Boffa Miskell

Ecological Connectivity Roadmap

Rodney East

Prepared for Rodney Local Board

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Cover photograph: Aerial imagery and extent of the Rodney East district, 2021.

Executive Summary

Ecological connectivity is the '*manner or extent to which species or resources disperse and interact across landscapes*'. Maintaining and enhancing connectivity is crucial to protect native biodiversity and ensure the health and efficient functioning of ecosystems. This is especially important in increasingly fragmented landscapes, such as across Auckland.

This Roadmap aims to identify gaps and evaluate opportunities to protect, enhance, connect, and extend existing valuable habitats to create functional networks of green spaces, and ultimately, to enable the community and council to work cohesively to achieve conservation outcomes. It can be used to:

1. *Where* - Identify areas for conservation action;
2. *What* - Identify conservation actions in particular areas;
3. *Who* - Identify and connect surrounding conservation groups; and
4. *How and Why* - Aid funding applications and gain support for conservation action.

To inform the Roadmap, connectivity analyses were undertaken for 'umbrella species', to determine the functional connectivity of terrestrial ecosystems present in Rodney East. The umbrella species concept is widely used in conservation planning, and is based on the idea that conservation actions undertaken for the selected species will have substantial benefits for both the ecosystems they inhabit and other native species in those habitats.

Based on the results, the Roadmap identifies priority areas to enhance connectivity, with priority actions for each area and guidance on:

- Enhancing existing habitat patches;
- Improving connectivity between patches;
- Improving connectivity on private land;
- Undertaking predator control;
- Utilising transport infrastructure as greenways; and
- Planning projects effectively.

The Roadmap comprises this written report and an online, interactive StoryMap. This project was funded by Rodney Local Board, and was developed by Boffa Miskell in collaboration with Auckland Council and local communities.

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1.0 Introduction

1.1 Biodiversity in New Zealand

New Zealand is internationally recognised as a hotspot for biodiversity, with a large proportion of endemic species (e.g. 80% of vascular plants, more than 90% of insects and 25% of all bird species; Meister et al., 2012). In other words, many of New Zealand's species are unique, contribute substantially to global biodiversity and are unable to be replaced if lost (Ministry for the Environment & Stats NZ, 2018).

As well as its intrinsic value, maintaining indigenous biodiversity is important for the health and functioning of native ecosystems, and the vital role it plays in maintaining the health and functioning of many ecosystems (Ministry for the Environment & Stats NZ, 2018). Biodiversity plays a role in many ecosystem services, including supporting services (e.g. nutrient cycling, primary production, and pollination), provisioning services (e.g. the availability of food and clean water), regulating services (e.g. climate regulation and pest control) and cultural services (e.g. cultural heritage, education, recreation and ecotourism).

1.2 Biodiversity threats

Unfortunately, biodiversity is in a state of decline, both in New Zealand and around the world. In New Zealand, biodiversity has greatly reduced in species diversity and spatial extent over the past 700 to 800 years since the arrival of humans (Meister et al., 2012).

Native species and ecosystems are under increasing stress from both existing and emerging pressures (Bellingham et al., 2016). These key pressures include invasive, introduced species, including mammalian predators (rats, stoats, ferrets, weasels, possums, and feral cats), climate change, increased urbanisation, an increasing human population, and the loss, destruction, modification, and fragmentation of natural habitats.

A report on the state on New Zealand's indigenous biodiversity and ecosystems (Our land 2018; Ministry for the Environment & Stats NZ, 2018) revealed that:

- Our ecosystems suffer continued loss of indigenous land cover, with multiple compounding pressures including intensification of land use, urbanisation, and an increasing human population, with urgent conservation actions required to halt and reverse the decreasing trend;
- Almost two-thirds of New Zealand's rare and 'naturally uncommon' ecosystems are threatened, and both coastal and lowland ecosystems are continuing to decline in extent;
- Nearly 83% of the land vertebrates classified in the threatened species system were either threatened or at risk of extinction (285 of 344 taxa), and the conservation status of 11 species declined (seven bird species, three gecko species, and one species of ground wētā);
- Although the conservation status of 20 bird species has improved, this was dependent on intensive conservation management for more than half of these species; and
- Exotic pests are found almost everywhere in New Zealand, except for some offshore islands and fenced sanctuaries.

Regional councils also undertake State of the Environment (SOE) monitoring. The most recent report on Auckland concluded that several of Auckland's forest ecosystem types are severely depleted, and many of our remaining forests are small and fragmented (Auckland Council, 2021). The combination of multiple pressures and threats mean that integrated conservation strategies are required that aim to protect and restore natural ecosystems.

1.3 Conservation in Rodney East

The Auckland Region encompasses a diverse range of terrestrial and wetland ecosystems which host many indigenous species, many of which are Threatened or At Risk. Within the Auckland Region, 36 terrestrial and wetland ecosystems and their regional variants have been identified by Auckland Council (Map 2). These are described in the guide document "Indigenous terrestrial and wetland ecosystems of Auckland" (Singers et al., 2017) and form the basis of this Roadmap.

Rodney East is part of a major local board of Auckland and the focus area of this Roadmap. It stretches from the Auckland Region boundary at Te Arai at the northernmost point (a key breeding site for the Nationally Critical tara iti / New Zealand fairy fern), to Waiwera and the historic Wenderholm Regional Park at the southernmost point. From east to west, the area is bounded by the eastern coastline to the Ara Tūhono – Pūhoi motorway and State Highway 1 in the west (Map 1).

This landscape forms a substantial part of the Rodney Ecological District, with many ecologically significant areas, including Te Arai, Pakiri, Tāwharanui (Fig. 2), Scandrett, Mahurangi and Wenderholm Regional Parks, as well as Leigh and Goat Island Marine Reserves, Kawau Island, and many other reserves and esplanades.

The local community is highly engaged, and many groups are striving towards achieving conservation and restoration outcomes. A plan which brings these groups together would benefit biodiversity and ecosystem functioning at a landscape-scale.

Fig. 1. Aerial image of Tawharanui Regional Park (Boffa Miskell, 2021).

1.4 Purpose of the Roadmap

As part of a wider conservation strategy with a strong community focus, this Roadmap was commissioned by Auckland Council, funded by the Rodney Local Board, to map current conservation activities, identify gaps and evaluate opportunities to enhance connectivity to improve the health and functioning of ecosystems within Rodney East.

This Roadmap aims to help inform community groups and Council where conservation activity could be prioritised across the Rodney East landscape to achieve effective landscape-scale ecological restoration and connectivity. The Roadmap maps existing conservation actions, identifies habitat linkages and then prioritises conservation areas and actions based on ecological data as well as information from community, council, Department of Conservation (DOC) and other environmental initiatives.

In particular, this project aims to:

- Map and describe terrestrial and freshwater areas of existing and potential high ecological value (with a primarily terrestrial focus);
- Identify gaps and evaluate opportunities to protect, enhance, connect, and extend existing valuable habitats, conservation areas, habitat corridors and ecological connections, as well as to reconnect and/or expand linkages across the Rodney East area, so as to form functional networks of green spaces;
- Prioritise areas and actions to ensure functional connectivity outcomes are realised throughout Rodney East.
- Recommend management techniques and prioritise conservation actions that will contribute most to enhancing the functional integrity of the ecological network; and
- Ultimately enable the community, council, and other agencies to work together to achieve conservation outcomes.

To best achieve these objectives, the Roadmap comprises this written report and an accompanying interactive online StoryMap (Fig. 1). The StoryMap is intended to be maintained by Auckland Council as part of a wider ecological strategy and be accessible and a practical tool for use by the Rodney East community.

It provides a starting point to guide and communicate our ongoing conservation efforts, and is intended to contribute a local level of information to further inform Auckland Council's Tiaki Tāmaki Makaurau / Conservation Auckland website.

1.5 How to use the Roadmap

The online StoryMap contains interactive maps to guide conservation actions. This written report provides users with a scientific report structure if preferred, and also contains more technical detail as to how the Roadmap was developed.

Users can use the Roadmap to:

1. **Where - Identify areas for conservation action that are of most benefit to enhancing connectivity.**

To identify new areas for conservation actions that enhances connectivity, or existing areas that require protection and enhancement, explore the maps in the Management Actions and Connectivity Analysis sections of the online Roadmap.

2. **What - Identify what conservation actions in a particular area would be of most benefit to enhancing connectivity.**

If users already have an area for restoration in mind (e.g. a local reserve or even a backyard), zoom in on the maps to see the existing connectivity in that area for each of the selected umbrella species reflecting the functional connectivity of different habitat types. Refer to the Management Actions section on the online Roadmap for the combined analysis and to identify the actions recommended in any particular area in the interactive maps.

3. **Who - Identify potential groups that may have interest in undertaking conservation within a particular area (*who*).**

To see how an existing, new, or potential community group or project is contributing to connectivity in the wider region (e.g. if you are considering expansion or alignment of groups/projects, or identify where there are gaps), and where gaps might exist between current management activities, explore the community group, council, and DOC map layers and in the Ecosystem Maps section of the online Roadmap. Also refer to the Tiaki Tāmaki Makaurau / Conservation Auckland website for up-to-date information.

Users can also use these layers when planning to connect projects or fill important gaps between managed areas to ensure efforts and resources align but do not overlap.

4. **How and why - Aid funding applications and gain support for conservation projects that incorporate connectivity.**

If users are applying for funding applications to undertake conservation activities in an area (e.g. pest control in a small reserve), they can set any of the maps to their desired extent and area and take screenshots to include in the application.

Users can also adapt wording from anywhere in the Roadmap to create project-specific goals. The maps will show how actions in a small area or across multiple large habitat patches contribute to achieving the wider aim of restoring ecological connectivity across Rodney East. Overall, this will strengthen funding applications and help to gain traction for a project (in both the community and council) by justifying your actions with scientific reasoning, and ensuring maximum benefit for our native biodiversity and ecosystems.

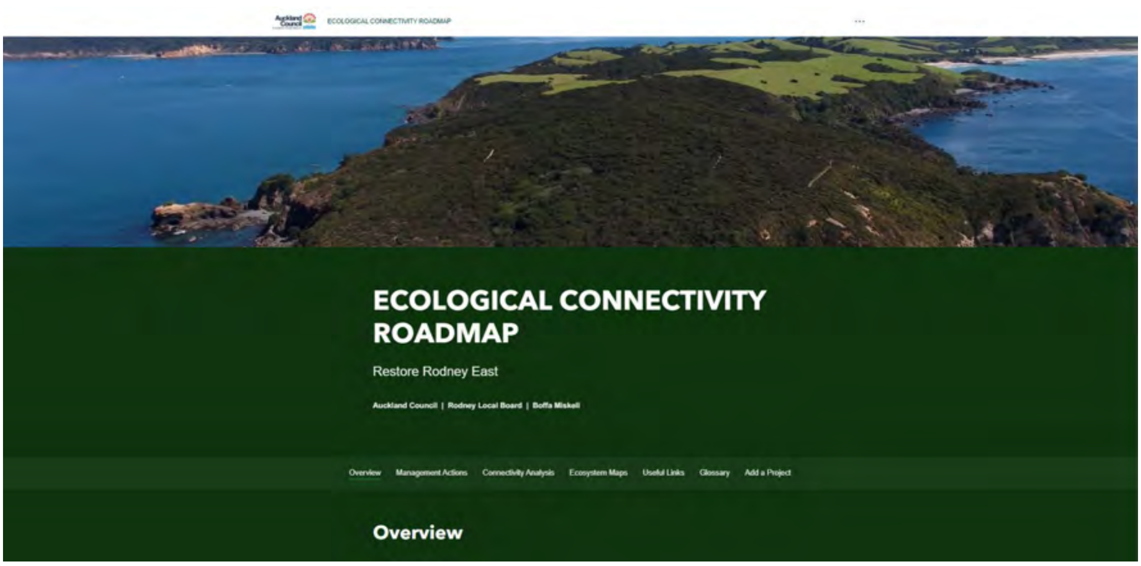

Fig. 2. The online, interactive StoryMap that along with this report, comprises the Ecological Connectivity Roadmap.

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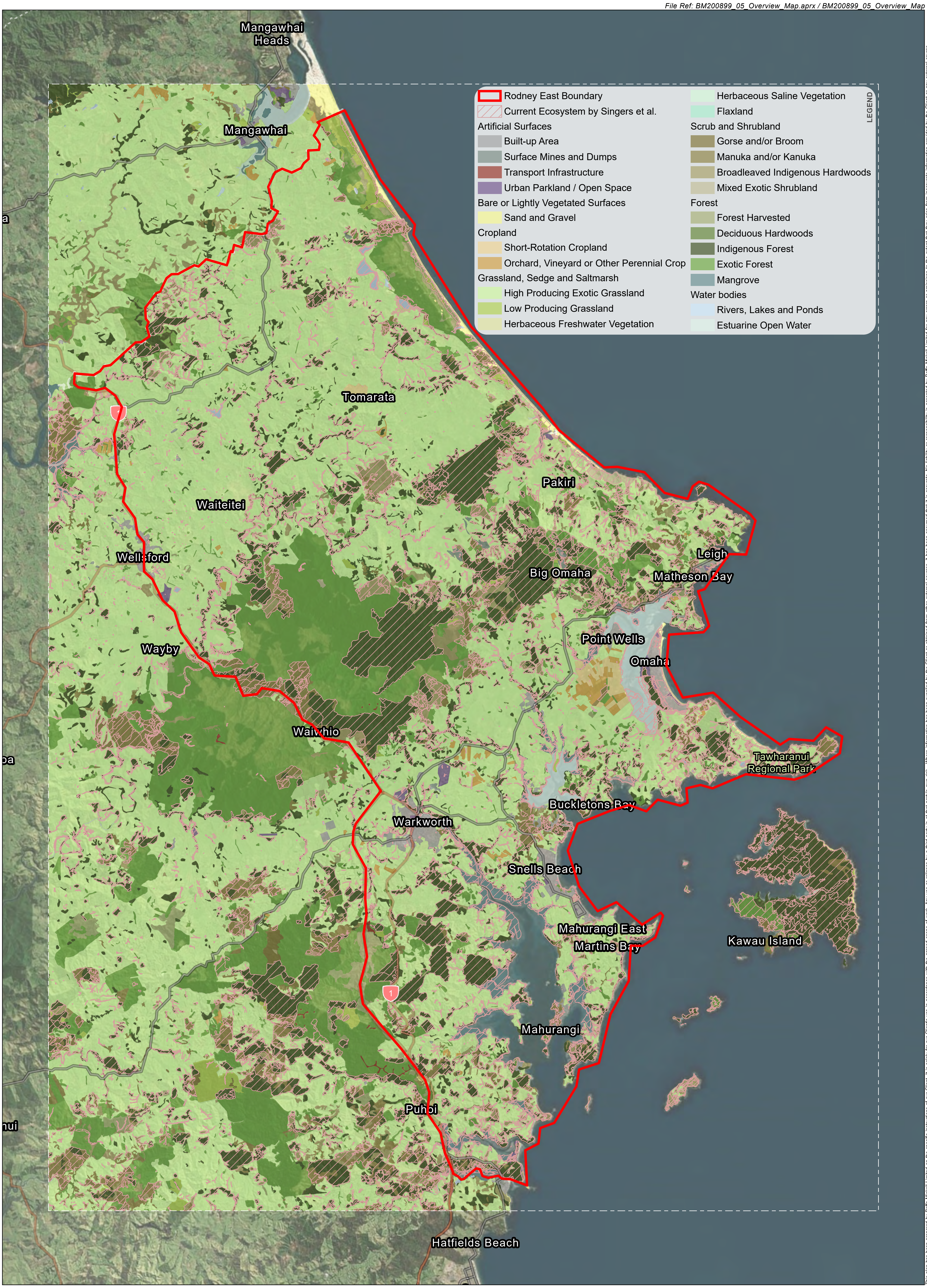

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Data Sources: BING Aerials, Auckland Council, Landcare Research, BML

Projection: NZGD 2000 New Zealand Transverse Mercator

EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 1: Overview Map

Date: 30 April 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate Heaphy | Drawn: SGa | Checked: KHe

2.0 Ecological connectivity

2.1 Definition

Connectivity is the '*manner or extent to which species or resources disperse and interact across landscapes*' (Kukkala & Moilanen, 2017). It describes the spatial distribution of habitat patches and resources (food, water, mates etc.) within a landscape. A landscape with high connectivity for a given species indicates there are numerous patches of suitable habitat for that species within the maximum dispersal distance of that species. Conversely, low connectivity indicates barriers (e.g. a highway) or landscape types (e.g. open pasture or industrial buildings) are present in the landscape which restrict movement between areas for that species with potential consequences for their survival and the species they interact with.

2.2 Importance of connectivity

Maintaining connectivity, especially in increasingly fragmented landscapes, is crucial to ensure healthy and efficient functioning of ecosystems, and the provision of ecosystem services. Many of these ecosystems services depend on the movement of organisms and resources (Kukkala & Moilanen, 2017), such as facilitating dispersal and migration, pollination, gene flow, nutrient cycling, and also aid also movement and range shift in response to climate change (McRae et al., 2012). Increased connectivity typically increases the carrying capacity (K) of the landscape, effectively making reserves 'bigger' by linking them together and ensuring animals can reach different food resources, helping to prevent local (and potentially complete) extinction of species.

2.3 Evaluating connectivity

There are two main ways to consider and evaluate ecological connectivity in a landscape: by examining structure and/or function (Hilty et al., 2012). Structural connectivity describes the physical presence, location, shape and dimensions of habitat and resource patches. Functional connectivity describes how easy it is for individuals or populations of a species (including both plants and animals thus incorporating a biological perspective), or the functioning of other specific ecosystem processes that require flow of certain elements around the landscape.

The degree of connectivity in a landscape varies depending on the species and ecological processes in question (Fig. 3). Different species use the landscape in different ways, depending on a wide range of factors including habitat preferences (e.g. forest vs wetland), movement behaviour (e.g. gap avoidance), movement ability (e.g. flight ability, speed), life history traits and stage (e.g. adults vs. juveniles, mode of juvenile/seed dispersal). This means that conservation strategies need account for multiple species with different movement traits and habitat needs to identify and preserve a connected and functional ecological network (Zhang et al., 2020).

Connectivity is also crucial for plants, which may occur via wind, water, seed dispersal or pollination, and ecological process (e.g. water and nutrient cycling). Given the complexities of connectivity, analyses most commonly focus on one (or several) key fauna species, which can be referred to as 'focal species' or 'umbrella species'. These species are often a focus of conservation objectives and/or reflect ecological processes.

Fig. 3. The level of connectivity in a landscape for terrestrial fauna varies depends on the species and their movement behaviour and ability, habitat preferences and food availability. For example, connectivity needs differ between kaka (left; photo courtesy of David Irvine), geckoes (top right; photo courtesy of Tony Payne) and stick insects (bottom right; photo courtesy of Sarah Hockings).

2.4 Modelling connectivity

It is common for planners to only consider distances between habitat patches (structural connectivity) in plans or models, and not other landscape features or ecological factors such as habitat quality and type and specific movement requirements of species (functional connectivity) (Nor et al., 2017). However, many groups and organisations are increasingly focusing efforts to identify and conserve areas that facilitate movement and enhance connectivity as part of effective, landscape-scale conservation, and using connectivity modelling to help identify and prioritise actions that have the most benefit to biodiversity and ecosystem functioning (McRae et al., 2012).

Fortunately, multiple Geographical Information System (GIS) tools for spatially analysing landscape connectivity for different species have are now available, including Linkage Mapper, Circuitscape and Graphab (Norden, 2016). The outputs of these models typically include a map identifying areas along a spectrum from high to low resistance to movement, which relating to the ease of movement through any given area for the given species. In addition, these analyses can identify patches that are too isolated for an average individual of that species to easily be able to reach, and key linkages that, if made, would greatly enhance the functional connectivity of the landscape for that species.

Modelling *structural* connectivity involves identifying and connecting similar ecosystem types, while modelling *functional* ecological networks for a range of species creates more reliable and effective networks (Fig. 4; Baguette et al., 2012). The latter involves five main steps, with the resulting ecological network emerging from the stacking up of individual networks designed for umbrella species living in different ecosystems. Umbrella species is the term used to refer to one or more key species of high ecological importance and/or is able to reflect the health and functioning of the ecosystems it inhabits.

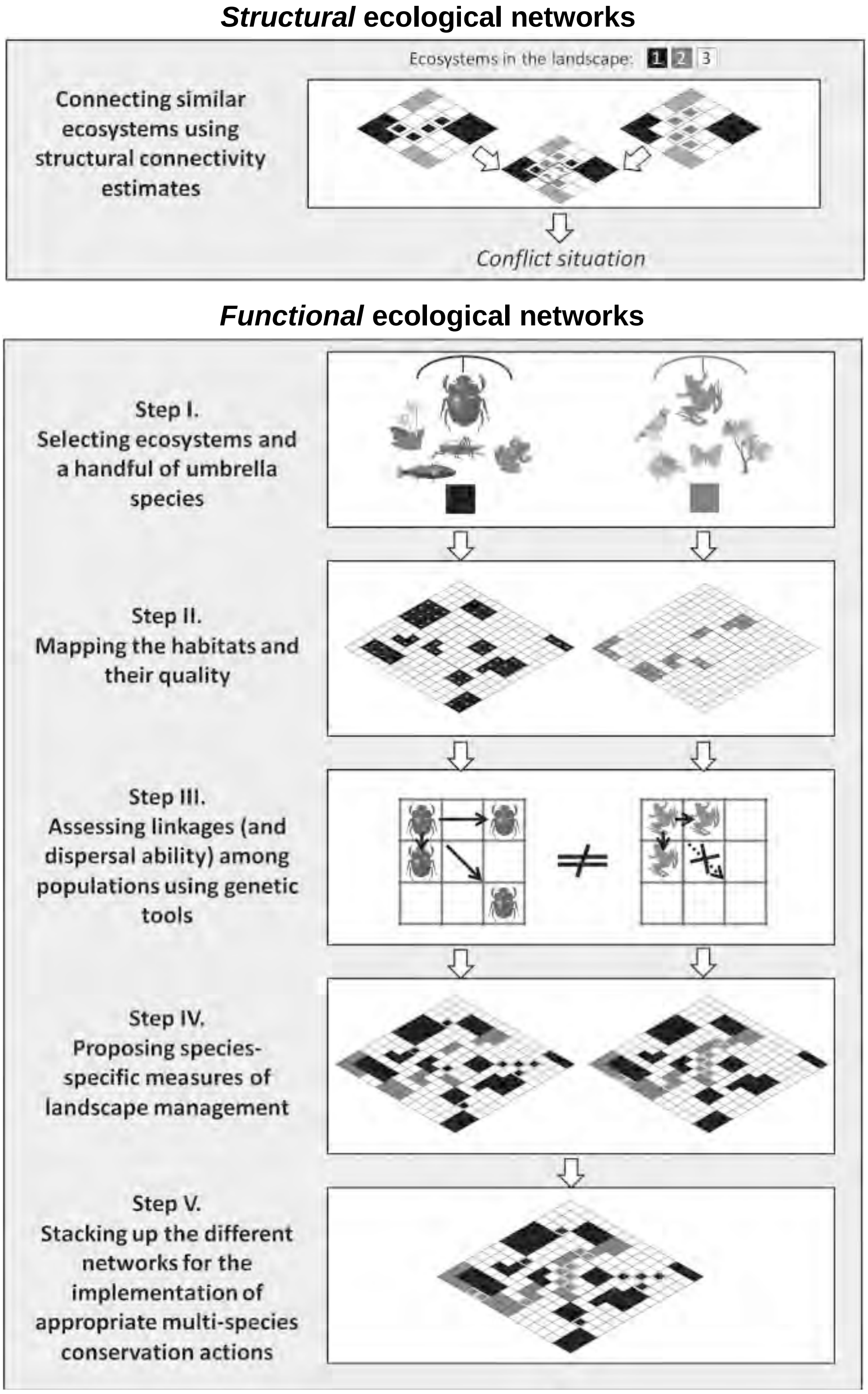


Fig. 4. Differences and methods between developing structural (top) and functional, multi-specific (bottom) ecological networks. Image adapted from Baguette et al. (2012).

2.5 Improving connectivity

Connectivity (both structural and potentially functional, depending on the purpose and species in question) can be increased by creating additional habitats as corridors and/or stepping stones (Fig. 5; Berges et al., 2010; Hilty et al., 2012). Corridors are direct, continuous, linear habitat connections between important habitat patches. These linkages themselves may or may not be suitable for breeding or feeding, but they provide a low-resistance land cover type (typically natural habitat) that facilitates easy movement of individuals between habitat patches. Stepping stones are small patches or 'islands' of habitat that serve as refuges between larger habitat patches, in contrast to a single continuous corridor.

To support animal movement and dispersal, stepping stones must be functionally connected, that is, a biological element must be incorporated in planning to ensure that stepping stones are able to be reached by individuals (i.e. within a typical dispersal distance and not be surrounded by any barriers). Other actions to improve connectivity includes reducing resistance of the matrix between habitat patches creating a landscape mosaic of more suitable land cover types (Fig. 5), increasing the size of habitat patches (e.g. reserves) and creating buffer zones around patches. When done well, the combination of these features increases the effective size of habitat patches, while also reducing the risk and movement cost between patches.

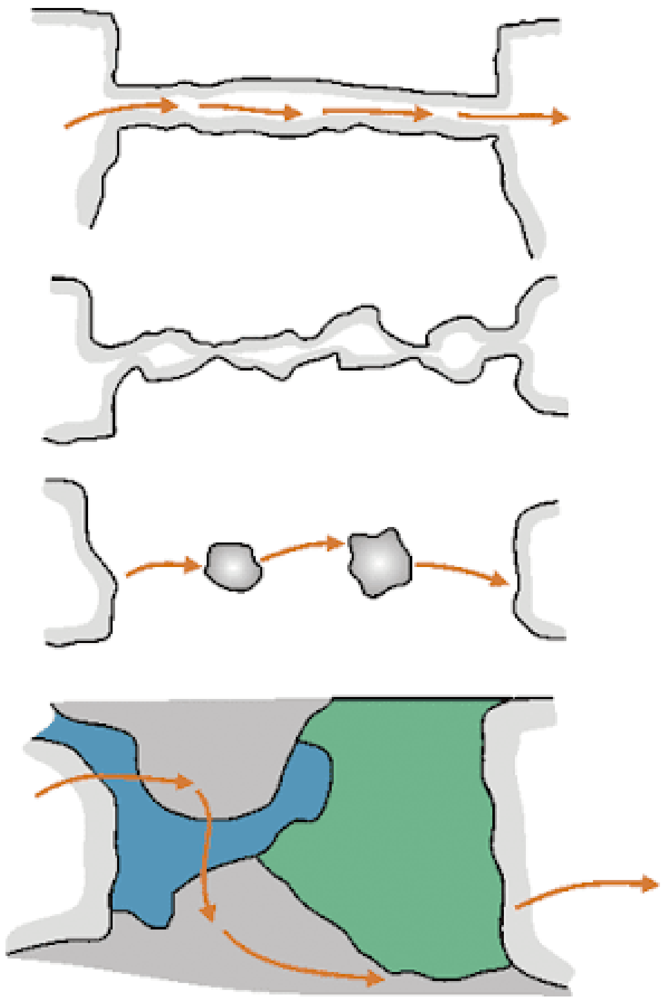


Fig. 5. Four main methods of connecting habitat patches to facilitate animal movement. Image from Berges et al. (2010).

The best way to increase connectivity in a landscape overall for a wide range of species and ecological processes is to use a range of methods and different habitat structures, forming an ‘ecological network.’ Such networks comprise multiple components that aid connectivity, notably core habitat areas, ecological corridors, stepping stones and buffer zones, between which varying levels of connectivity exists (Nor et al., 2017).

For example, stepping stones might involve restoring and replanting discrete patches of native bush, while creating corridors might involve planting hedgerows, shelter belts and greenways along transport infrastructure. Riparian margins along streams also create useful corridors used by many species. The types of plant species present all in these linkage influence how easy the linkages are to traverse and their utility as habitat; those that provide food resources and/or shelter are more useful for improving connectivity for the focal species. Buffer planting can also both improves the surrounding matrix and expand the effective size of habitat patches by increasing the quality of internal core habitat.

Such conservation actions to maintain and enhance connectivity between protected areas and other habitat patches needs to occur in conjunction with the management and protection of core habitat areas, and do not replace the protection and conservation of core habitats (Hilty et al., 2020). Each linkage created should be linked to a specific ecological purpose or reason, such as being designed to connect populations of a particular threatened species (Hilty et al., 2020). In areas like Rodney East, private land often forms a substantial proportion of areas between large habitat patches such as reserves or regional parks. Both public and private land therefore has a crucial role in either facilitating or hindering connectivity (Awasthy, 2012).

3.0 Methods

3.1 Data collection and compilation

Key map layers that were gathered and used in the connectivity analysis and online Roadmap included:

- **Current and Potential Ecosystem Extent** (based on the 36 terrestrial and wetland 'ecosystem types' of the Auckland Region as per Singers et al. 2017).
- **New Zealand Landcover Data Base** (LCDB; version 5.0 was released in January 2020).
- **Significant Ecological Areas (SEAs)**, which are areas of significant indigenous vegetation or habitats of indigenous fauna, located either on land or in freshwater environments identified under the Auckland Unitary Plan. These areas are protected from the adverse effects of subdivision, use and development to maintain indigenous biodiversity.
- **Biodiversity Focus Areas (BFAs)**. Auckland Council's BFA network represents the minimum set of sites that require targeted management to ensure Auckland Council's Biodiversity Strategy objectives are met. BFAs on public land are shown on the online Roadmap (BFAs on private land will be available soon).
- **Department of Conservation (DOC) land**.
- **Auckland Council Public Open Space**, including regional parks, reserves, esplanades, and sports grounds.
- **Waterways**. The connectivity and health of rivers and streams are vital for healthy ecosystems. They connect important habitats for many native species, including native fish species, matuku (bittern), pūweto (spotless crake) and koitareke (marsh crake).
- **Roads**. Roads act as a barrier for many species, impeding or even preventing their movement between patches. The impact of roads on connectivity differs depending on the species and the road type. For example, busy multi-lane highways are larger barriers than single-land country roads with little traffic.
- **Community Group Project Areas**. This layer show where current community conservation projects are currently underway, as were gathered via an online survey of known community groups within the Rodney East area.

3.2 Linkage Mapper software

The software Linkage Mapper was used to model connectivity for the selected umbrella species. It is an ArcGIS toolbox comprising open source Python scripts for analysing regional wildlife habitat connectivity patterns and habitat corridors developed in 2010 (McRae & Kavanagh, 2011; McRae & Kavanagh, 2017). Linkage Mapper was selected for analysing connectivity of Rodney East for each of the selected umbrella species as it is considered to be more effective at showing connectivity among habitats and modelling potential corridors at a smaller spatial scale (e.g. within an Auckland Local Board boundary compared to across extensive parkland in Europe and the Americas) (Norden, 2016). In addition, the inputs and outputs were considered more transparent for the community needs of the Rodney East project compared to other software.

The two main inputs into Linkage Mapper for each selected umbrella species are 1) core habitat polygons (as a GIS vector layer), and 2) a cost-resistance raster or resistance surface (as a GIS raster layer). Core habitat areas are identified for each species based on the underlying land cover (ecosystem types) and minimum patch size as ecologically appropriate. For the resistance surface, each pixel (different sizes depending on the species and study area extent) is assigned a numeric value that reflects the energetic cost or difficulty of moving across that pixel. These resistance values are based on the underlying land cover, features that may increase or decrease mortality risk (e.g. roads and protected areas respectively) and ecological knowledge of that species.

Combining these two inputs then creates a map of modelled least-cost linkages between core areas for that species and the functional connectivity of the ecosystem types it inhabitants. The software identifies linkages between adjacent core habitat patches, and calculates routes of maximum efficiency (lowest cost) based on the composition and configuration of the landscape. The outputs are maps of the possible Euclidian and least-cost pathways between habitat patches that are within or beyond the typical dispersal or movement of that species.

3.3 Species selection

3.3.1 Summary

Four ‘umbrella’ species were selected for a detailed analysis to assess connectivity across a range of terrestrial habitat types in Rodney East:

- Kereru (New Zealand wood pigeon)
- Piwakawaka (fantail)
- Matuku (bittern)
- Pekapeka-tou-roa (long-tailed bat)

These species represent a range of traits that influence connectivity, including differing movement abilities, behaviours, and habitat preferences (Table 1), as is important for developing functional ecological networks (Spencer et al., 2010) . Each species also plays a valuable role in providing different ecosystem services. Collectively, they provide insight into how we can better enhance ecological connectivity and ecosystem health in a meaningful way.

Birds were selected to act as the primary ‘umbrella’ species for the native terrestrial ecosystems in Rodney East because they are relatively mobile, well-studied and easy to observe/monitor, meaning models of connectivity are effective and more reliable across larger fragmented landscapes. Birds are also comparatively visible and easily identifiable compared to other species (e.g. lizards), meaning they can act as a indicators and measures of conservation action success. Indicators of avian abundance, such as via 5-minute bird counts and other well-established survey methods, are commonly used across New Zealand as an indicator of native biodiversity and ecosystem health (Auckland Council, 2021; Boffa Miskell Ltd, 2020; Landers et al., 2019; Nor et al., 2017). A frugivorous and an insectivorous bird (different functional guides) with contrasting dispersal distances and different ecosystem services (seed dispersal vs. insect control) were selected to represent forest ecosystems. A Nationally Critical wetland bird was selected to model connectivity of wetland and freshwater habitats, as restoring wetlands for threatened species is a common goal.

Table 1. Comparison of minimum patch sizes and maximum dispersal distances among the four selected 'umbrella' species used in the connectivity analysis. Note the definitions of patch size and dispersal distances differs among the species depending on the specific purpose of each analysis and are provided for each species in the sections below (e.g. the analysis for kereru uses the maximum home range size, while that for piwakawaka uses a typical territory size).

	Kereru	Piwakawaka	Matuku	Pekapeka-tou-roa
Min. patch size	20 ha	0.5 ha	0.5 ha	0 ha (all potential habitat)
Max. dispersal distance	4,620 m	200 m	1,280 m	19 km

As well as the ecological justification and reasoning behind umbrella species selection, the project team believed it was important to also obtain input from the local community and iwi regarding what they believe are the fauna species of focus for providing connectivity. It is hoped that involving the community, and taking into consideration their values and priorities throughout the development of the Roadmap, will increase community buy-in for improving connectivity, improve the Roadmap by incorporating valuable local knowledge, and facilitate the telling of a successful conservation story through relatable goals and objectives.

For this purpose, an online community survey was undertaken between 26 January and 3 February 2021, in which locals of the Rodney East area were asked about the species and areas of value for conservation. One of the questions asked was, 'which key fauna species should we be providing connectivity for?' Umbrella species selection was undertaken with these responses in mind; all four of the selected species are listed the top seven community-identified species, with matuku and kereru identified as the most important (Fig. 6).

Many other important ecosystem types, such as freshwater and coastal systems, and native species with different movement abilities, are present in Rodney East. Although not covered here, many still require conservation action and could also benefit from having similar connectivity strategies developed in the future.

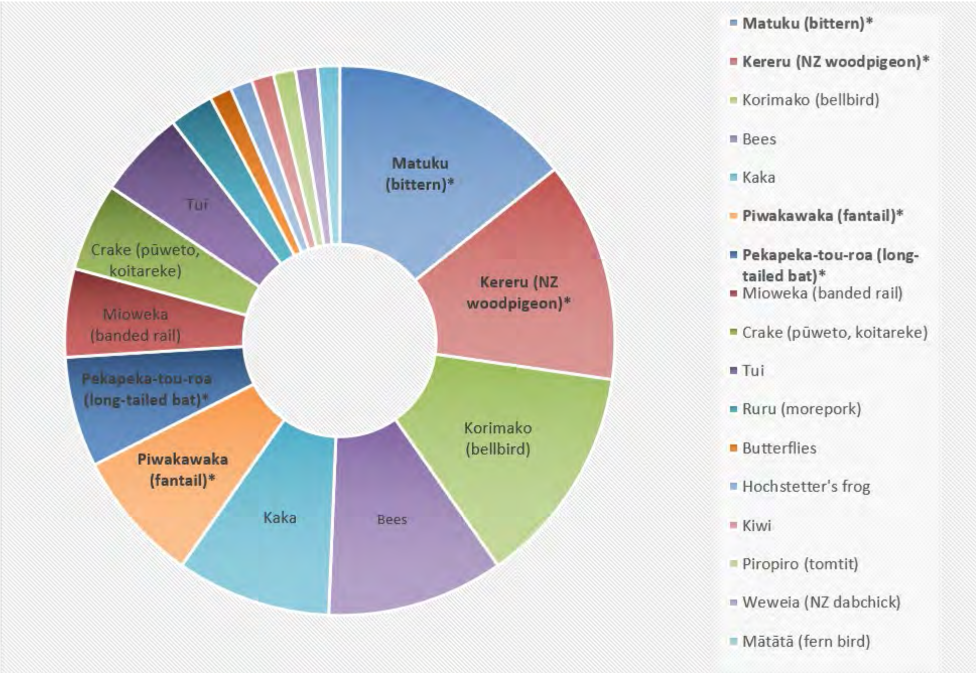


Fig. 6. Results of the online community survey undertaken in February 2020, showing the comparative number of votes for native terrestrial fauna species. The four species in bold with asterisks are those used as umbrella species.

3.3.2 Kereru

Fig. 7. Kereru. Photo courtesy of Rachel de Lambert.

Kereru (*Hemiphaga novaeseelandiae*; Fig. 7) are generalist frugivores (fruit-eaters) with relatively high mobility. They are typically found in patches of native bush where food is available, and forage across relatively large home ranges (~20 ha). Kereru play a vital role in dispersing seeds of native fruiting species. Since the extinction of moa and other large birds, they are now the only fruit-eater large enough to swallow fruit with large seeds such as tawa, miro, karaka, taraire and nikau.

Kereru are a taonga species of cultural and spiritual significance to Maori and New Zealanders overall. Unsurprisingly, this species was identified as of high value by the Rodney East community and for which maintaining connectivity was crucial, based on community survey responses (Fig. 6).

Their main threats are predation, habitat loss and competition for food (mainly from possums). Kereru are therefore an ideal ‘umbrella’ species for this connectivity analysis and a good indicator of effectiveness of management actions, such as planting native fruiting trees and predator control. They are included in the Roadmap to reflect the (potential) landscape-scale connectivity of large forest patches across Rodney East.

‘Core habitats’ inputted into the connectivity analysis were those patches of suitable habitat that were equal or greater to 20 ha, while the maximum dispersal distance was taken to be 4,620 m, the maximum pasture crossing for kereru (Table 1). These are the same values used to model ‘core habitat’ patches and maximum dispersal in a recent article by Zhang et al. (2020).

However, kereru home range size and movements are directly linked to availability and distribution of food resources. Kereru also use small patches within large home ranges, meaning that even a 1 ha forest patch may provide important food sources at certain times of year. For example, home ranges of adult kereru in Wenderholm Regional Park ranged between 20 and 30 ha, while using core areas of 1 to 2 ha (R. Bell, 1996). Other studies have yielded similar results (as reviewed by Campbell, 2006); at Pelorus Bridge Scenic Reserve in Nelson, kereru moved up to 18-20 km to reach other areas of native forest, while in Whirinaki Forest Park in the central North Island, kereru moved up to 24 km with a relatively large average home range size of 163 ha. Core areas utilized within home ranges around Lyttleton Harbour near Christchurch comprised approximately 6% of the total home range size, indicating kereru were only using very small parts of their home range (Campbell, 2006).

Given the large extent of Rodney East and the massive number of polygons that reflect different potential habitats requiring considerable computing power to model (Table 2), only large habitat patches equal or greater to the typical home range size of kereru were used in the analysis. These are likely to be the most important patches for breeding and act as a source population, from which kereru can disperse. It is important to note in the interpretation of the connectivity analysis that it represents the large-scale connectivity of ideal, preferred habitat for kereru, and smaller patches are also crucial for maintaining and enhancing connectivity within different land uses and types.

3.3.3 Piwakawaka

Piwakawaka (*Rhipidura fuliginosa*; Fig. 8) are small, friendly, endemic birds that are widespread and locally abundant. Their conservation status is Not Threatened. Their home ranges/territories are relatively small (~0.5 ha), and can often survive in farmland landscapes with some forest patches. This small insectivore eats invertebrates, including moths, flies, beetles and spiders, and some fruit. Their main threats are predation, in particular, nesting adults, eggs and chicks by ship rats.

Fig. 8. Piwakawaka. Photo courtesy of David Irvine.

Piwakawaka are a valuable addition to inform this Roadmap given their contrasting differences with kereru, including habitat use, home range size and diet, as well as also being a good indicator of the effectiveness of predator control activities. This species is of cultural importance, and occur in many Maori myths and legends. Maintaining and enhancing connectivity for this iconic species was also identified as being a goal of conservation actions to enhance connectivity by the Rodney East community (Fig. 6).

In this Roadmap, core habitats were identified as patches of suitable habitat that is equal or greater to 0.5 ha, sufficient for at least one breeding fantail pair, with a conservative estimate of 200 m easy movement distance across open habitat (Table 1). According to the New Zealand Handbook of birds (Higgins et al., 2006), piwakawaka occur wherever there are trees and shrubs, either native or introduced, that provide cover, including native forests, plantations of exotic pines, suburban gardens, farmland and orchards with scattered trees, shelter belts or hedgerows, although ideal habitat where they are most common are mixed native podocarp-hardwood forests.

Regarding home range, one study estimated a territory near Gisborne to be approximately 0.3 ha, while on Cuvier Island, the minimum diameter of territories was 100 m. However, little information exists on breeding dispersion, and no information on migratory populations (Higgins et al., 2006), hence the need for conservative estimates in patch size and movement distances, and management actions that facilitate easy movement within these parameters. It was not computationally possible to model all potential habitat patches within the study area due to the large number of identified patches (Table 2). A representative analyses conducted within a 4 x 4 km area with farmland habitat and small forest patches that is typical of much of the Rodney East landscape was selected to demonstrate effectiveness of the recommended management actions and as a close-up example of the more fine-scale connectivity that exists between smaller forest patches, and the importance of even these small patches in aiding connectivity.

3.3.4 Matuku

Matuku (*Botaurus poiciloptilus*; Fig. 9) are a cryptic (hard to find), predominantly wetland bird. They can be found in freshwater and brackish riverine, estuarine, palustrine and lacustrine habitats, and may also forage in drains and wetland/farmland edges. The mangroves around Mangawhai Estuary are also known to be habitat for matuku (Bell & Blayney, 2017; pers. comm. Alex Flavell-Johnson), and mangroves in this area were also included in the analysis. Their minimum core habitat patch size is estimated at ~2 ha, but they will often make use of even smaller patches.

Fig. 9. Matuku. Photo courtesy of Imogen Warren.

Concerningly, their range is thought to have decreased by ~50% in the last 100 years, primarily due to the clearance and drainage of approximately 90% of New Zealand's wetlands. Their main threats are the continued habitat loss, habitat degradation, and predation by introduced mammals. Maintaining connectivity among these habitats is crucial for this Nationally Critical species. Their inclusion in this Roadmap helps to capture the connectivity of important wetland and freshwater habitats across Rodney East.

Little information is available on the ecology of matuku in New Zealand (O'Donnell et al., 2013), including how they utilise patches of different habitat types, sizes and quality within their home range. Given that wetland-type habitat of all sizes and qualities may be potential habitat for matuku, and that they are able to range over large areas using small patches, no minimum core habitat patch size was set for the analysis (Table 1). This was possible computationally for the study area as there were significantly less polygons of suitable habitat for matuku than the forest habitats of kereru and piwakawaka (Table 2).

Their dispersal distance used in the analysis was adapted from several existing studies; a radio-tracking study on 10 adult male matuku in the Hawke's Bay showed that birds utilised a network of wetlands, within a 15 km radius with seasonal influences, while the longest journey reported in 2017 was 140 km by a juvenile female in the Canterbury region (Williams, 2013). Most movements are typically short, and the average observed distance that a tracked bird moved between sightings was 286.7 m per day, with a maximum of 1,280 m (Williams & Brady, 2014). This daily maximum distance moved was used in this Roadmap to reflect a comfortable movement distance between patches for this species (Table 1).

3.3.5 Pekapeka-tou-roa

The North Island subspecies of long-tailed bat (*Chalinolobus tuberculate*; Fig. 10) is found throughout the North Island. As insectivores, they play an important ecological role in managing insect populations and are an indication of a healthy, functioning ecosystem. They commonly forage along linear features in the landscape (e.g. shelter belts) and require tall, mature forest.

With a conservation status of Threatened: Nationally Critical, maintaining and enhancing ecological connectivity is crucial for the survival of New Zealand’s only native land mammal. Their key threats include habitat loss and degradation associated with land development, felling of roost trees, and predation of adults and young by cats, mustelids (particularly stoats), possums and rats.

Fig. 10. Pekapeka-tou-roa. Photo courtesy of Ruby Bennett.

Little information is known about dispersal or movement distances for Auckland populations. This species is also likely to use small patches or even individual trees, so all habitat identified may be important with no minimum patch size set. Their preferred natural habitat is mature forest with many large hollow trees, but they may forage over both indigenous forests (including northern coastal *Metrosideros excelsa* ecosystems, *Agathis australis* dominant forest remnants and podocarp forests) and exotic forests (including plantation forest), open ground and cutover forest. A best estimate range size of approximately 19 km is recommended used to assess connectivity and ease of movement among these habitat patches (Table 1). This value is adopted from O’Donnell (O’Donnell, 2001), who reported frequent and rapid movements of bats within the range (mean = 790 m per 15 min), with average range lengths of 3.3 to 10.9 km and a maximum of 19 km.

All habitat types with potential for mature, tall-stature trees were considered to be important habitat for bats. Bats are able to fly large distances but there is little information about how this species uses habitat patches in the landscape. Given the large amount of potential habitat in Rodney East, we considered that analysing the connectivity between these patches using Linkage Mapper was unlikely to provide robust or reliable results. Instead, a habitat map was created following similar methods as for the bird species, which can be used to help identify potential areas for restoration and protection.

3.4 Connectivity analyses

3.4.1 Landcover maps

A base land cover map was created to determine the location and extent of different land cover and habitat types across Rodney East (66,089 ha). This was based on the Current Ecosystem Extent layer from Auckland Council, based on Singers’ terrestrial ecosystem types of Auckland, combined with the NZLCDB.

The study area was then clipped to a rectangular box that encompasses all of the Rodney East local board area (area of land within box = 112,062 ha). This simplifies the analysis by ensuring all pixels are square and the same size. It also increases the reliability of the analysis as patches immediately outside the local board boundary, which may greatly influence connectivity especially around the edges of the legislative boundary, were also included in the analysis.

3.4.2 Habitat suitability maps

Habitat patch suitability maps for each of the four umbrella species were constructed based on the habitat preferences and foraging ecologies of the two species, following the recommendations of the Corridor Design Project (http://corridordesign.org) and methods of Zhang et al. (2020), who conducted a comparative Linkage Mapper analysis for kereru and kiwi to assess the impact of different movement abilities. This was one of the few New Zealand papers found that used Linkage Mapper on native species.

For each umbrella species, a habitat suitability value was assigned for each landcover class / ecosystem type in the study area. Suitability is a unitless variable specific to the species scaling from 0 - 100 with the following breaks: 0 no use at all; 1 - 30 avoided; 30 - 60 occasional use for non-breeding; 60 - 80 consistent use for breeding; 80 - 100 best habitat for survival and breeding (McRae & Kavanagh, 2017; Nor et al., 2017; Poodat et al., 2015). Habitat suitability scores for ranged from 1-100 for the three bird species, while habitat types for pekapeka-tou-roa were assigned a binary 1 or 0 for each cover class due to lack of information about specific use and preferences of habitat. All values were assigned based on a combination of expert opinion and evidence from published literature, which has been found to be more informative and reliable than when based solely on often limited quantitative data and species distribution models (Liu et al., 2018; Parrott et al., 2019).

Landscape features play an important role in determining habitat suitability and ease of an individuals' movement through the landscape. They were also incorporated into the analysis by either increasing or decreasing the habitat suitability value or resistance value as deemed ecologically appropriate. For example, the presence of protected land (DOC land, Auckland Council parkland and open space, SEAs and QEII covenants) increased the habitat suitability as these areas are likely to have effective predator control and other management activities that increases survival and breeding success (note the effect of roads was incorporated into the resistance layer for all four species).

Any pixels with a final habitat suitability value of equal or greater to 60 was considered suitable habitat, and is seen in the habitat suitability maps for each species. Finally, habitat patches used in the 'core habitat' layer of the Linkage Mapper analysis were those equal or larger than the minimum patch sizes in Table 1 (explained for each species in Sections 3.3.2 to 3.3.5).

3.4.3 Resistance layers

To create the resistance raster layer input for Linkage Mapper, resistance values were assigned to each pixel for each species based on the inverse of the final habitat suitability value for kereru, piwakawaka and matuku, and ranged from 1 - 100. A resistance value of 0 was therefore applied to ideal habitat, while a resistance value of 100 was applied to completely unsuitable habitat which that species is known to avoid.

Roads were then buffered and the resistance value of pixels within that buffer was increased depending on the road speed. This reflects the increased mortality risk near large, faster-flowing roads and the most substantial barrier to movement that roads present to many species.

For bats, resistance values were scored between 1 - 50 for each cover class due to their weaker habitat preferences and strong flying ability. A wider range in resistance values (e.g. 1 - 100) gives more contrasts in model outputs and therefore more distinct movement corridors, while narrower ranges (even as narrow as 1 - 3) give broad connections with less defined edges (Helldin & Souropetsis, 2017). As with habitat suitability values, all scores were assigned based on a combination of expert opinion and evidence from published literature.

A barrier is defined as a landscape feature that impedes movement between ecologically important areas, the removal of which would increase the potential for movements between those areas. Barriers may be human-made (e.g. roads, fences, or urban areas) or natural (e.g. rivers or canyons); linear (e.g. highways) or cover a large area (e.g. agricultural fields) (McRae et al., 2012). Barriers would be assigned a resistance value of 1000, however, no significant barriers were identified in Rodney East for any of the umbrella species.

4.0 Results of connectivity analyses

4.1.1 Summary

The connectivity analyses identified the current gaps and pinch-points of functional connectivity for kereru in forest ecosystems and for matuku in freshwater/wetland ecosystems across Rodney East.

It is recommended these maps are explored on the online Roadmap, where users are able to zoom in on particular areas and select their layers of interest. A selection of these connectivity maps for kereru, piwakawaka, matuku and pekapeka-tou-roa are also provided in print form in Appendix 2 (Maps 2-9).

A summary of the number and area of core habitats identified for each species (within their respective study areas) is provided in Table 2, upon which the large-scale connectivity across Rodney East was modelled. For kereru and matuku, whose analysis covered the entire Rodney East extent and their minimum core habitat size was estimated at 20 ha and 2 ha respectively (Table 1), the total number of all suitable patches are also provided. These smaller patches are crucial to aid connectively between larger habitat patches and may also provide important breeding and food resources.

The number of linkages identified within and beyond the dispersal distance of kereru and matuku during the large-scale connectivity analyses are provided in Table 3.

Table 2. Number of core habitat patches and their total area for each of the four umbrella species based on habitat suitability models.

	Kereru	Piwakawaka	Matuku	Pekapeka-tou-roa
No. core habitat patches	105	61 (in example 4x4 km square)	216	6,073
Area of core habitat	34,757 ha	223 ha	645 ha	36,452 ha
No. all suitable habitat patches	971	-	1,369	-
Area of all suitable habitat patches	39,115 ha	-	764 ha	-

Table 3. Number and mean distance of least-cost paths for kereru and matuku between core habitats based on the connectivity analysis. Dispersal distance for kereru and matuku were estimated at 4,620 m and 1,280 m respectively (Table 1).

	Kereru	Matuku
No. linkages identified *within* dispersal distance	204	147
Mean distance of linkages within dispersal distance	1,685 m	565 m
No. linkages identified *beyond* dispersal distance	24	26
Mean distance of exceeded linkages	5,854 m	1,386 m

5.0 Management recommendations

5.1 Overall management approach

Existing habitat condition and pressures both vary widely across the large extent of Rodney East. Connectivity Models for forest and wetland ecosystems have been developed based on the results of the Linkage Mapper analyses of the umbrella species (Maps 2 and 3, and are available in more detail on the online StoryMap).

Table 4 summarises the conservation focus, priority actions and priority areas across Rodney East for both forest and wetland ecosystems:

- For forest ecosystems, management priorities have been divided into three Zones (Northern, Central and Southern). Each Zone has a different priority focus to enhance functional connectivity, based on the existing habitat conditions and pressures in each Zone.
- Wetland habitats are currently extremely fragmented, and many are likely degraded. The priority is to protect and enhance existing core habitats, and then start connecting these within functional linkages. An estimated model of wetland connectivity has been developed for Rodney East, which would benefit from ground-truthing (testing the model against real matuku movement data) prior to use.

The section outlines specific conservation activities and guidance on how to undertake the recommended actions in the priority areas within each zone, in particular, how to:

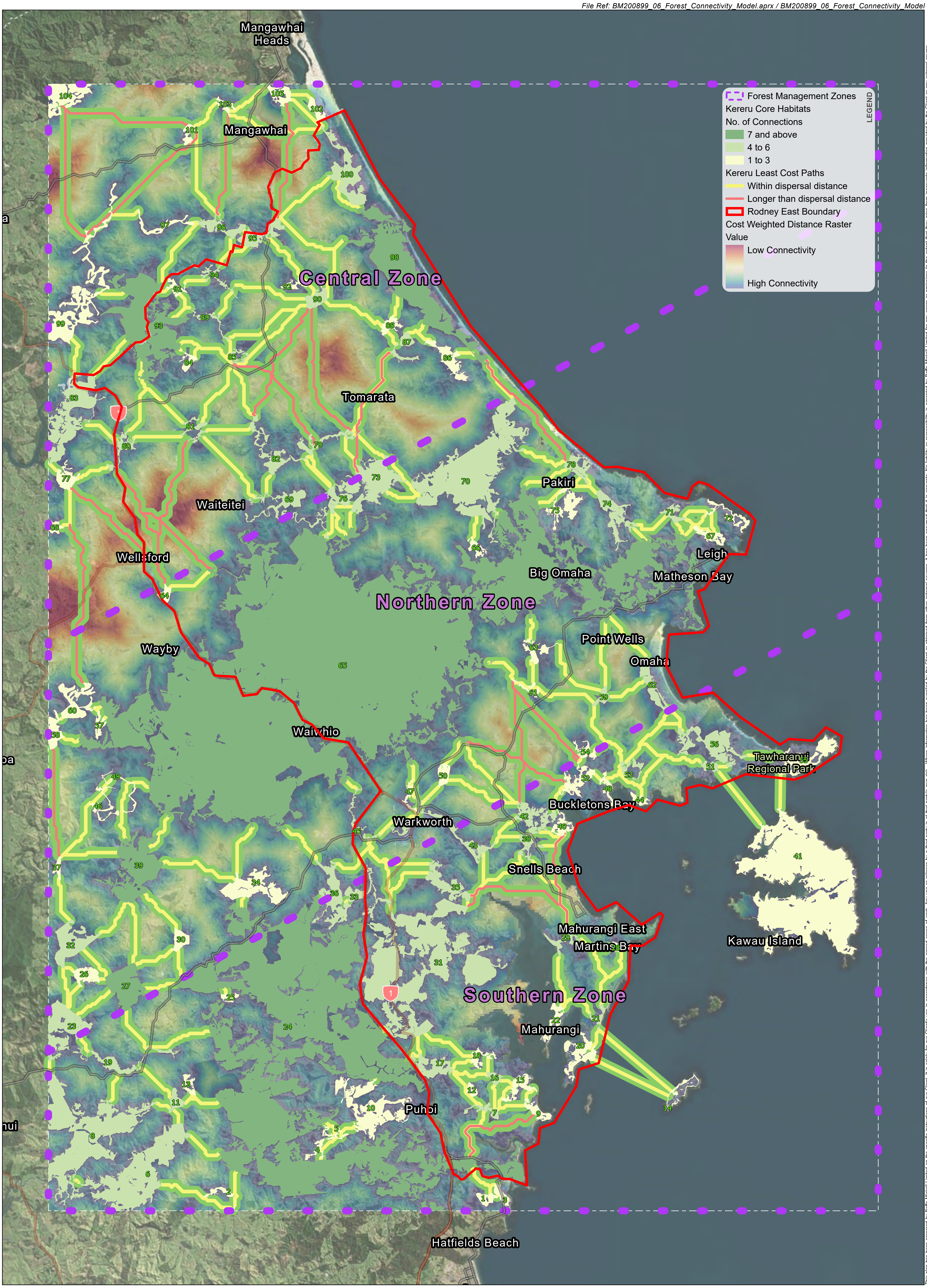
- Enhance existing habitat patches;
- Improve connectivity between patches;
- Improve connectivity on private land;
- Undertake predator control;
- Utilise transport infrastructure as greenways; and
- Plan projects effectively.

Note that the priorities outlined here are only intended to guide limited resources/funding towards actions that will provide the most benefit for the effort required. Even if an area or action is not classified as a ‘priority’ in a particular Zone, the conservation actions and activities listed below can and should still be applied across Rodney East, which will also help improve connectivity.

Table 4. Priority focus, actions, and areas across Rodney East for forest and wetland ecosystems.

Ecosystem	Focus	Priority Actions	Priority Areas
Forest ecosystems			
Northern Zone	Connect and expand	• Improving connectivity between patches (creating new linkages and filling gaps)	• Gaps between core habitats *(red patches on kereru CWD layer)* • Within current and potential linkages *(yellow and pink linkages respectively on kereru least-cost paths layer)*
Central Zone	Protect and connect	• Enhancing existing habitat patches • Improving connectivity between patches	• Core habitats, prioritised by number of linkages *(from forest connectivity model)* • Within current and potential linkages between core habitats, both east-west and with Northern and Southern Zones *(yellow and pink linkages on kereru least-cost paths layer)* • Prioritise increasing connectivity starting from core habitats and working outwards *(working from blue to yellow to red areas on the kereru CWD layer)*
Southern Zone	Protect and enhance	• Enhancing existing habitat patches	• Core habitats, prioritised by number of linkages *(from forest connectivity model)* • Small habitats within existing and potential linkages between core habitats *(from kereru other suitable habitat layer and forest connectivity model)*
Wetland ecosystems			
Across Rodney East	Protect and enhance	• Enhancing existing habitat patches • Ground-truthing matuku habitat use and movement pathways	• Core habitats, prioritised by number of linkages *(from wetland connectivity model)*

File Ref: BM200899_06_Forest_Connectivity_Model.aprx / BM200899_06_Forest_Connectivity_Model



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0 2.5 5 km

1:150,000 @ A3

Data Sources: BING Aerials, Auckland Council, Landcare Research, BML

Projection: NZGD 2000 New Zealand Transverse Mercator

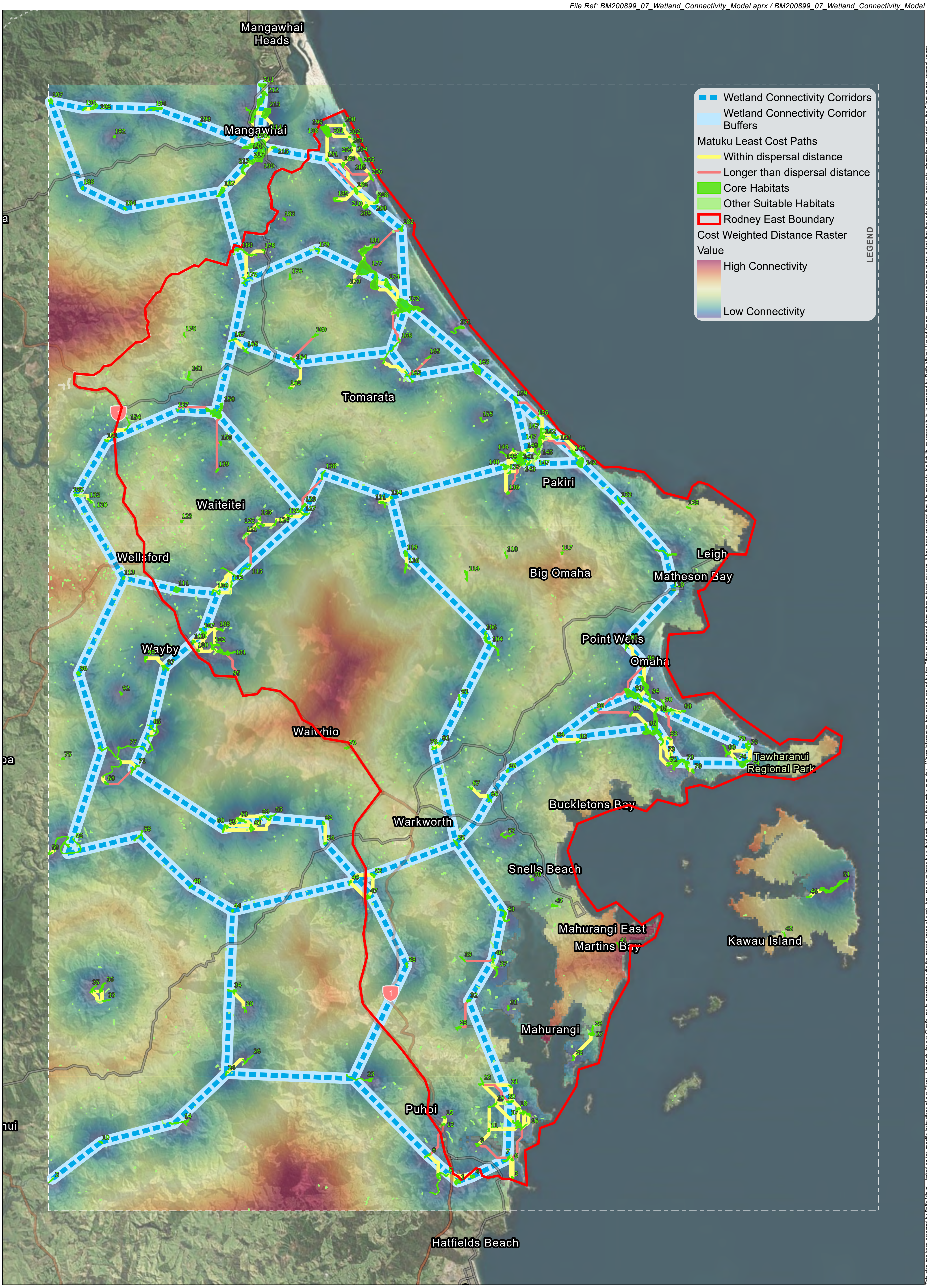
EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 2: Forest Connectivity Model

Date: 30 April 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate Heaphy | Drawn: SGa | Checked: KHe



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Data Sources: BING Aerials, Auckland Council, Landcare Research, BML

Projection: NZGD 2000 New Zealand Transverse Mercator

EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 3: Wetland Habitat Connectivity

Date: 30 April 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate Heaphy | Drawn: SGa | Checked: KHe

5.2 Management actions

5.2.1 Enhancing existing habitat patches

Core habitats with the most connections should be prioritised for protection and enhancement, as these areas have the most benefit to connectivity (see Forest and Wetland Connectivity Models for heat maps of core habitats with the most connections). Improving core habitats is a priority focus of the Central and Southern Zones for forest habitats, and across Rodney East for wetland habitats.

Smaller habitat patches (i.e. those not identified as core habitats) also play a crucial role in connectivity for many species and would benefit from protection and enhancement, especially within existing and potential linkages (i.e. creating a stepping-stone habitat). This is a priority focus in the Southern Zone.

Table 5 summarises the potential conservation activities to enhance exiting habitat patches.

Table 5. Conservation actions to enhance existing habitat patches.

Action	Potential conservation activities
1. Enhance quality of existing core habitat patches	• Pest animal control (trapping and/or toxic baiting, in particular for rats, mustelids and possums) • Pest plant control • Restoration planting, with a focus on planting native species that provide habitat, as well as food sources for both frugivores (e.g. kereru) and nectar-feeders (e.g. tui, korimako). Ideally, plants should be ecosourced where possible. Ecological advice should be sought prior to planting new trees to ensure they are suitable for the area • Fencing/stock exclusion (especially for small habitat patches on farmland that are likely currently unfenced) • Wetland restoration, including pest animal and pest plant control, improving water quality, and restoring wetland vegetation and hydrological regimes. Specialist ecological advice from Auckland Council should be sought prior to wetland restoration
2. Improve habitat quality of existing small habitat patches	• As per Action 1: Enhance quality of existing core habitat patches • Conversion to native-dominated plant assemblages with food sources for native species such as kereru, tui and korimako • Fencing/stock exclusion

3. Increase size of habitat patches	• Additional planting of suitable native vegetation around edges of habitat patches to increase landcover • Extend fencing/stock exclusion around larger area
4. Establish buffer zones around habitat patches	• Buffer planting around habitat patches to decrease edge effects • Pest control within a buffer zone to reduce predation risk both inside core patches and during travel between patches

5.2.2 Improving connectivity between patches

Creating and strengthening functional linkages between core habitats can be achieved using either ecological corridors or stepping stones (Table 6). Undertaking these actions within the current and potential linkages between core patches (yellow and pink lines respectively on the kereru and matuku least-cost paths layers) will yield the most benefit for connectivity.

When resources are limited, potential (pink) linkages are a priority focus on the Northern Zone, while strengthening existing (yellow) connections are a priority focus for the Central Zone. Actions to improve connectivity should also start from core habitats and working outwards. Core habitats are likely important breeding and feeding grounds for these species, and have potential to act as source populations that will spread into the surrounding landscape as connectivity increases.

The cost-weighted distance (CWD) layers show areas that are currently difficult for the umbrella species to move through, and which would benefit from undertaking the conservation actions listed in the table below. These gaps in the network (red areas) are currently a priority in the Northern Zone.

For wetlands, it is recommended to obtain field data of matuku movements to better understand how this umbrella species uses the landscape to ground-truth the wetland connectivity model. Creating and enhancing suitable habitat within the updated model will then become a priority.

Table 6. Conservation actions to improve connectivity between patches.

Action	Potential conservation activities
1. Create small 'stepping stone' habitat patches. These are additional areas of high-quality habitat created in areas of low-quality habitat (e.g. farmland)	• Fence off intended area from stock • Undertake pest plant control • Undertake replanting as required (ideally using natives with consideration to food sources and preferred habitat for native species) • Establish a pest animal control network that is regularly serviced (trapping and/or toxic baiting), in particular targeting rats, mustelids and possums

2. Create continuous ecological corridors of high-quality (or suitable) habitat. Ideally these start and finish at substantial habitat patches, but creating linear habitats (e.g. hedgerows and shelterbelts) will improve connectivity for a number of species. Waterways are important linkages among patchy resources in a landscape that are utilised by many species	• Plant hedgerows and shelterbelts instead of (or in addition to) fences. Wider, longer and connected hedgerows are ideal • Replant with a range of native species, as practical • Fence waterways to exclude stock. This allows habitat to regenerate • Riparian planting of suitable native vegetation to provide habitat, improve stream health and restore nutrient/water cycling. Riparian margins along a substantial length of stream and of decent width can form effective ecological corridors, often without conflicting land use interests

5.2.3 Improving connectivity on private land

Privately owned land comprises the majority of landscape separating (and potentially connecting) core habitats. This means everyone has a part to play, and should be encouraged and supported to manage their land as functional habitat, either by enhancing existing features or adding new features.

Individual landowners can assess opportunities for enhancement on their own land by zooming in on their properties on any of the habitat and connectivity maps. Along with the actions listed in the tables above, landowners can contribute to connectivity by:

- Planting hedgerows and shelterbelts instead of fences. These should comprise a range of plant species and ideally be of a complex structure (e.g. trees where possible, shrubs and understory).
- Restoring waterways on their property, with fencing and native riparian planting of complex structure along the length of the waterway.
- Planting native food sources for native birds such as kereru, tui and korimako around the property.
- Undertaking predator control across the full extent of Rodney East is one of the most important conservation actions towards improving connectivity.
- Refer to the Useful links section for more information on plant species selection, ecosourcing for particular ecosystems, and pest management information, and where to get more specific advice.

5.2.4 Undertaking predator control

Predation from introduced mammals is one of the key threats facing many of our native species, including all four umbrella species. Consequently, there is a strong link between predator control and enhancing the habitat suitability of existing and new habitat patches (e.g. improving survival rates and breeding success of the four umbrella species), as well as reducing the resistance (cost or risk) of animals moving between patches.

Alongside habitat restoration, pest management is therefore key action in all areas across Rodney East and beyond, linking in to help achieve Predator Free 2050 and Pest Free Auckland eradication objectives. Predator Free groups and predator management projects are encouraged to add their efforts to the community map layer in the Add a Project section of the online Roadmap if not already, to show where predator control is currently occurring and remaining gaps still requiring control.

Target species across the full extent of Rodney East (and beyond) are rats, weasels, stoats, ferrets, possums, and feral cats, primarily using traps and toxins. A range of both trap and bait types should be used to target different individuals of the target species. A list of traps that have passed (and failed) humane testing for each target species can be found on the Bionet website.

To increase control efficacy, traps/bait stations should be located at a minimum of the recommended spacing for each target species along lines in key habitats or likely movement corridors for predators. Mustelids and feral cats often move along linear features such as roads, fences and habitat boundaries, waterways and around wetlands, which also make for easier serving than a standard grid. A range of lure types should also be used, with the type changed occasionally. Pulses of toxic control can also be used, primarily to control rats and possums, and must always be deployed as per label instructions. All pest management data should be accurately recorded (e.g. in TrapNZ) to allow for review of the control network and analysis of management effectiveness.

Comprehensive guides and resources to establish an effective predator control network is provided in the Useful Links section of the online Roadmap.

5.2.5 Transforming transport infrastructure into greenways

Transport infrastructure is among the largest barriers to movement for most terrestrial species. However, with environmentally friendly planning, roads, walkways, and railways all have potential to become greenways that both facilitate movement between core habitats and provide potential habitat.

For transport infrastructure to become effective greenways, Auckland Council should support:

- Strips of planting that are as wide as possible, ideally on both sides of the transport route.
- Include ‘nodes’ of larger habitat patches along the greenway, and connect larger habitat patches that exist adjacent or near the route (i.e. greenways that ‘go’ somewhere).
- Planting a diverse range of native plant species, selected, and planted with the purpose of providing for movement of particular native species (e.g. kereru and fantail). Plant species should achieve a range of mature sizes and structures (e.g. trees and bushes), infilled as appropriate. Species that also provide food sources for birds such as kereru and tui (i.e. both frugivores and nectar-feeders) should also be considered.
- Seek specific ecological advice for appropriate and effective planting plans for each greenway, based on its particular location and surrounding habitat.

5.2.6 Planning projects to enhance ecological connectivity

It is crucial that conservation projects are planned with specific goals and species in mind to achieve functional connectivity for specific species, as well as to for overall structural connectivity. To align with this Roadmap, species of focus should include kereru and piwakawaka for forest ecosystems, and matuku for wetland ecosystems. Actions for other species can also be undertaken, such as for pekapeka-tou-roa or particular threatened species.

To be successful, all conservation projects need to have defined goals. Guidance for establishing effective projects that incorporate connectivity is provided in the flow diagram, *Roadmap for planning additional actions to improve ecological connectivity*, on the following page.

Projects should be planned with specific species in mind, such as kereru for forest ecosystems, to ensure functional as well as structural connectivity is obtained. Monitoring success is then important to ensure the project is meeting its intended outcomes. Recommended monitoring methods include:

- Standard 5-minute bird counts to assess avian diversity and provide an index of abundance for indicator/umbrella species at particular locations throughout Rodney East. Native species (diversity and relative abundance) should increase over time.
- All community are encouraged to partake in the annual Great Kereru Count. This is a citizen science project organised by the WWF and the Kereru Discovery Trust. It usually occurs in the last week of September each year, and observations can be uploaded via the i-Naturalist website. This is a great way of recording distribution and abundance of the primary umbrella species selected to reflect connectivity of native forest ecosystems in Rodney East.
- Other useful project-specific measures, such as chew card indices for pest presence or area of habitat created/restored.

Refer to the Useful links section of the online Roadmap for more information on planning successful restoration projects.

Conservation groups are strongly recommended to add their project using the survey at the end of this Roadmap to identify where gaps are being filled and further work is still required. Tiaki Tāmaki Makaurau also has options to contact groups in your area to help collaboration and if people are interested in joining/connecting.

Roadmap for planning additional actions to improve ecological connectivity

1. Define the goal/objective

- For each project, set SMART goals and objectives (*Specific, Measurable, Achievable, Relevant, Time-bound*)
- Use umbrella or indicator species to make goals specific and measureable
- Link goals/species back to ecosystem services and functioning

For example:

- Improve connectivity of native forest ecosystems for kereru and/or fantail
- Improve connectivity of wetlands for matuku
- Protect remnant habitats for pekapeka-tou-roa
- Actions for other key indicator species

2. Choose an area

- For **exisiting areas**, refer to the **large-scale habitat maps** for kereru (native forest ecosystems), pekapeka-tou-roa (potential forest habitat and tall-stature trees) and matuku (wetlands) for exisiting habitat patches of different habitat types

- For **new areas**, refer to the **connectivity analysis heat maps** and **linkage maps** for kereru and matuku for areas/links that improving would benefit these species (and associated biodiversity) the most

3. Select management action(s)

To improve existing habitat patches (forests and wetlands):

1. Enhance quality of existing core habitat patches
2. Improve habitat quality of existing small stepping-stone patches
3. Increase size of habitat patches
4. Establish buffer zones around habitat patches

To improve connectivity between habitat patches:

1. Add in small stepping stone habitats
2. Create ecological corridors of high-quality (or suitable) habitat
3. Improve waterways and riparian strips

4. Select measure(s) of success

Select measures of success prior to project and assess at set time intervals. For example:

- Increase in diversity and abundance of native species (e.g. 5-min bird counts of kereru, fantail and/or other indicator species)
- Increase in landcover of a native habitat type that is replanted
- Decrease in predator numbers (e.g. chew card index for rats, mustelids and/or possums)
- Number/extent of conservation groups recorded on this Roadmap

5. Record the project on this Roadmap

6.0 Online Roadmap

6.1 StoryMap structure

The online StoryMap focusses on the management recommendations and providing interactive maps users can explore. The StoryMap structure therefore differs slightly from this written report, with seven main sections:

Overview

- Outlines the purpose, study location (Rodney East) and objectives of the Roadmap
- Describes the historical context of landcover patterns and changes
- Outlines specific ways to use the Roadmap effectively (as per Section 1.5 of this written report)

Management Actions

- Contains an interactive map viewer that contains all map layers used in the Roadmap, and the overall prioritised Forest and Wetland Connectivity Models
- Lists actions and high-level guidance on how to:
    - Enhance existing habitat patches
    - Improve connectivity between patches
    - Improve connectivity on private land
    - Undertake predator control
    - Utilise transport infrastructure as greenways
    - Plan projects effectively, including a flow diagram

Connectivity Analysis

- Briefly discusses ecological connectivity
- Introduces the four ‘umbrella’ species selected for analysis with background ecology on each species
- Outlines the model assumptions and limitations
- Presents the results of the connectivity analysis, including habitat maps, resistance heat maps and linkages

Ecosystem Maps

Contains an interactive map with the following layers:

- Current ecosystem extent
- New Zealand Landcover Database (NZLCDB)
- Water courses/overland flow paths
- SEAs, DOC land, Council land

- Biodiversity Focus Areas (BFAs) on public land
- Community Group Project Areas (based on the responses received from the community surveys as part of the Roadmap's development and are intended to be updated and maintained in future, as per Section 6.3 of this written report)

Useful Links

- Useful links and extra information, and where to find more specific advice

Glossary

- Provides definitions for technical terms, as per Appendix

Add a project

- Contains a survey form that allows users to add their conservation group, project, or area to the public data layer on Auckland Council's Tiaki Tamaki Makaurau Conservation Map. This is strongly encouraged for all community groups to help identify remaining gaps between projects and how connectivity is enhanced as more groups undertake conservation work in Rodney East.

7.0 References

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Appendix 1: Glossary

Barrier. A landscape feature that obstructs the movement of an animal or ecological process.

Corridor. A linear, connected land area that joins habitat blocks or sources of ecological flows to provide opportunities for the movement of animals or ecological processes.

Ecosystem service. Benefits to humans provided by the natural environment and from healthy and well-functioning ecosystems. The four main groups are: provisioning, regulating, cultural and supporting services.

Euclidian distance. The straight-line distance between two points.

Habitat Patch. Patches of habitat that serve as the features between which linkages are modelled using least-cost distance or other approaches. Patches classified as suitable habitat for a species are referred to a core habitat patches.

Landscape permeability. The quality of a heterogeneous land area to provide for passage of animals or other ecological functions.

Least-cost corridor. The set of map cells for which the least-cost path distance between two sources passing through the cell falls below a user-defined threshold.

Least-cost distance, weighted distance, or cost-weighted distance. The least accumulative cost distance (the sum of cell size times resistance of the cell) to the nearest source.

Least-cost path. The one-cell-wide path between two sources with the least accumulative cost distance (the sum of cell size times resistance of the cell for the cells along the path).

Linkage Mapper. A GIS-based software which enables users to map areas of core habitat and apply resistance values to identify and map linkages between core areas for a particular species.

Raster data. Is a type of data that consists of a matrix of cells organised into rows and columns (or a grid) in which each cell (also called pixel) represents specific information, such as elevation or temperature.

Resistance (or cost) surface. A map of how much the habitat characteristics at each map cell facilitates or impedes the movement of an animal or ecological process.

Resistance (or friction) values. Integer values that describe the habitat permeability or ease of movement for a species through particular habitat types, usually given for an area or map pixel.

StoryMap. A series of interactive and informative web maps hosted via the ESRI's ArcGIS platform.

Umbrella species. A concept used in conservation planning, where by protecting a key 'umbrella' species, protection will also be provided for the ecosystems they inhabit and other species that use the same habitat.

Vector data. Is a coordinate-based data structure that represents geographic features as point, lines, and polygons.

Appendix 2: Connectivity maps

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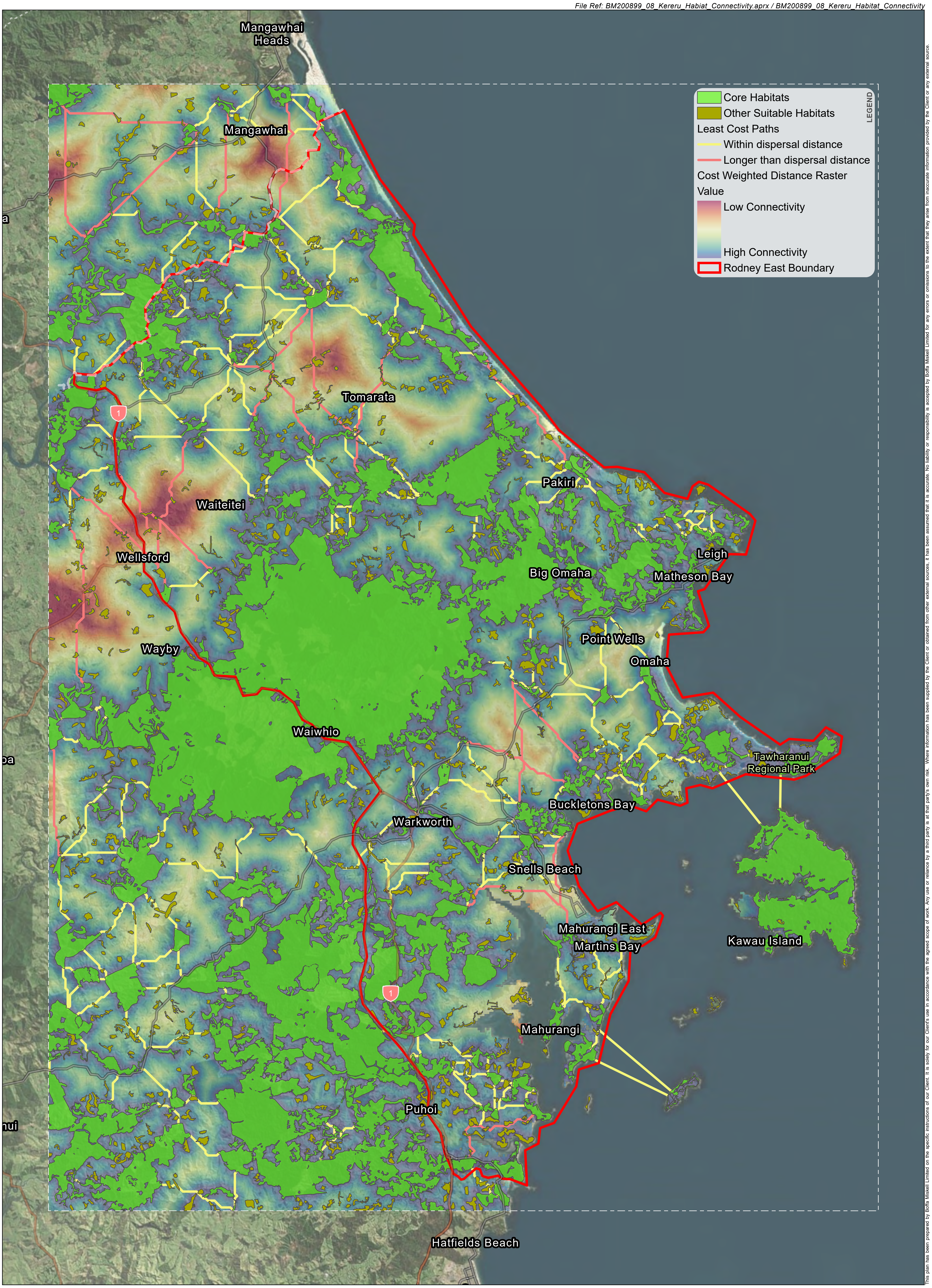

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Data Sources: BING Aerials, Auckland Council, Landcare Research, BML

Projection: NZGD 2000 New Zealand Transverse Mercator

EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

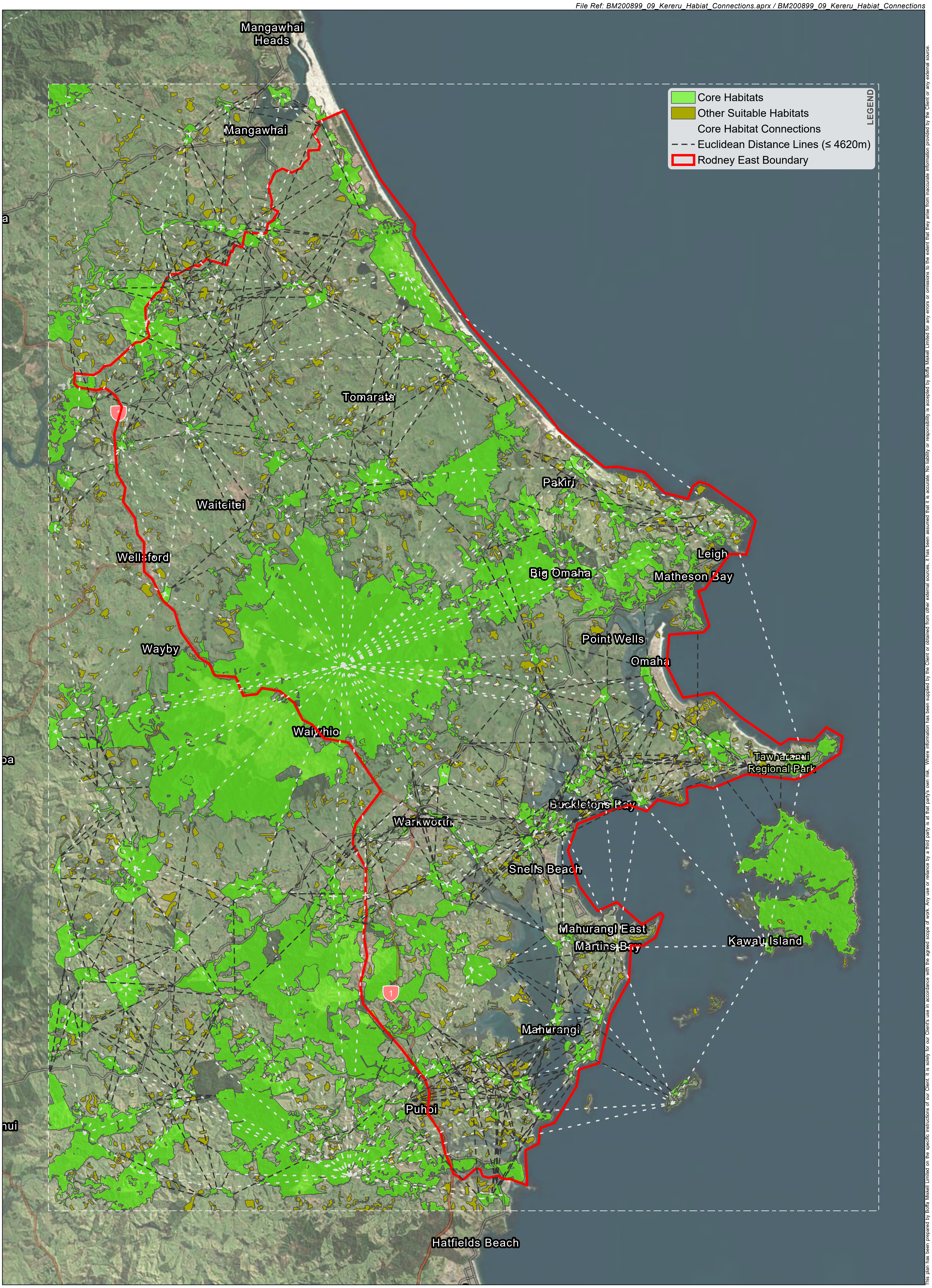
Map 4: Kereru Habitat Connectivity

Date: 30 April 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate Heaphy | Drawn: SGa | Checked: KHe

File Ref: BM200899_09_Kereru_Habiat_Connections.aprx / BM200899_09_Kereru_Habiat_Connections



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EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 5: Kereru Habitat Connections

Date: 30 April 2021 | Revision: 0

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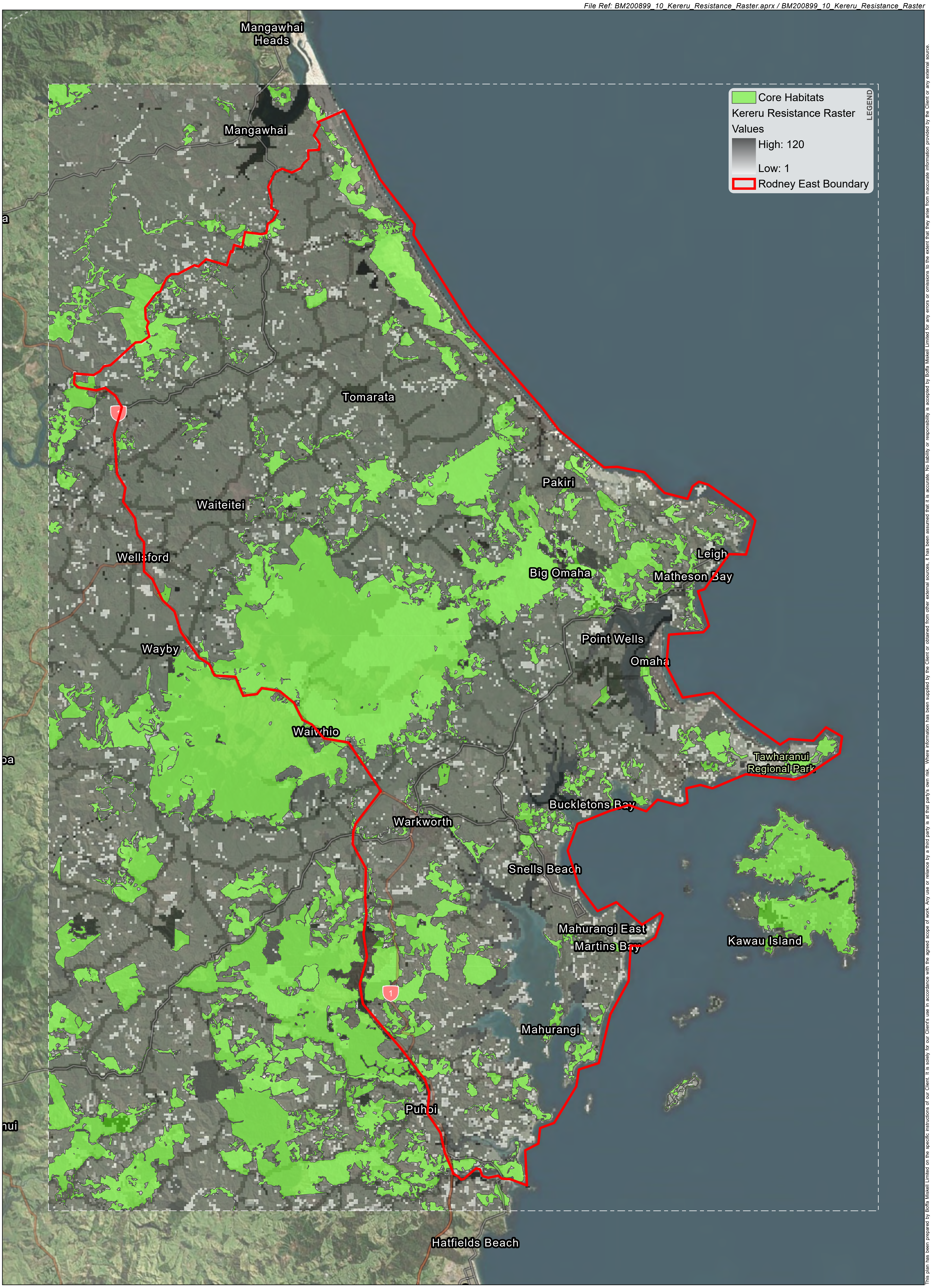

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Map 6: Kereru Resistance Raster

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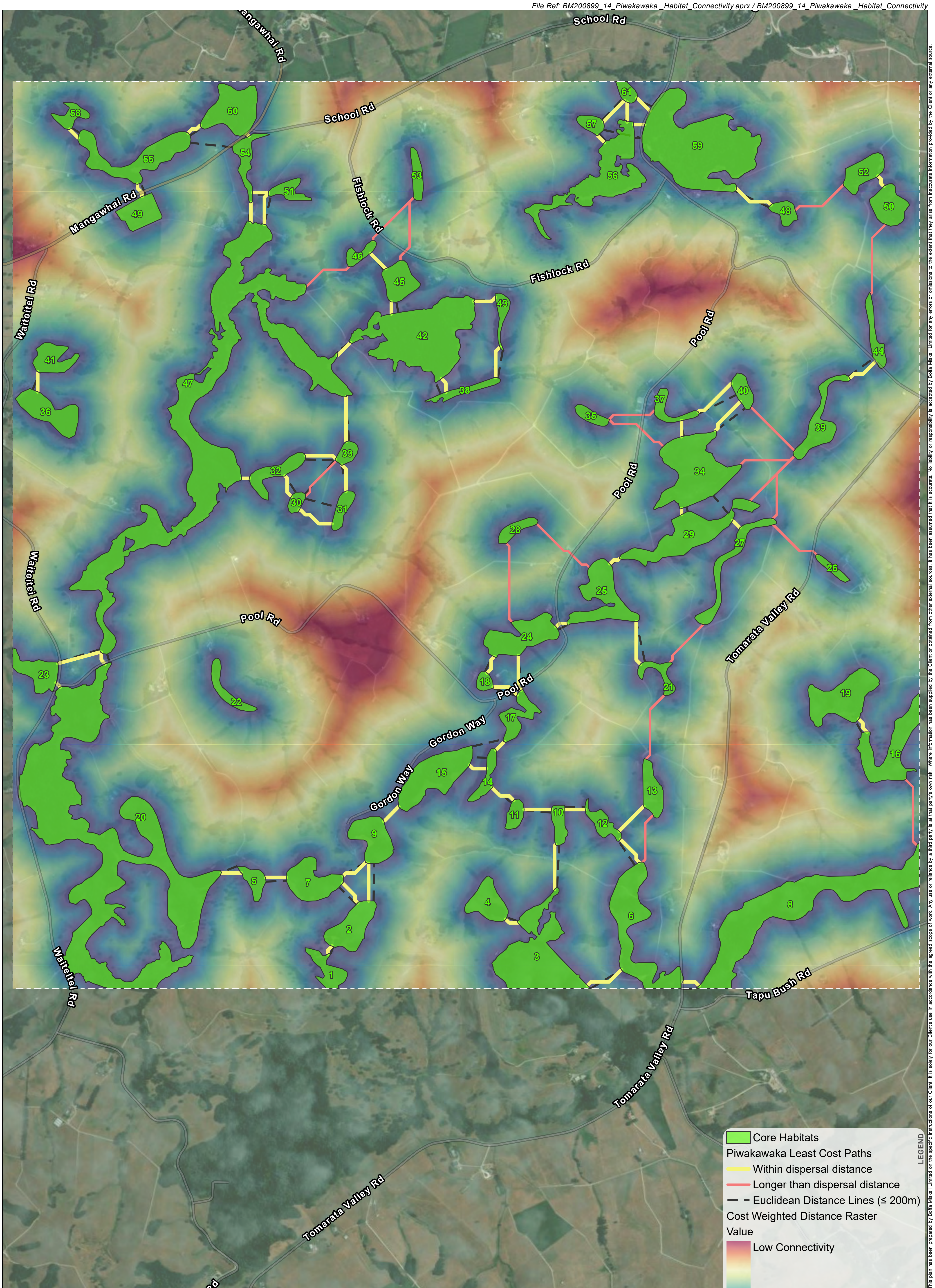

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Map 7: Piwakawaka Habitat Connectivity

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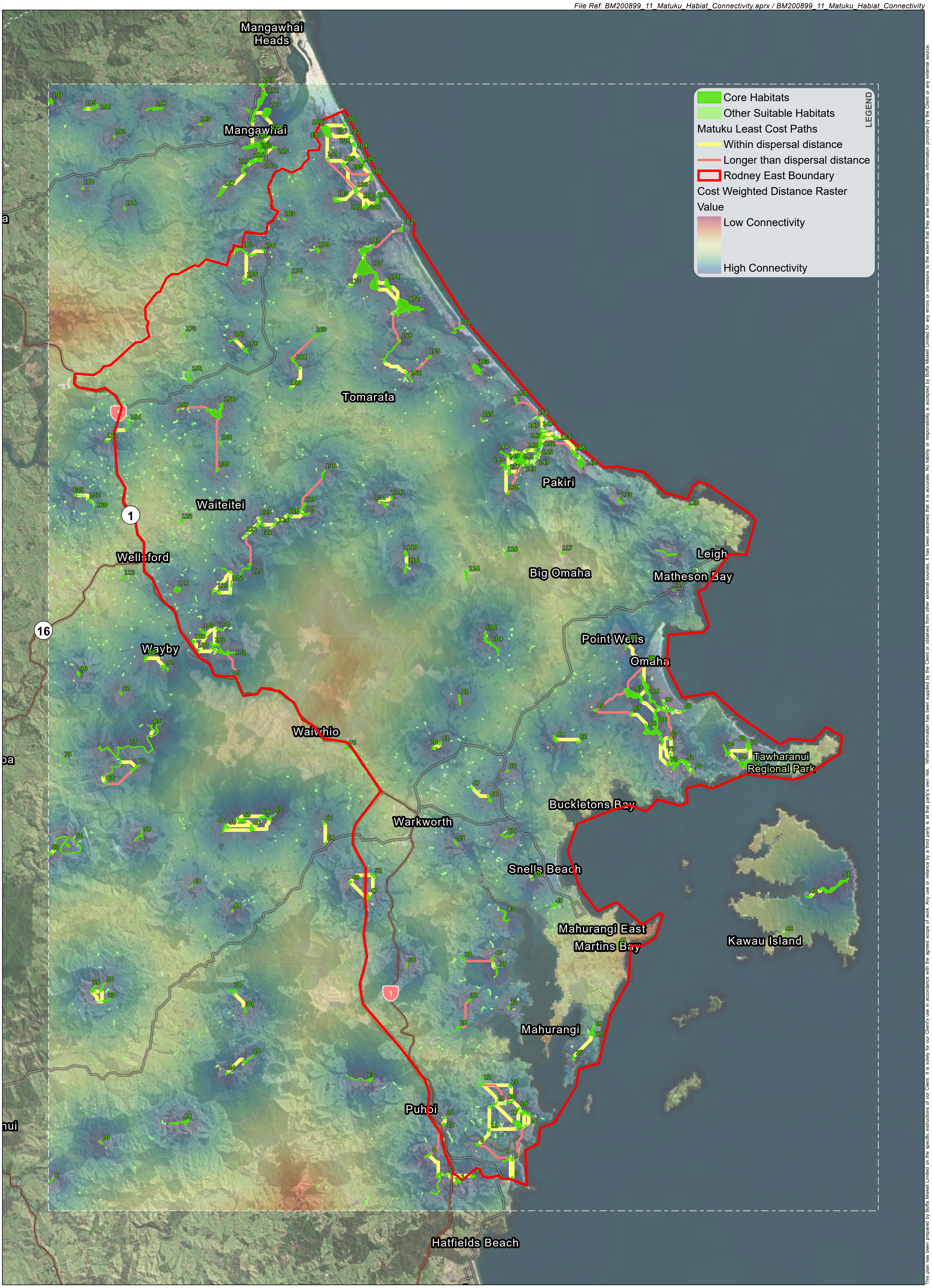
File Ref: BM200899_11_Matuku_Habiat_Connectivity.aprx / BM200899_11_Matuku_Habiat_Connectivity



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EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 8: Matuku Habitat Connectivity

Date: 30 April 2021 | Revision: 0

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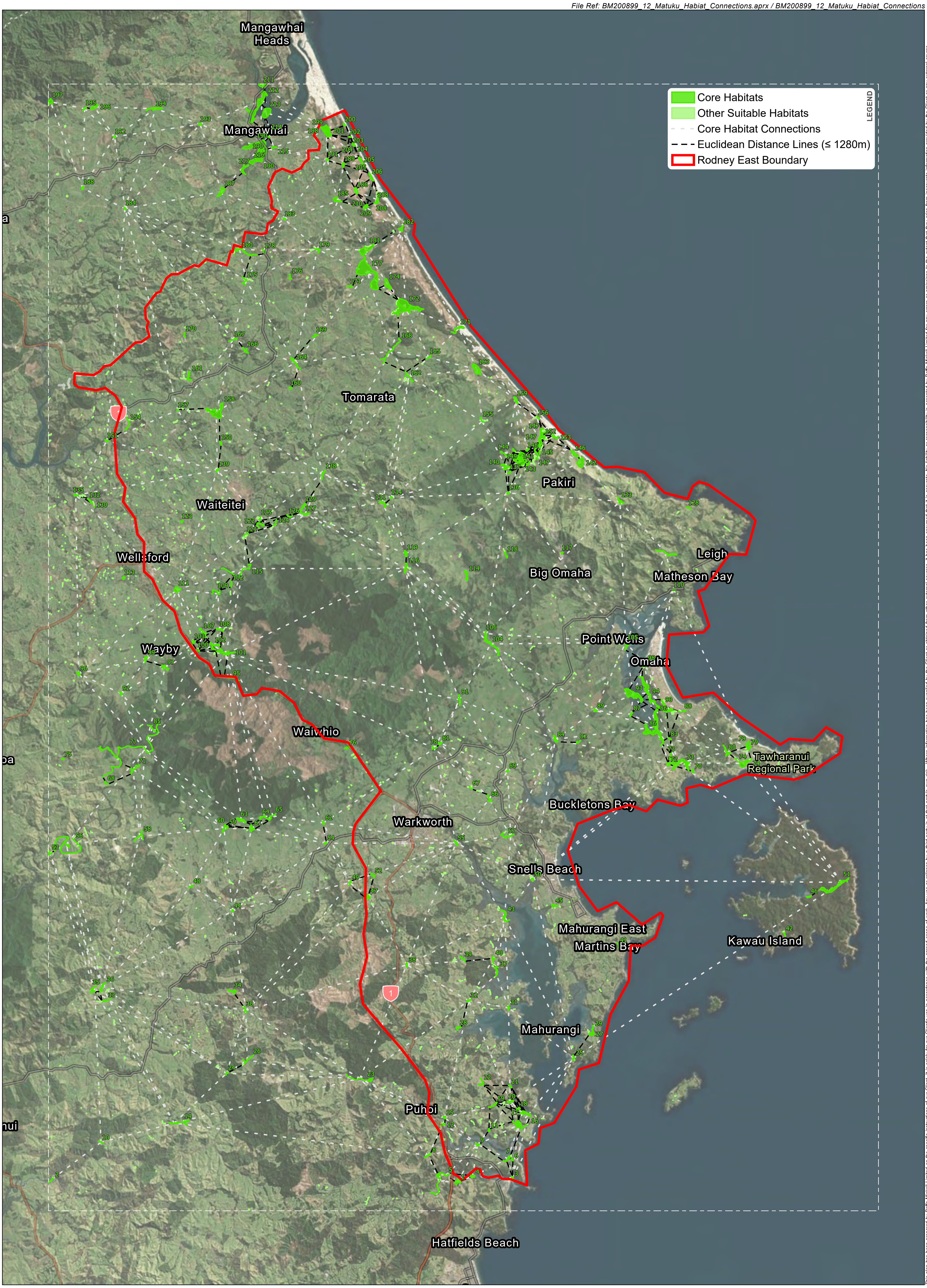
Project Manager: Kate Heaphy | Drawn: SGa | Checked: KHe



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EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 9: Matuku Habitat Connections

Date: 30 April 2021 | Revision: 0

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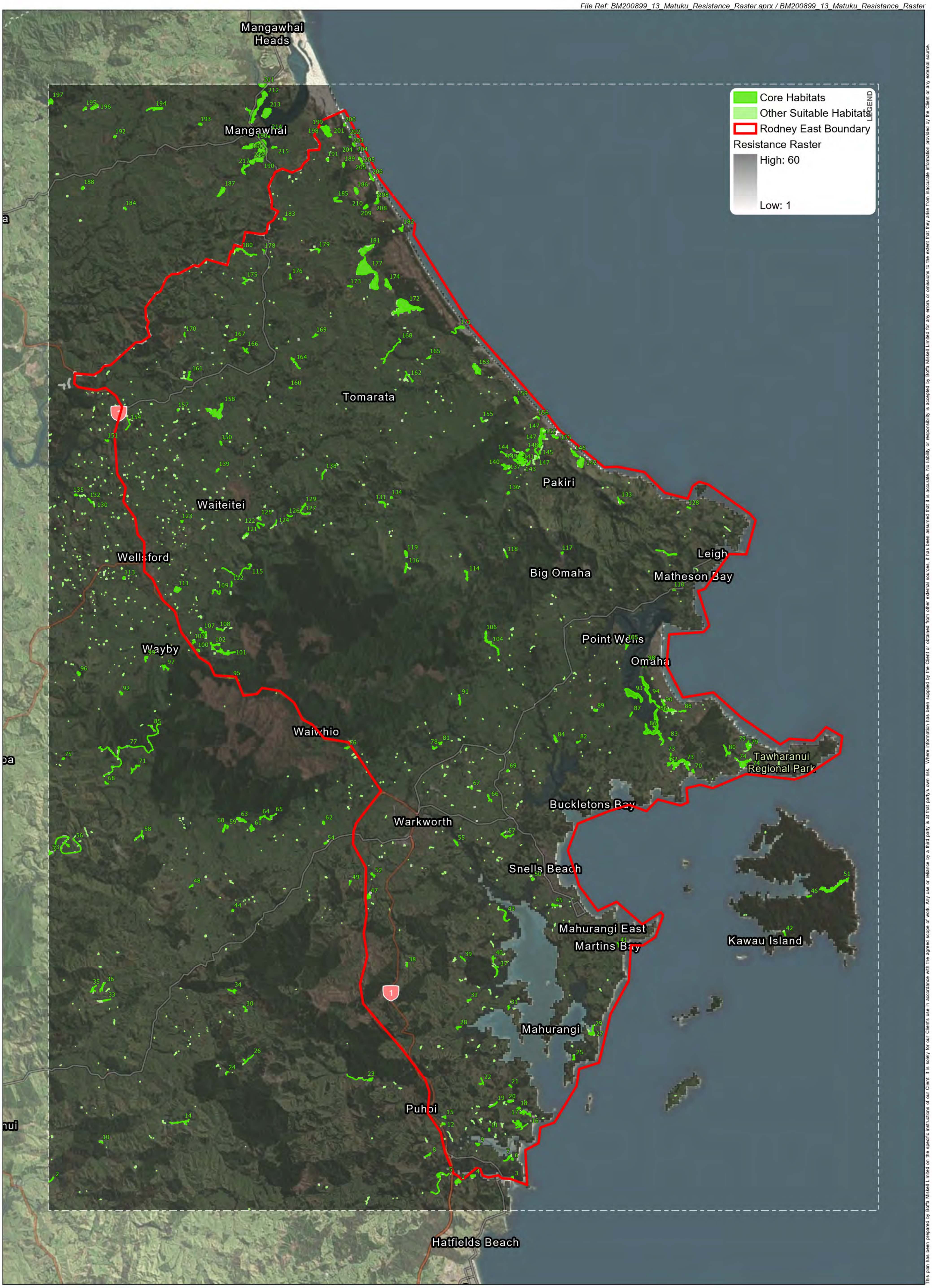

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Projection: NZGD 2000 New Zealand Transverse Mercator

EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 10: Matuku Resistance Raster

Date: 30 April 2021 | Revision: 0

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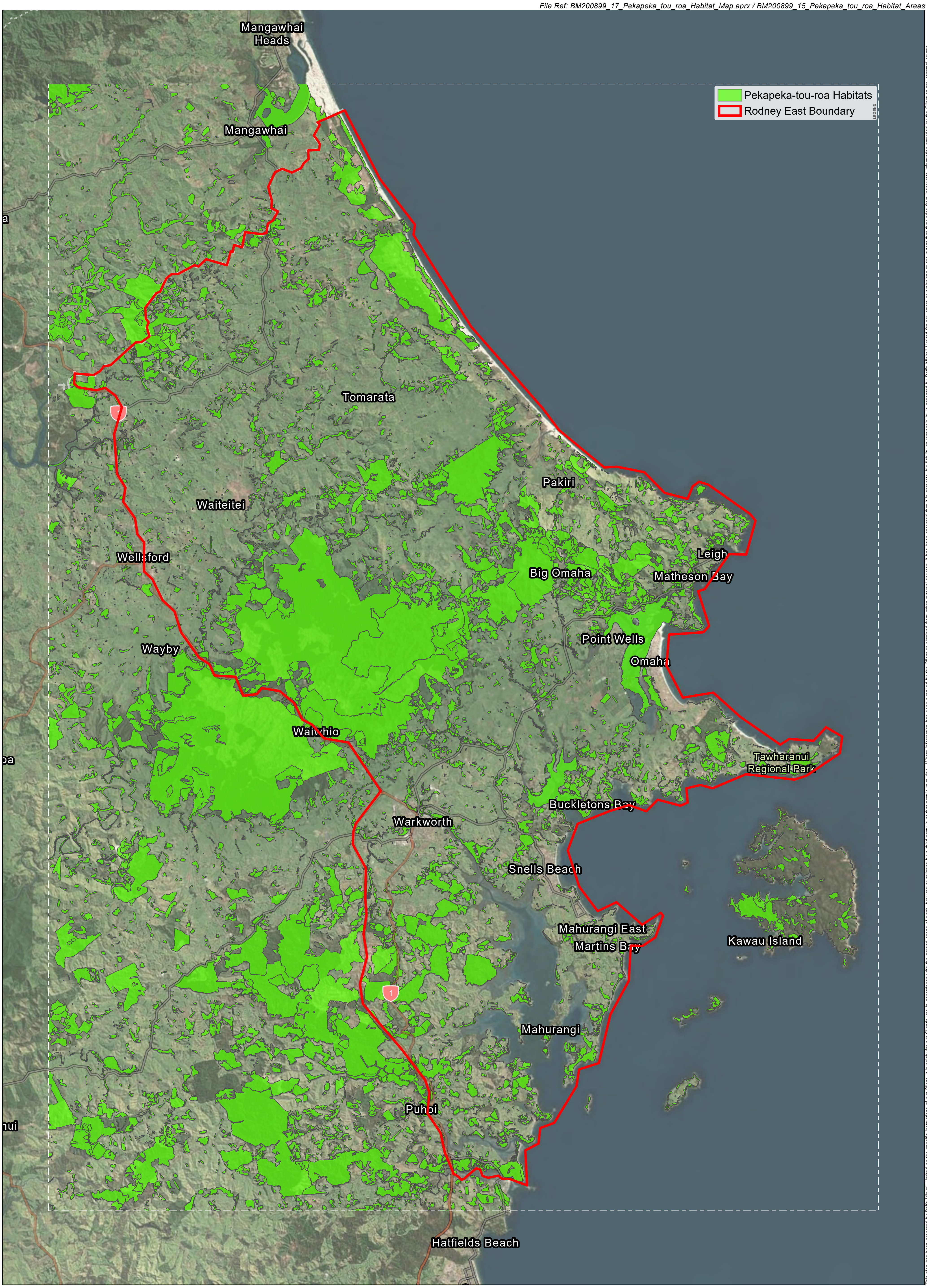

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EAST RODNEY ECOLOGICAL CONNECTIVITY ROADMAP

Map 11: Pekapeka-tou-roa Habitat Areas

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