have been less exposure and consequent movement of sand, and regrowth across breaches in the vegetation cover would have been more rapid (Gadgil 2006).

Protective exotic buffer

Exotic coastal buffers of 50 - 400m have been established and retained to provide protection along the coast. These protective buffers generally include combinations of macrocarpa and Norfolk Island pines along the most seaward edge and radiata pine.

This study indicates that sites on the west coast generally have wide protective exotic buffers. This is likely due the vigorous onshore westerly winds causing greater sand movement inland and suppressing height growth significantly (and resulting in a lower-angled vegetation wedge). In contrast, the more benign conditions on the east coast result in a more abrupt vegetation wedge.

Re-establishment of a diverse native buffer
There are a number of key factors that need to be addressed to initiate restoration of our lost coastal forests.

- **Browsers -** The successful establishment and spread of diverse natural regeneration and plantings can be hindered by introduced browsing animals. Where browser levels are high, they will need to be controlled. Ideally to be efficient and effective this would be via community supported control programmes at a landscape scale.

- **Drought -** Succession of plant species will be key to helping establish a diverse coastal forest. The use of drought tolerant species to establish a canopy cover is already an important factor in the early establishment of coastal forest vegetation. Providing fast shelter is likely going to become even more important with climate change. The establishment of a drought tolerant canopy will allow subsequent less drought tolerant coastal forest species to establish by reducing wind incursion inland, providing shade and building up leaf litter (mulch). Existing drought tolerant pine buffers can provide this initial canopy cover relatively quickly.

- **Lack of native seed sources and loss of suitable establishment conditions -** The lack of nearby seed sources will limit what natural regeneration can occur in an area. These will need to be planted if missing. Even where seed sources are nearby, the loss of shelter, suitable germination surfaces and competition with exotic vegetation cover can severely reduce natural regeneration.
  Once a drought tolerant canopy (e.g. pine or karo) has established this will start to provide microhabitats such as fallen logs that will enhance the germination of different species. For example, the tiny seed of pōhutukawa is easily desiccated out in the open sand. However, if a seed can settle on a rotting log or punga it has a much higher chance of establishing.

  Native species found during surveys to be naturally regenerating under pine forest (where seed sources allowed) included karo, houpara, taupata, mingimingi (Leucopogon fasciculatus), tī kōuka, mahoe, karaka, houpara/five-finger, akeake, tōtara, taraire, kānuka and pūriri.

Left - A typical large open gap due to natural dieback and wind damage within an ageing protective pine buffer and resulting growth of exotic wattle and pampas and native pohuehue. Right - An open pine buffer with a light understory of scattered native species. Te Hiku Forest (Far North)

Case Study – a planted pōhutukawa coastal buffer, Far North

The New Zealand Forest Service established a 30 m wide native forest buffer along part of the coastline at Te Hiku in the Far North during the 1970s and 80s. This was to add to the pine buffer zone immediately landward protecting the exotic production forestry.

The site was prepared and planted over a number of years using forestry planting crews when there was time between their radiata pine planting and silvicultural operations. Site preparation involved ripping the swale between the seaward foredune and a forestry access road running parallel to the coast 100m inland from high water mark.

The frontal zone of pōhutukawa-dominant forest that was planted during the 1970s and 80s by the NZ Forest Service, Te Hiku Forest, Northland.

Only two native species were planted – karo and pōhutukawa. Plant spacing was approximately 1.5 m, equivalent to 4,500 stems per ha with approximately an equal proportion of pōhutukawa and karo.

Some 40 years later, only pōhutukawa remain, forming a dense canopy over 8 m high of rounded crowns (Table 4). The average diameter of trunks is 40 cm and most trees have multiple leaders. The high stocking of close to 950 stems per ha has likely provided a heavily shaded open understorey for some years and minimal ground cover or lower tier vegetation. The interplanted karo would have long died out due to the dominance of the pōhutukawa (however karo seedlings/saplings are present along the pine buffer edge and scattered with houpara seedlings under the pōhutukawa).

Table 4: Tree size and stand density for a pōhutukawa dominated coastal buffer planted within 50 m of the Ninety Mile Beach high water mark, at Te Hiku, Far North, Northland.

	Plot size (radius m)	Average Height (m)	Average diameter (cm)	Density - live only (spha)	Trees (all) with multi leaders (%)
Pōhutukawa	9	8.325	40.3	943	87.5

This pōhutukawa buffer is seaward of the main pine buffer and bears the full force of the salt winds in a similar manor as a macrocarpa buffer does nearby. A remnant pōhutukawa growing 170m inland from the pōhutukawa buffer is the same height (approx. 14m) as the pine buffer that surrounds it.

Right - Inside the planted pōhutukawa buffer at Te Hiku, Northland. Like the pine buffer, the planted dense pōhutukawa buffer has only a scattered understory of native species including houpara, karo, native spinach, mingimingi and pohuehue.

Of note, a 2019 planted buffer line of pōhutukawa just inside the existing exotic buffer (ie. further inland) had very high plant loss from drought except where pōhutukawa were located in a dune swale often with the presence of rushes (indicating a higher water table).

This established dense pōhutukawa coastal buffer is an excellent case study of a planted native forest zone along our coastal sand dunes providing protection to landward diverse coastal forest, forestry, and farming land uses. Such as native buffer utilising pōhutukawa as the frontal defence backed by more diverse coastal forest species is an alternative to using short-lived exotic pines as a sacrificial forested buffer. This should give forestry owners and managers, iwi, community groups and coastal landowners confidence in the role of natives planted as a viable alternative to shorter lived exotic pine options in addition to providing a potentially more diverse indigenous corridor for wildlife along coastal sand dunes.

The planted pōhutukawa buffer at Te Hiku, Northland

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