Ecological Connectivity Strategy

Pest Free Upper Harbour

Auckland Council
Te Kaunihera o Tāmaki Makaurau

Table of Contents

EXECUTIVE SUMMARY

Upper Harbour is home to many areas of high ecological significance. However, the current extent and quality of these native ecosystems is significantly reduced from pre-human times due to development and is continuing to decrease at an alarming rate. The decrease in quality habitats and their connectivity has been a direct pressure to local native biodiversity. Local biodiversity faces multiple significant pressures, including from invasive pest plants and animals, urbanisation and development, climate change, and the resulting loss of habitat and connectivity. Multiple community and council-led projects are underway to help protect and enhance biodiversity. Our collective, coordinated efforts are crucial to maintain the remaining areas and their linkages, and restore those we have lost.

This Ecological Connectivity Strategy was funded by the Upper Harbour Local Board to help achieve landscape-scale ecological restoration and connectivity. To inform the Strategy, connectivity analyses were undertaken on several 'umbrella species', to determine the functional connectivity of terrestrial ecosystems present in Upper Harbour. 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 of the analyses, the Strategy identifies priority areas to enhance connectivity, with priority actions for each area. It also provides guidance on the following key actions:

- Mammalian predator control;
- Pest plant control;
- Buffer planting (forest, riparian and wetland margins);
- Creating and enhancing forest habitat;
- Utilising transport infrastructure as ecological corridors; and
- Planning and delivering projects to improve ecological connectivity.

This Strategy comprises this written report and an accompanying online StoryMap with an Interactive Map Viewer, which provides a starting point for improving terrestrial connectivity in Upper Harbour. It has been designed to further the environmental objectives of existing conservation initiatives, including the North-West Wildlink, the Urban Ngahere Strategy and the Upper Harbour Open Space Network. There are four key ways to use this Strategy:

1. **Where** – To identify areas for conservation action;
2. **What** – To identify conservation actions in a particular area;
3. **Who** – To identify surrounding conservation groups and engage with mana whenua where required; and
4. **How and why** – To aid funding applications and gain support.

The Strategy was created by Boffa Miskell for Auckland Council in collaboration with mana whenua, local communities, and Council.

1 Introduction

Ecology of Upper Harbour

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 1). These are described in the guide document '[Indigenous terrestrial and wetland ecosystems of Auckland]' (Singers et al., 2017) and form the basis of this Strategy.

Upper Harbour covers 8,276 ha around the north western branch of the Waitemata Harbour. It is home to many areas of high ecological significance, including Pāremoremo Scenic Reserve, the largest bush reserve on the North Shore.

Threats to biodiversity

Biodiversity is in a state of decline, both in New Zealand and worldwide. In New Zealand, biodiversity has greatly reduced in species diversity and spatial extent over the past 700 - 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, hedgehogs, and unowned cats), climate change, increased urbanisation, and an increasing human population. 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; and
- Exotic pests are found almost everywhere in New Zealand, except for some offshore islands and fenced sanctuaries.

Upper Harbour's ecosystems face many of these pressures at a significant level, in particular, from rapid urbanisation and development and the resulting loss of natural habitats and connectivity. The current extent and quality of native ecosystems in this area is significantly reduced from pre-human times, and is continuing to decrease. Our combined efforts are crucial to maintain the remaining areas and their linkages, and restore those we have lost.

Ecological connectivity

'Connectivity' is the degree to which the landscape facilitates or impedes movement among habitat patches and spatially distributed resources (Taylor et al., 1993). In other words, ecological connectivity describes how much the landscape enables or impedes movement among feeding and breeding areas for fauna, facilitate dispersal of plants, animals and other organisms, and link ecological processes (e.g. gene flow, pollination, seed dispersal, nutrient cycles).

Ecological connectivity can be assessed by examining structure and/or function (Hilty et al., 2012). Structural connectivity describes the physical presence, location, shape, and dimensions of habitat. Functional connectivity describes how easy it is for individuals or populations of a species, or the functioning of ecosystem processes that require flow of certain elements around the landscape.

The degree of connectivity depends on the species and ecological processes of interest. Different species use the landscape in different ways; depending on the habitat preferences, movement ability and their life stage (e.g. juvenile/seed dispersal). Conservation strategies therefore 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).

Maintaining connectivity, especially in increasingly fragmented landscapes such as Upper Harbour, 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 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.

Modelling ecological connectivity

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.

Improving ecological 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. 1; 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.

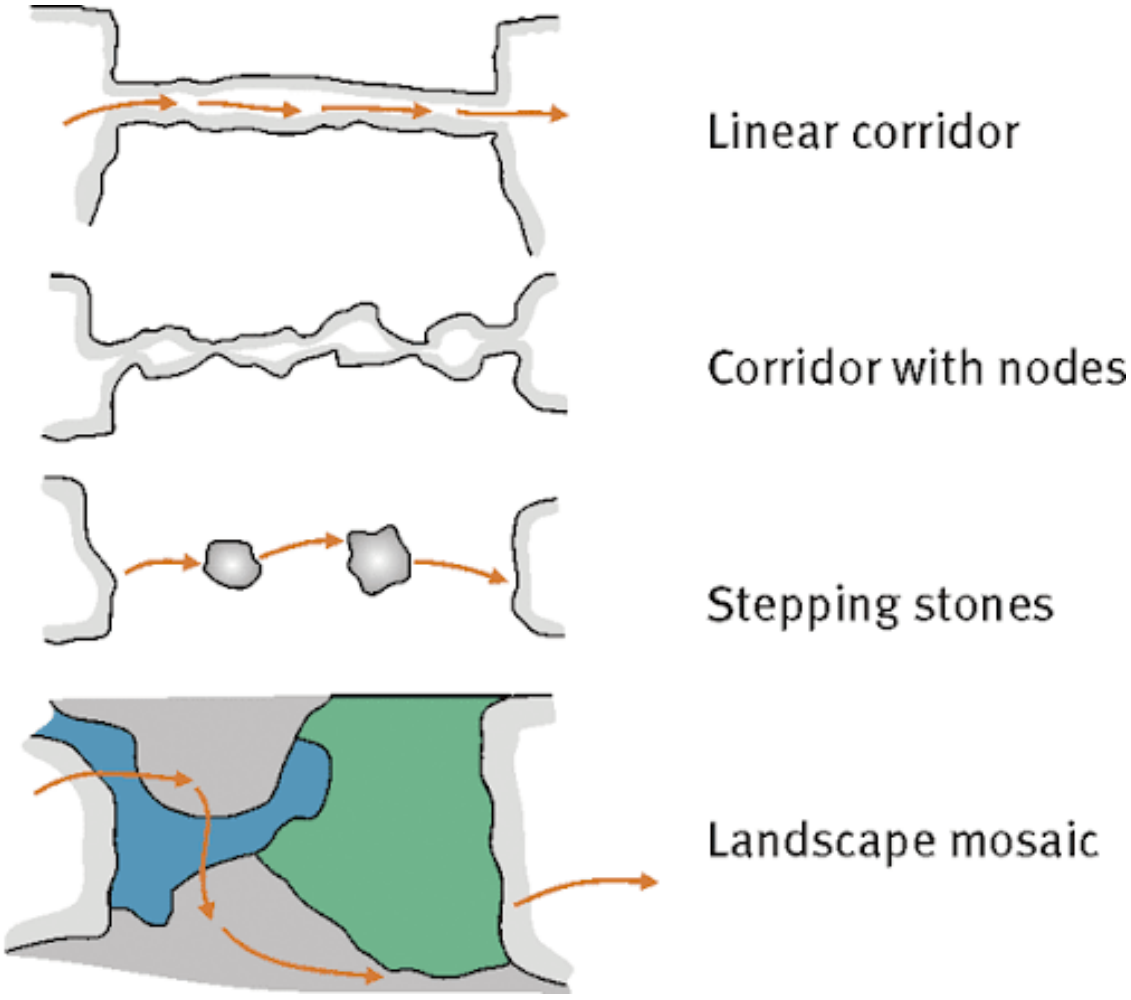


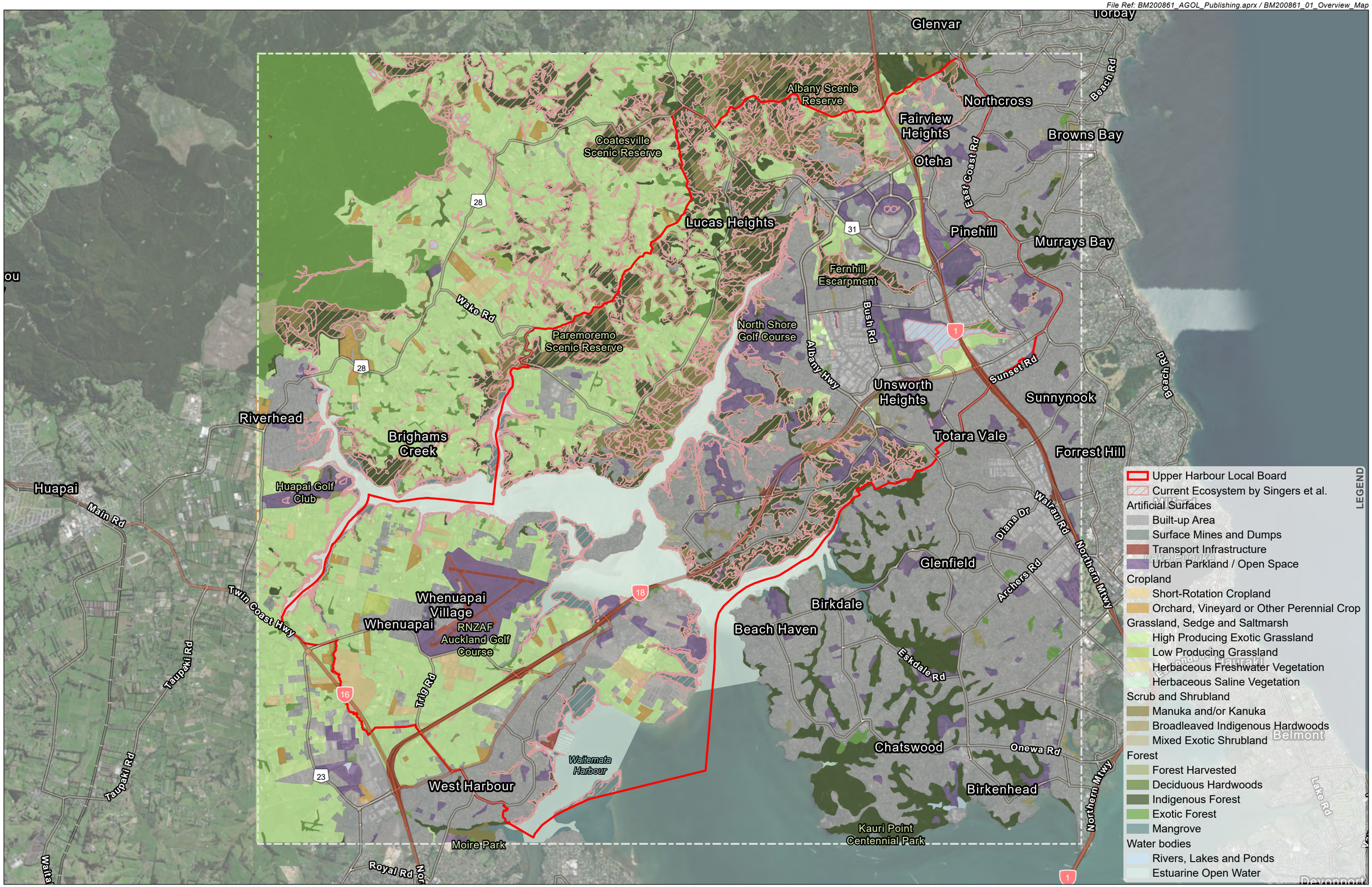
Fig. 1. Four main methods of connecting habitat patches to facilitate animal movement. Image from Berges et al. (2010).

Umbrella species

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.

The concept of umbrella species is widely used to help guide and prioritise conservation management. Umbrella species are often conservation priorities (e.g. endemic threatened species), or species for which conservation actions undertaken to protect them will benefit a wide range of other species and the ecosystems in which they inhabit.

This Strategy for Upper Harbour has been developed with the aid of connectivity analyses undertaken for key umbrella species selected based on ecological justification, and alongside mana whenua, community, and council to align with local priorities.



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

Projection: NZGD 2000 New Zealand Transverse Mercator

UPPER HARBOUR ECOLOGICAL CONNECTIVITY STRATEGY

Overview Map

Date: 07 July 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate.Heaphy@boffamiskell.co.nz | Drawn: SGa | Checked: KHe

Map 1

2 Strategy objectives

Strategy objectives

Multiple community and council-led projects are already underway to help protect and enhance biodiversity. The Upper Harbour Local Board funded the development of this Ecological Connectivity Strategy to help achieve landscape-scale ecological restoration and connectivity and maximise the efforts of these conservation groups.

This Strategy aims to help inform community groups and Council where conservation activity could be prioritised across the Upper Harbour landscape to achieve effective landscape-scale ecological restoration and connectivity, with four key objectives:

1. **Map** and **describe** areas of high ecological value within the Upper Harbour district;
2. **Identify** gaps and **evaluate** opportunities to protect, enhance, connect, and extend existing valuable habitats, conservation areas, habitat corridors and ecological connections;
3. **Prioritise** areas for management with recommended management techniques; and
4. **Enable** mana whenua, communities, Council, and other agencies to work together to achieve conservation outcomes.

Note this Strategy focusses primarily on enhancing the connectivity of forest, wetland, and estuarine ecosystems. Many other native habitats and species in Upper Harbour are also threatened, and require conservation action to improve their quality and connectivity, including streams and rivers. The current Strategy provides a starting point for guiding effective conservation action, with potential for other species (such as kauri snail and inanga) and ecosystems (e.g. rivers and streams) to be added in future.

Link with existing conservation groups and strategies

This Strategy is designed to align with, and help further, the multiple existing conservation initiatives and strategies present in Upper Harbour. These include:

- The North-West Wildlink;
- The Urban Ngahere Strategy;
- The Upper Harbour Open Space Network Plan (UHOSNP); and
- Community groups, including those that are part of the Upper Harbour Ecology Network (UHEN).

The North-West Wildlink is an initiative to connect nature across North-West Auckland via a pest-free vegetation corridor of stepping stone habitats, from Tiritiri Matangi to the Waitakere Ranges. The diverse Partnership Group includes Auckland Council, the Department of Conservation (DOC), Forest and Bird, the QEII National Trust, and multiple other community and non-profit groups.

Given its central location, Upper Harbour has multiple large reserves and habitat patches that play an important role in the North-West Wildlink (Fig. 2). These areas include Pāremoremo Scenic Reserve, Lucas Creek Scenic Reserve, Redfern Nature Reserve, Kereru Reserve and Gills Reserve and Oteha Scenic Reserve, which all form ecological corridors used by tui in transit from Tiritiri Matangi to the west coast and Goldie's Bush (as

recorded from banded birds; Auckland Council, n.d.). Kaka have also been tracked from the Gulf Islands across Pāremoremo to Riverhead Forest and South Head. These corridors form crucial links within the wider North-West Wildlink.

'Wildlink Wonders' are areas with key biodiversity values such as food sources, safe refuges or breeding areas that are vital for the wildlife to survive in a fragmented landscape that were identified as important stepping stones in the North-West Wildlink. A number of council-owned parks were classified as 'Wildlink Wonders', namely: Burnside Reserve, Fernhill Escarpment and Oteha Stream esplanades (Albany); Hellyers Creek Reserve, Kereru Reserve and Taihinui Reserve (Greenhithe); Hosking Reserve and Lucas Creek west bank escarpment (Lucas Heights) and Pāremoremo (Pāremoremo Scenic Reserve).

Fig. 2. The North-West Wildlink, stretching from Tiritiri Matangi to Arc in the Park in the Waitakere Ranges.

Auckland's Urban Ngahere (Forest) Strategy has the vision Auckland's urban ngahere for a flourishing future, which includes increasing canopy cover across Auckland's urban area and improving linkages between green spaces by establishing ecological corridors. The nine key principals of the Urban Ngahere Strategy are:

1. Right tree in the right place;
2. Preference for native species;
3. Ensure urban forest diversity;
4. Protect mature, healthy trees;
5. Create ecological corridors and connections;

6. Access for all residents;
7. Manage urban forest on public and private land; and
8. Deploy regulatory and non-regulatory tools.
9. Manage the whole lifecycle of urban trees

This Connectivity Strategy has been developed to align with these nine principals and become a tool to help further the objectives of the Urban Ngahere Strategy to know, to grow, and to protect Auckland's urban ngahere.

The Upper Harbour Open Space Network Plan (UHOSNP) provides the framework for prioritising actions for future development of the Upper Harbour open space network over the next 10 years (Auckland Council, 2018). It aims to deliver a sustainable open space network, and address issues impacting on local parks including inundation, erosion, and the pressure from population growth. The UHOSNP also links in with the Upper Harbour Greenways Plan seeks to create a greenways network that links to the circulation networks on land and water (Fig. 3).

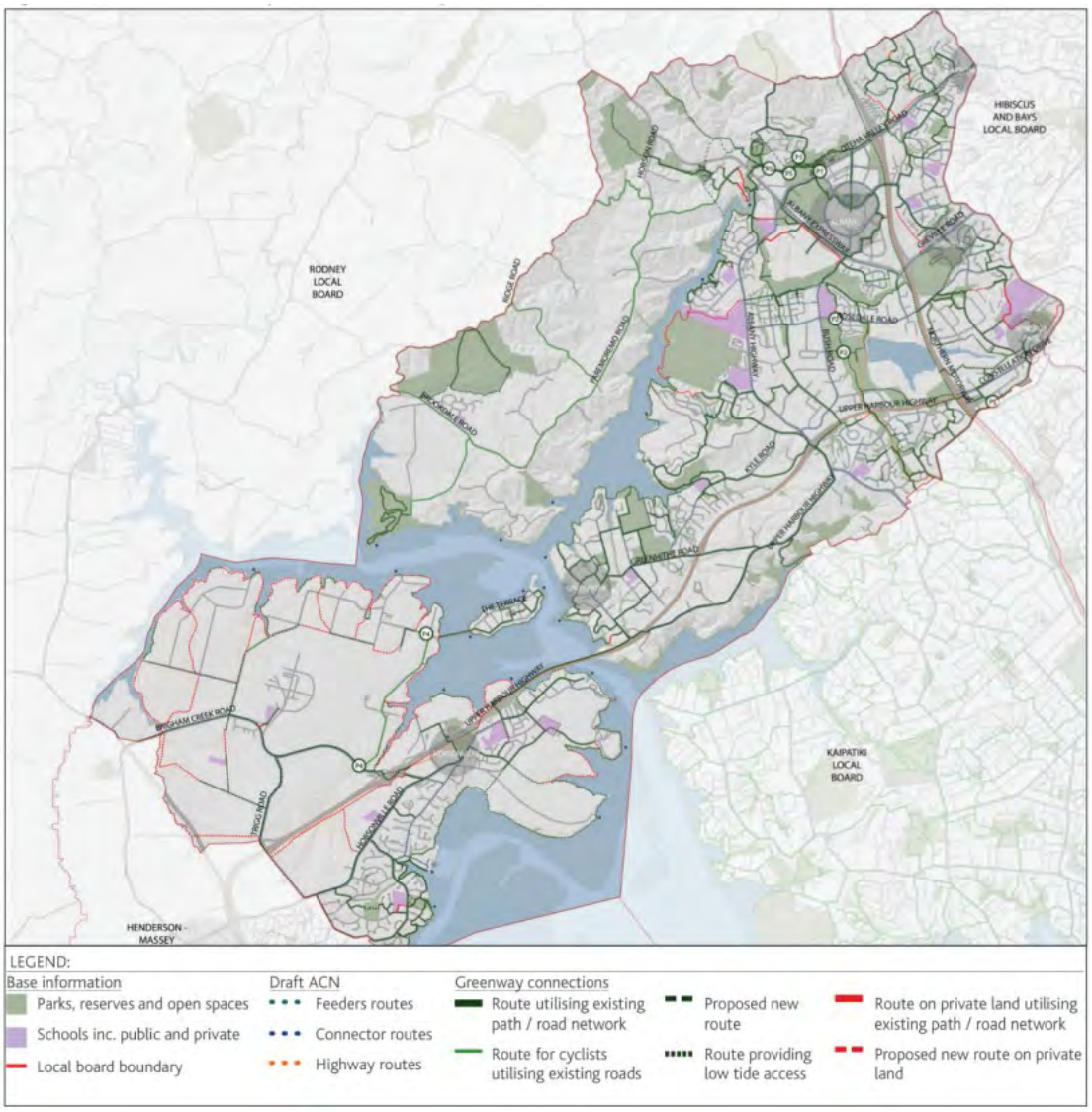


Fig. 3. Upper Harbour Greenway Plan with Auckland Cycle Network. From the Upper Harbour OpenSpace Network Plan (Auckland Council, 2018).

The Upper Harbour Ecology Network is a consortium of local community groups with the collective vision to *"...be an effective and sustainable network that is valued by its members and other stakeholders and acknowledged widely as a force for environmental restoration and enhancement of the Upper Harbour area*" (Upper Harbour Ecology Network, 2020). Their objectives include "*to be an advocate and champion for the Upper Harbour ecology and its role in the North-West Wildlink*" and "*to create and leverage greater environmental impact through the synergistic activities of its members*".

This Strategy has been designed to provide a local level of ecological connectivity information within the Upper Harbour Local Board area, identifying specific areas and management actions that align with these existing documents, to help support and achieve the environmental objectives of existing strategies and groups.

3 How to use the Strategy

Ways to use the Strategy

The Strategy comprises this written report and an accompanying interactive online StoryMap (Fig. 3). The online StoryMap contains an Interactive Map Viewer, where users can select different layers and zoom in on their areas of interest to see the key areas and linkages for the different 'umbrella' species and the ecosystems they inhabit.

This Strategy is a tool to help groups and organisations strategically plan and prioritise conservation actions to improve ecological connectivity. It allows groups to be more specific around the ecosystems and species they are protecting, and maximise the benefits of limited resources (e.g. time and funding) through prioritising areas for management. It can also be used to demonstrate to stakeholders and potential funders how their actions benefit biodiversity as part of a much larger landscape-scale effort.

There are four main ways to use this Strategy, discussed din more detail below:

1. *Where* – To identify areas for conservation action
2. *What* – To identify conservation actions in a particular area
3. *Who* – To identify surrounding conservation groups and engage with mana whenua where required
4. *How and why* – To aid funding applications and gain support

This Strategy is designed to align with, and be used in conjunction with, existing high priority areas for conservation and other Auckland Council strategic documents, including Significant Ecological Areas, Biodiversity Focus Areas, the Upper Harbour Green Pathways Plan, and the Urban Ngāhere Strategy.

This Strategy is based on a snapshot of ecological connectivity in Upper Harbour as at June 2021, and provides a local level of information to inform Auckland Council's Tiaki Tāmaki Makaurau website. Refer to the Tiaki Tāmaki Makaurau website for up-to-date conservation information and maps, including updated community group locations.

1. Identifying priority areas

Ideally, conservation actions (in particular predator and pest plant control) should be undertaken across the full extent of Upper Harbour for maximum biodiversity benefit. However, given limited resources (e.g. time and money) recommended priorities have been identified for each ecosystem.

Refer to the table of recommended management priorities in the Management Actions section. Use this table alongside the Interactive Map (see menu across top of page), which contains all relevant maps, to identify priority areas for management. Different map layers can be turned on and zoomed-in on to provide different information:

- Priority areas (as listed in the table) can be seen by viewing Core Habitats for each ecosystem (forests, wetlands, and estuarine margin). Given limited resources, Core Habitats with the highest

number of connections can be prioritised (Core Habitats are colour-coded by number of connections).

- Core Habitats can also be prioritised by those that contain SEAs, BFAs, and Wildlink Wonders (click on any Core Habitats of interest to see to see its number of connections, and whether it contains an SEA, BFA, and/or a Wildlink Wonder). The SEA, BFA, and Wildlink Wonders layers (listed under 'Land Cover Layers') can also be turned on to overlay Core Habitats in the Interactive Map.
- Linkages between Core Habitats (the second Priority Objective for forest ecosystems) can be seen by clicking on the Least Cost Paths (LCPs) layer for each ecosystem. Actions to improve connectivity should be undertaken within a buffer either side of these linkages, which can be viewed in the LCP buffers layer.
- Areas currently of high resistance (the third Priority Objective for forest ecosystems) can be viewed by clicking on the Cost Weighted Distance (CWD) layer.

2. Identifying recommended actions

Refer to the table in the Management Actions Summary section for a list of recommended management actions within each prioritised area, for each ecosystem. The Management Actions section contains more detail and practical advice on undertaking the recommended actions. A range of resources are also provided in the Useful Links sections.

A section is also included on planning and delivering projects effectively, which includes a flow diagram on defining the goal/objective, selecting an area and action(s), and measures of success. Note the selected 'umbrella species' for each ecosystem are not necessarily 'indicator species' of the success of management actions. As it is not possible to model connectivity for all species, umbrella species were those selected to represent broad ecosystem types, and actions undertaken to protect the modelled habitats will have overarching benefits for both the ecosystem and the many other species that inhabit it. Depending on the project, other indicators could include brown teal/pāteke for wetland health, or inanga for freshwater habitats.

3. Identifying surrounding conservation groups

Community groups are shown on the Interactive Map, as at June 2021. This shows how existing, new, or potential conservation groups and projects are (or could) contribute to connectivity in the wider region. Refer to the Tiaki Tāmaki Makaurau / Conservation Auckland website for up-to-date information on group locations, such as if you are considering expansion or alignment of groups/projects; or to identify where there are gaps that need conservation action.

All conservation projects are encouraged to add their project to the Auckland Council database, by filling out the survey form in the Add a Project section.

4. Aid funding applications and gain support

This Strategy is a powerful engagement and communication tool for community groups and conservation organisations to learn about areas of interest and adopt a wider landscape-scale perspective.

If you are applying for funding to support conservation work, or trying to rally your community, you are able to take screenshots of the relevant map layers and adapt wording from anywhere in this Strategy document to create project-specific goals and communicate the wider benefits (e.g. by demonstrating that pest control in even a small local reserve is beneficial to provide a stepping-stone habitat).

The Strategy aims to empower people to know more about their site of interest to contribute to the bigger picture, and identify the environmental impacts of their work (e.g. protecting endangered ecosystems, protecting habitat for endangered and/or native species, improve landscape connectivity, with a focus on the bigger picture).

When preparing a funding application, groups can use this Strategy to be more specific about the ecosystem(s) and/or species they are protecting, and the ecological function they are restoring (e.g. providing connectivity for species currently there such as kereru, and species that will require high levels of effort before they may be more readily observed, such as matuku, pekapeka-tou-roa and tomtit).

Who can use the Strategy?

Auckland Council: This Strategy can help to inform and guide where Council-led environmental management should take place to achieve landscape-scale restoration objectives. It can be used to engage with new and existing conservation groups, and ensure a cohesive approach to get the maximum biodiversity benefit from available resources.

Upper Harbour Local Board: This Strategy is a tool that can be used by the Local Board to inform environmental investment in Local Parks. This includes identifying strategic projects for funding that work towards achieving landscape connectivity and facilitate communication between the Local Board, community, and Council. Refer to the table of recommended management objectives and areas for an ordered list of priorities, that can be used to compare proposed conservation projects for funding.

Existing community conservation groups: This Strategy can be used to strategically expand conservation activities, apply for funding, and effectively communicate the groups' objectives by identifying priority areas and specific actions within those priority areas. It can also be used to inform funding applications by demonstrating the impact of the proposed conservation work and its landscape-scale biodiversity benefits.

New community conservation groups: This Strategy can be used to plan strategic conservation activities, support funding applications, and gain volunteer support, by identifying priority areas and specific actions within those priority areas, with objectives that incorporate a landscape-scale approach. When beginning or expanding activity in a new area, first look at removing core pressures on core habitats, and add the project to the to the Auckland Council database. Volunteers can use the directory on the Tiaki Tāmaki Makaurau / Conservation Auckland website to identify nearby groups to join or contact.

How to navigate the online StoryMap

The online StoryMap presents the results of the connectivity analyses and the management recommendations alongside interactive maps that users can explore. The StoryMap structure therefore differs slightly from this written report, with five main sections:

Overview

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

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 for each umbrella species, including habitat maps, resistance heat maps and linkages

Management Actions

- Overall Connectivity Models (compiled maps) for forest, coastal estuarine and wetland ecosystems, with a summary table of management priority areas and actions for each ecosystem.
- Table of recommended management priorities for each ecosystem, including priority objectives and areas
- Recommends management actions and provides some high-level guidance on how to deliver efficient:
    - Pest animal control;
    - Pest plant control;
    - Buffer planting (forest, riparian and wetland margins);
    - Creating and enhancing forest habitat;
    - Utilising transport infrastructure as ecological corridors; and
    - Planning and delivering projects to improve connectivity (with flow diagram).

Interactive Map

- An Interactive Map Viewer with the key map layers, which users can select and explore. Includes landcover and protected area layers used in the development of the Strategy, as well as the results of the connectivity analyses and the overall prioritised Forest, Coastal Estuarine and Wetland Connectivity Models (option to open and explore layers in a new window)

Useful Links

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

4 Connectivity analysis methods

'Umbrella species' selected for analysis

To develop connectivity models, four 'umbrella species' were selected for analysis:

- **Kererū** (NZ woodpigeon) – forest ecosystems
- **Matuku** (Australasian bittern) – wetland ecosystems
- **Mohu-pererū** (banded rail) – estuarine ecosystems
- **Pekapeka-tou-roa** (long-tailed bat) – mature trees/forest habitat

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 plays a valuable role in providing different ecosystem services.

Birds were selected to act as the primary 'umbrella' species for the native terrestrial ecosystems in Upper Harbour 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).

Note bats were also used as an umbrella species given their utility as indicators of tall, mature tree and forest ecosystems. Maps of their habitat are included as a focus of this Strategy, however, a connectivity analysis using Linkage Mapper was not undertaken for bats due to the reasons listed for bats below.

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 kererū uses the maximum home range size, while that for pekapeka-tou-roa assumes even individual trees may provide potential important habitat).

	Kererū	Matuku	Mohu-pererū	Pekapeka-tou-roa
Habitat type	Forest	Wetlands	Estuaries	Mature/tall trees
Min. patch size	2 ha	0.2 ha	0.5 ha	0 ha (all potential habitat)
Max. dispersal distance	4,620 m	1,280 m	200 m	19 km

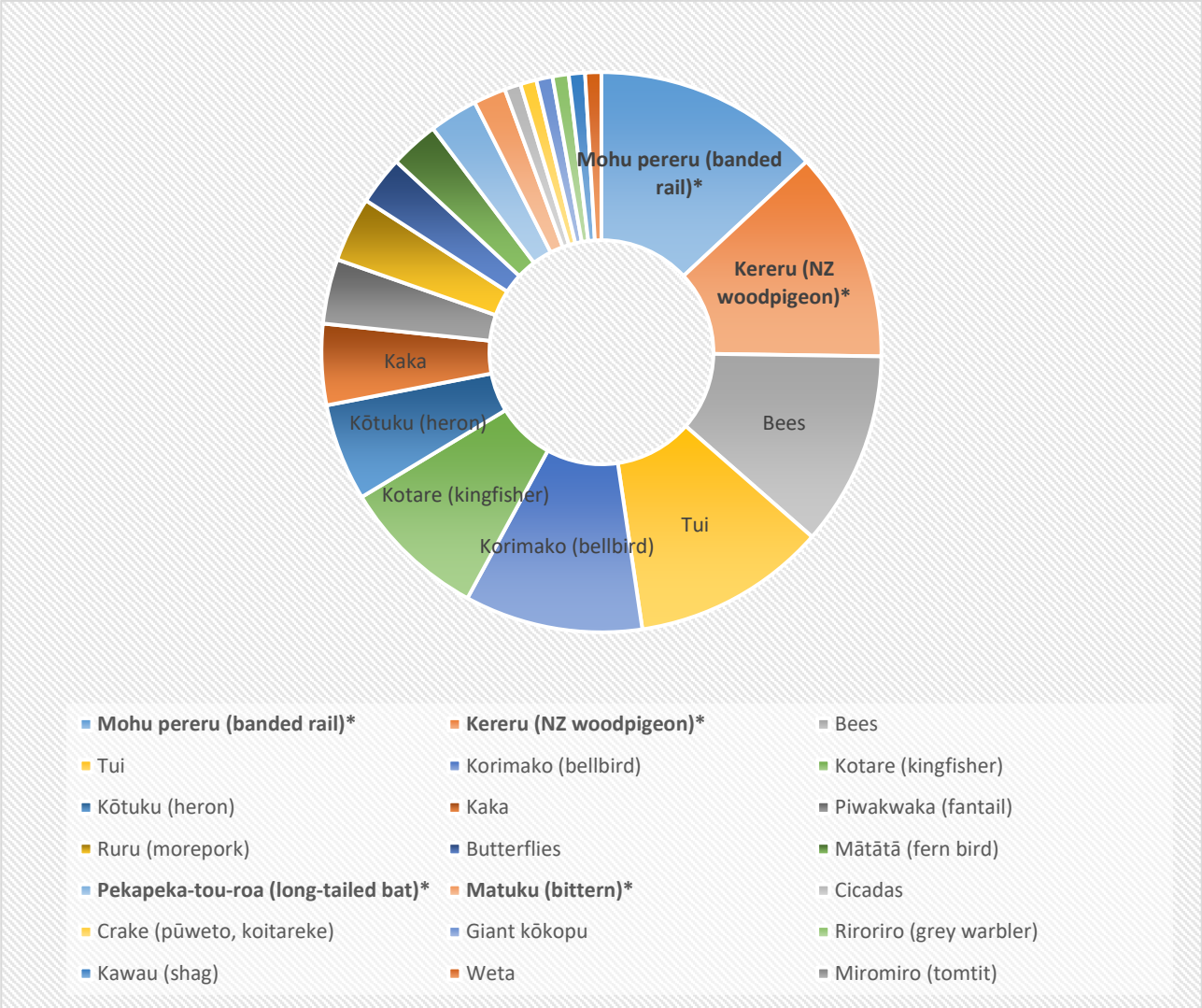


Fig. 4. Results of the online community survey undertaken in February 2020, showing the comparative number of votes for native terrestrial fauna species. The four species in bold with asterisks are those used as umbrella species. The legend is ordered from highest to lowest number of votes, reading from left to right. The first eight species are also named on the diagram.

Kererū

Kererū (New Zealand woodpigeon; *Hemiphaga novaeseelandiae*) are generalist frugivores (fruit-eaters), and play a vital role in dispersing seeds of native fruiting species. Since the extinction of moa and other large birds (and range restriction of others), they are now the only fruit-eater large enough to swallow fruit with large seeds such as tawa, miro, karaka, taraire, and nikau. They are typically found in patches of native bush where food is available.

Kererū have relatively high mobility, and utilise small patches of a minimum 1-2 ha within much larger home ranges (~20 ha). Their maximum movement distance used to inform the connectivity analysis was taken to be 4,620 m, their maximum reported pasture crossing distance. The main threats for kererū are predation, habitat loss, and competition for food

(mainly from possums). Their conservation status is Not Threatened (Robertson et al., 2017).

These attributes can make kererū an ideal ‘umbrella’ species for forest ecosystems and a good indicator of effectiveness of management actions, such as predator control and planting additional native fruiting trees (providing that good baseline and subsequent trend data is obtained).

Matuku

Matuku (Australian bittern; *Botaurus poiciloptilus*) are a cryptic (hard to find) predominantly wetland bird, included in this Strategy to capture the connectivity of important wetland and freshwater habitats. They can be found in a range of freshwater to semi-salty environments (including farm drains and wetland/farmland edges, as well as brackish riverine, estuarine, palustrine, and lacustrine habitats).

Their minimum core habitat patch size is estimated at 0.1 ha for the connectivity analysis, but they may make use of even smaller patches within a much larger home range. Most movements are typically short, averaging 287 m per day in one study, with the maximum daily distance travelled of 1,280 m used in the analysis. The main threats to matuku are the continued habitat loss, habitat degradation, and predation by introduced mammals.

Their distribution 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. Maintaining connectivity among these habitats is crucial for this species with a conservation status of Nationally Critical (Robertson et al., 2017).

Mohu-pererū

Mohu-pererū (banded rail; *Gallirallus philippensis*) are a cryptic (hard to find) bird found in coastal wetlands, mangroves, and saltmarshes. They feed on crustaceans, insects, and worms; as well as dead fish, seeds, eggs, and fruit when available.

Although they are not often seen, mohu-pererū may be spotted in open areas less than 10 m from dense cover, or up to 280 m on tidal flats with mangroves. They have been found in even small habitat patches of 0.01 ha. The main threats of mohu-pererū are main threats are predation and clearance / drainage of wetlands and estuaries (also associated with grazing, water pollution, water take and coastal development). Their conservation status is At Risk – Declining (Robertson et al., 2017).

This species is a potential indicator of wetland health because they are dependent on the presence of high quality and ecologically diverse habitats and rich food supplies. Mohu-pererū have disappeared from much of New Zealand since the 1970s, and require management actions including protection of habitat and predator control.

The Rail Trail is a recent community initiative that links predator control efforts around the Upper Harbour coastline. The aim of the Rail Trail is to aim is to bring back mohu-pererū and other shore birds to the coastline of the Upper Waitematā Harbour, and is a

collaboration between existing predator control groups that are all members of the Upper Harbour Ecology Network.

Pekapeka-tou-roa

Pekapeka-tou-roa (North Island subspecies of long-tailed bat; *Chalinolobus tuberculata*) 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.

Their preferred natural habitat is mature forest with many tall, hollow trees, but they may forage over both indigenous and exotic forests (including plantation forest), open ground and cutover forest. All habitat types with the potential to contain mature, tall-stature trees were considered potentially important habitat, including even small patches or individual trees. The main threats of pekapeka-tou-roa include habitat loss and degradation associated with land development, the felling of roost trees, and predation by cats, mustelids (particularly stoats), possums and rats.

Bats are able to fly large distances and commonly forage along linear features in the landscape (e.g. shelter belts). However, there is little information about how this species disperses or uses habitat patches in the landscape, especially within the Auckland region. With a conservation status of Threatened – Nationally Critical (O'Donnell et al., 2018), maintaining and enhancing ecological connectivity is crucial for the survival of New Zealand's only native land mammal.

Conducting a connectivity analysis using Linkage Mapper was considered unlikely to provide robust or reliable results, given the large number of potential habitat patches identified, limits of mapping accuracy to the required level of detail (i.e. to individual tree level), and limited knowledge about bat movements in the Auckland region. Instead, a habitat suitability map was created, with no minimum patch size specified, as a starting point for ongoing research and conservation actions. This map can be used to help identify potential areas for monitoring, restoration, and protection.

Linkage Mapper software

Habitat connectivity was analysed for the selected umbrella species using the software Linkage Mapper. The two main model inputs for each species are 1) core habitat areas, and 2) a resistance surface (a map that depicts how hard it is for a given species to move across the landscape). 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 of the analysis include linkages between core habitats based on the least-cost paths and dispersal distance of each species. These linkages are used to help identify and prioritise areas for conservation action.

Data sources

Key data sources used in the development of the Strategy included:

- **Landcover** – The landcover used to map core habitats of the selected umbrella species is a combination of both the 36 ecosystem types of Auckland (Singers et al., 2017) and the New Zealand Landcover Database.
- **Community Project Areas** – The many community groups projects shown here are those that have been registered with Auckland Council. To add your own project to Auckland Council's Tiaki Tāmaki Makaurau Conservation Map, fill out the form in the Add a Project section of this Strategy.
- **Land tenure** – Maps of Auckland Council land, DOC land, Significant Ecological Areas (SEAs) and Biodiversity Focus Areas (BFAs) were used to help identify existing areas of value, management, and priority. BFAs are Auckland Council's identified priority sites, and only those on public land are shown here.
- **Habitat features** – Maps of roads (classified by speed limit), waterways were also used to tailor the connectivity analysis and/or management recommendations depending on the species.
- **Existing reports and strategies** – Key documents used included the North-West Wildlink Prioritisation report (Boffa Miskell, 2017), Auckland Council's Urban Ngahere Strategy (Auckland Council, 2019) and the Upper Harbour Open Space Network Plan (UHOSNP; Auckland Council, 2018). Management recommendations for forest ecosystems were also aligned with existing Auckland Council reserve prioritisation (as per the Auckland Council prioritisation matrix in Appendix 1; Auckland Council, n.d.).

Data inputs

Data inputs for each connectivity analysis in Linkage Mapper included:

- **Landcover map** (a map of existing habitat types)**.** A base land cover map was created to determine the location and extent of different land cover and habitat types across Upper Harbour (8,276 ha). This included the Current Ecosystem Extent layer from Auckland Council, based on Singers' terrestrial ecosystem types of Auckland, combined with the New Zealand Landcover Database (NZLCDB). The study area was clipped to a rectangular box that encompasses all of the Upper Harbour local board area (area of land within box = 19,619 ha) to ensure all pixels are square and the same size, and ensure 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.
- **Core habitats** (a map of the key habitat patches for each umbrella species that Linkage Mapper tries to connect). 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, using a scale from 0 - 100 was used 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).
- **Resistance layers** (a pixelated map showing how difficult it is for each umbrella species to move through each pixel based on the underlaying habitat type). To create the resistance raster layer input for Linkage Mapper for kererū, resistance values were assigned to each pixel for each species based on the inverse of the final habitat suitability value for (range 1-100). To create the resistance raster layer input for matuku and mohu-pererū**,** values were assigned to each pixel based on the habitat suitability values used to map the core habitats, using an exponential scale (range 1 – 32). The exponential scale provides greater distinction between areas of different resistance, and thus reflect stronger habitat preferences of these species than kererū. Landscape features were then incorporated into the analysis by either increasing or decreasing the habitat suitability value or

resistance value as deemed ecologically appropriate (e.g. reducing resistance for SEAs; increasing resistance with 50 m of a road based on speed limit).

Connectivity analysis outputs

The outputs of the analysis include linkages between core habitats based on the least-cost paths and dispersal distance of each species. These linkages are used to help identify and prioritise areas for conservation action.

Maps for each umbrella species include:

- **Core Habitats** – A primary model input, which shows patches of suitable habitat for each umbrella species. For this analysis, Core Habitats are defined as areas equal or greater to the minimum home range size or minimum patch size for that species. These large patches are priority areas for protection, enhancement, and connection.
- **Other Suitable Habitats** – Areas of suitable habitat smaller than Core Habitats (i.e. areas that are smaller than the minimum home range or patch size for that species). These smaller areas play an important role in connectivity, potentially offering stepping stone habitats between Core Habitats and seasonal food resources. These areas would benefit from protection and enhancement, especially those within the buffers around the Least Cost Paths.
- **Least Cost Paths (LCPs) and buffers** – A key model output, which shows the path of least resistance (easiest movement) between core habitats, based on the Resistance Surface. Yellow lines indicate current linkages within the estimated maximum dispersal distance. Pink lines show potential linkages, currently beyond the estimated maximum dispersal distance. Management actions to improve connectivity should focus efforts within the buffers shown either side of least-cost paths (200 m for kererū and matuku; 100 m for mohu-pererū).
- **Core Habitat Connections** – These are straight-line connections between adjacent Core Habitats, shown on the maps as white dotted lines. Unlike the Least Cost Paths, these lines show connections without the influence of the Resistance Surface (depicting the underlying habitat type and landscape features such as roads).
- **Cost-Weighted Distance (CWD)** – Shows the movement resistance accumulated (i.e. total movement difficulty) as the species move away from Core Habitats. Blue areas are closer to Core Habitats and are therefore easiest to traverse, followed by yellow and then red areas, which are furthest away from any Core Habitat.
- **Resistance Surface** – A primary model input, which shows how easy (or hard) it is for the umbrella species to move between Core Habitats, based on the underlying habitat type and landscape features (e.g. roads). Areas that are currently difficult for that species to move through are shown in black, which should be the focus of conservation actions aiming to increase connectivity, while areas that are easier to move through are shown in white.

5 Results of the connectivity analysis

Overview

The connectivity analyses identified the current gaps and pinch-points of functional connectivity for kererū in forest ecosystems and for matuku in freshwater/wetland ecosystems across Upper Harbour.

The results of the kererū, matuku and mohu-pererū connectivity analyses are shown in Maps 2-4 as a connectivity model for forest, wetland, and estuarine ecosystems respectively. A more comprehensive selection of these connectivity maps for each umbrella species, as well as for pekapeka-tou-roa are also provided in print form in Appendix 2. It is recommended these maps are explored on the online StoryMap, where users are able to zoom in on particular areas and select their layers of interest.

A summary of the number and area of core habitats identified for each species (within their respective study areas), and the number of linkages identified during the connectivity analyses, is provided in Table 2, upon which the large-scale connectivity ecosystem connectivity across Upper Harbour was modelled.

Table 2. Number of core habitat patches and their total area, and number of linkages for each of the four umbrella species, based on the Linkage Mapper connectivity analyses. Dispersal distances for each species are provided in Table 1.

	Kererū	Matuku	Mohu-pererū	Pekapeka-tou-roa
No. core habitat patches	125	107	145	-
Area of core habitat	4,625 ha	45.4 ha	424.4 ha	-
No. all suitable habitat patches	323	390	145	348
Area of all suitable habitat patches	4,827.3 ha	57.3 ha	424.4 ha	3852.6 ha
No. linkages identified *within* dispersal distance	249	167	189	-
No. linkages identified *beyond* dispersal distance	-	69	70	-

6 Recommended management actions

Overall management approach

This section outlines recommended management areas and actions based on the connectivity models developed for forest, wetland, and estuarine margin ecosystems (Maps 2, 3 and 4, with interactive maps available on the online StoryMap).

Table 3 summarises the priority objectives, areas, and actions recommended for each ecosystem, numbered in order of priority if resources (time and money) are limited:

- Forest ecosystems are extensive, but fragmented through Upper Harbour. They require a three-pronged approach to effectively enhance connectivity; protect high priority core habitats (linking in with the Wildlink Wonders of the North-West Wildlink; Boffa Miskell, 2017), enhance linkages between core habitats, and increase the ease of movement in areas undergoing rapid development and urbanisation (linking in with the Urban Ngahere Strategy).
- The extensive estuarine margin in Upper Harbour is crucial habitat for species such as banded rail, and has reasonable levels of existing connectivity. As a priority, management should focus on protecting and enhancing the identified core areas through predator control (rats, stoats, ferrets, weasels, possums, hedgehogs, and unowned cats), disturbance management (in particular of dogs and people), and buffer planting around the edges of core habitats.
- Wetlands are highly fragmented and significantly reduced in extent in Upper Harbour. This is in part due to the intensive development and urbanisation, and in part to the topography that lends itself towards forest and estuarine margin ecosystems. The quality of the habitat data is also highly variable, so mapped core habitats would benefit from on-the-ground verification to identify any important areas for native species prior to extensive management. Within Upper Harbour, forest ecosystems and coastal margins remain a key management priority. Existing wetlands should still be protected and enhanced for their intrinsic values and habitat values for other wetland species prior to creating new areas (in particular for the more connected, less disturbed areas to the north-west of Upper Harbour).

All map layers can also be explored in the Interactive Map (link in the menu bar across the top). Click on individual core habitats to see the habitat number (a unique number identifying each core habitat for ease of communication), the number of core habitat connections (core habitats with a higher number of connections are more important for connectivity), and whether the core habitat contains an SEA, a BFA, and/or a Wildlink Wonder. See the User Guide section for more information on different groups can use the Strategy.

The remainder of this section provides guidance on how to undertake the recommended management actions, namely:

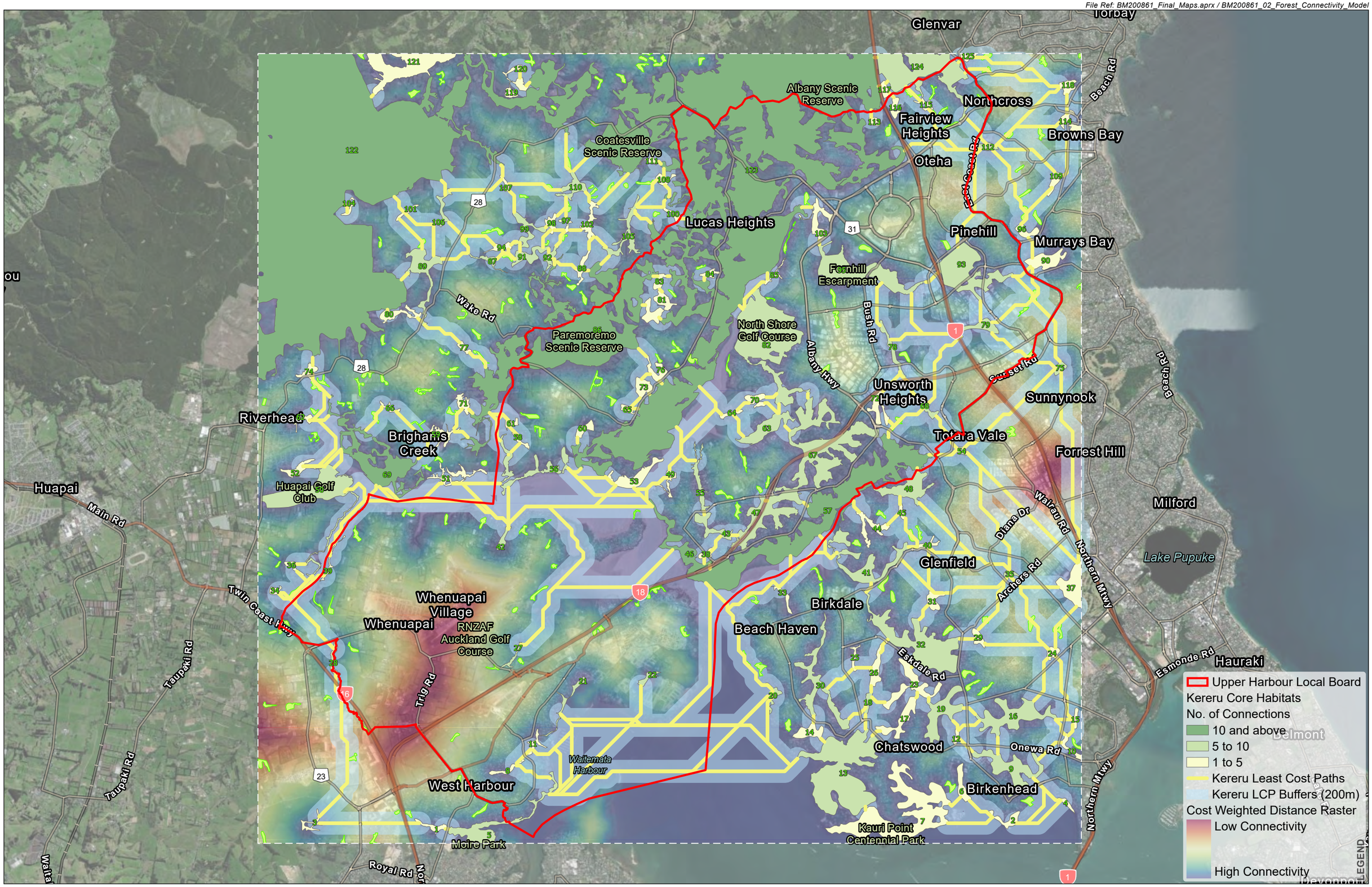
- Mammalian predator control
- Pest plant control
- Buffer planting (forest, riparian, and wetland margins)
- Creating and enhancing forest habitat
- Utilising transport infrastructure as ecological corridors
- Planning and delivering projects to improve ecological connectivity

Table 3. Recommended management priorities, numbered in order of priority for each ecosystem for areas that will most improve connectivity (prioritised by objective, and then area). The highest priority for all ecosystems is to protect Core Habitats by undertaking the priority actions in those areas, and then extend this protection in a buffer zone around each Core Habitat.

Objective	Priority Areas	Priority Actions
Forest ecosystems		
1. Protect and enhance To improve the habitat quality of existing Core Habitats	1. Core Habitats *(from kererū Core Habitats layer, linking with North-West Wildlink wonders and Auckland Council priority parks)* o Prioritise Core Habitats with highest number of connections and those with SEAs, BFAs and/or Wildlink Wonders present o Then prioritise Core Habitats by number of connections (starting with those with the highest number of connections) 2. Buffer zones around each Core Habitat. The size/width depends on the action and desired outcomes (ideally at least 500 m)	• Pest animal control • Pest plant control • Buffer planting around forest patches to increase central habitat area, with less influence from edge effects and less resistance of surrounding landcover type
2. Connect and extend To improve connectivity between core patches (within buffer zone areas around linkages)	3. Within buffers around current linkages between Core Habitats *(yellow linkages on kererū least-cost paths layer)* 4. Within buffers around potential linkages between Core Habitats, which are linkages further than the dispersal distance of the selected umbrella species *(pink linkages on kererū least-cost paths layer)*	• Pest animal control • Pest plant control • Creation and/or enhancement of habitat patches within linkages as stepping stones and to increase ease of movement • Fence and replant riparian margins
3. Create and connect To create new Core Habitats and linkages in areas of high development/ urbanisation	5. Gaps between Core Habitats *(red, and then white areas on kererū CWD layer, linking with the Urban Ngahere Strategy).* In particular, around Hobsonville and Whenuapai (excluding within 500 m of the RNZAF base)	• Pest animal control • Pest plant control • Habitat creation – from individual trees in private gardens to habitat patches in public parks and roadside edges
Wetlands		
1. Protect and enhance To improve the habitat quality of existing Core Habitats	1. Core Habitats *(from Core Habitats layer for matuku)* o Prioritise Core Habitats with highest number of connections and those with SEAs, BFAs and/or Wildlink Wonders present o Then prioritise remaining Core Habitats by number of connections (starting with	• Pest animal control • Pest plant control • Fencing/ stock exclusion • Buffer planting around pond/ wetland margins • Ground-truthing important habitats for native species

	those with the highest number of connections) 2. Buffer zones around each Core Habitat, with the size/width depending on the action and desired outcomes (ideally at least 500 m)	
Estuarine margin		
1. Protect and enhance To improve the habitat quality of existing Core Habitats	1. Core Habitats, prioritised by number of linkages *(from Core Habitats layer for moho-pereū)* o Prioritise Core Habitats with highest number of connections and those with SEAs, BFAs and/or Wildlink Wonders present o Then prioritise remaining Core Habitats by number of connections (starting with those with the highest number of connections) 2. Buffer zones around each Core Habitat, with the size/width depending on the action and desired outcomes (ideally at least 500 m)	• Pest animal control • Pest plant control • Fencing/ stock exclusion • Buffer planting around edges • Disturbance control (in particular from dogs and people)

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. The conservation actions listed below can and should be applied across the full extent of Upper Harbour. The core habitats have also been mapped based on habitat type, and thus include both public and private land. Consent from landowners must be obtained before undertaking any activities on private property.



Boffa Miskell

www.boffamiskell.co.nz

0 1 2 km

1:60,000 @ A3

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

Projection: NZGD 2000 New Zealand Transverse Mercator

UPPER HARBOUR ECOLOGICAL CONNECTIVITY STRATEGY

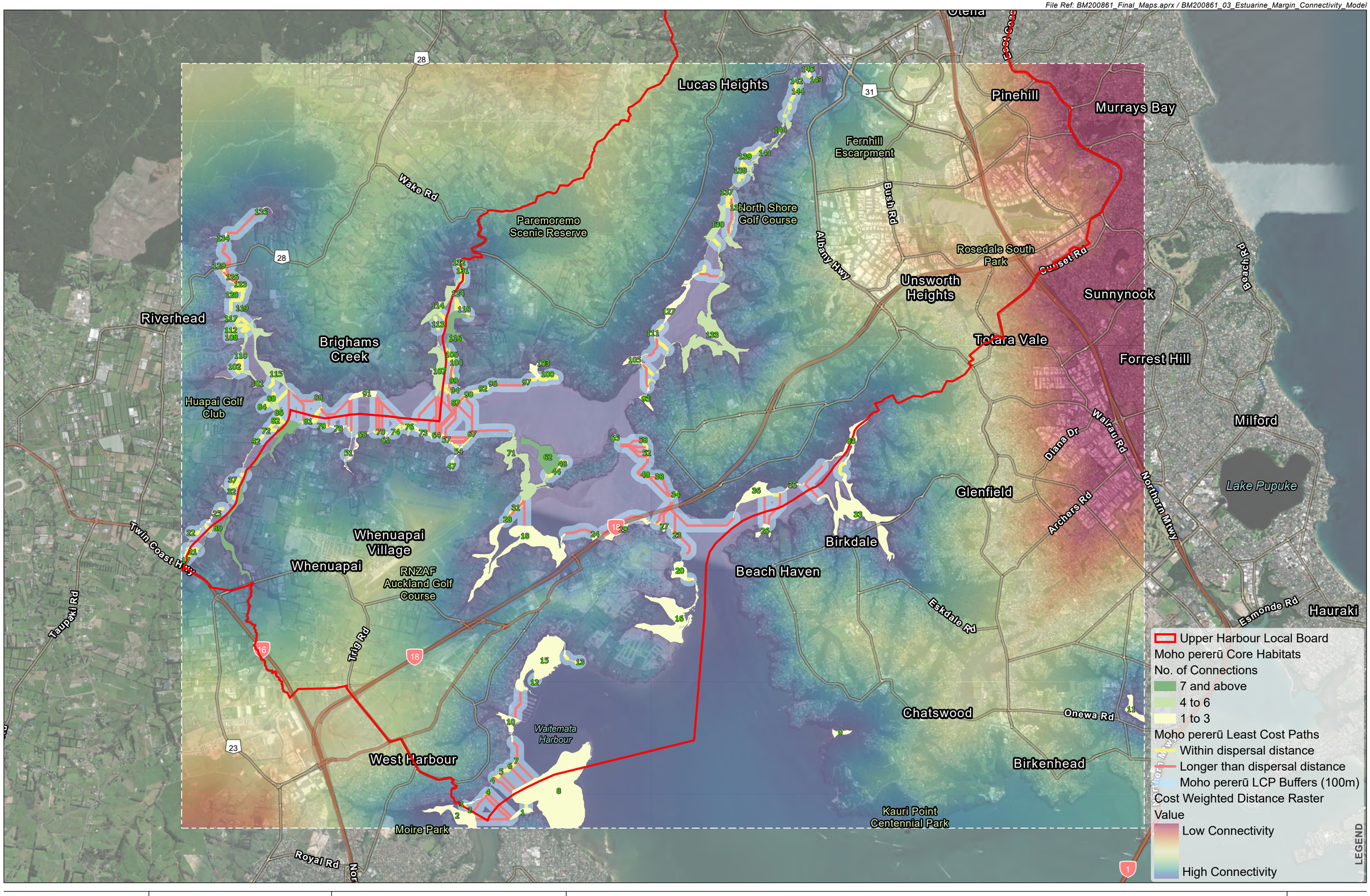
Forest Connectivity Model

Date: 07 July 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate.Heaphy@boffamiskell.co.nz | Drawn: SGa | Checked: KHe

Map 2



Boffa Miskell

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0 1 2 km

1:50,000 @ A3

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

Projection: NZGD 2000 New Zealand Transverse Mercator

UPPER HARBOUR ECOLOGICAL CONNECTIVITY STRATEGY

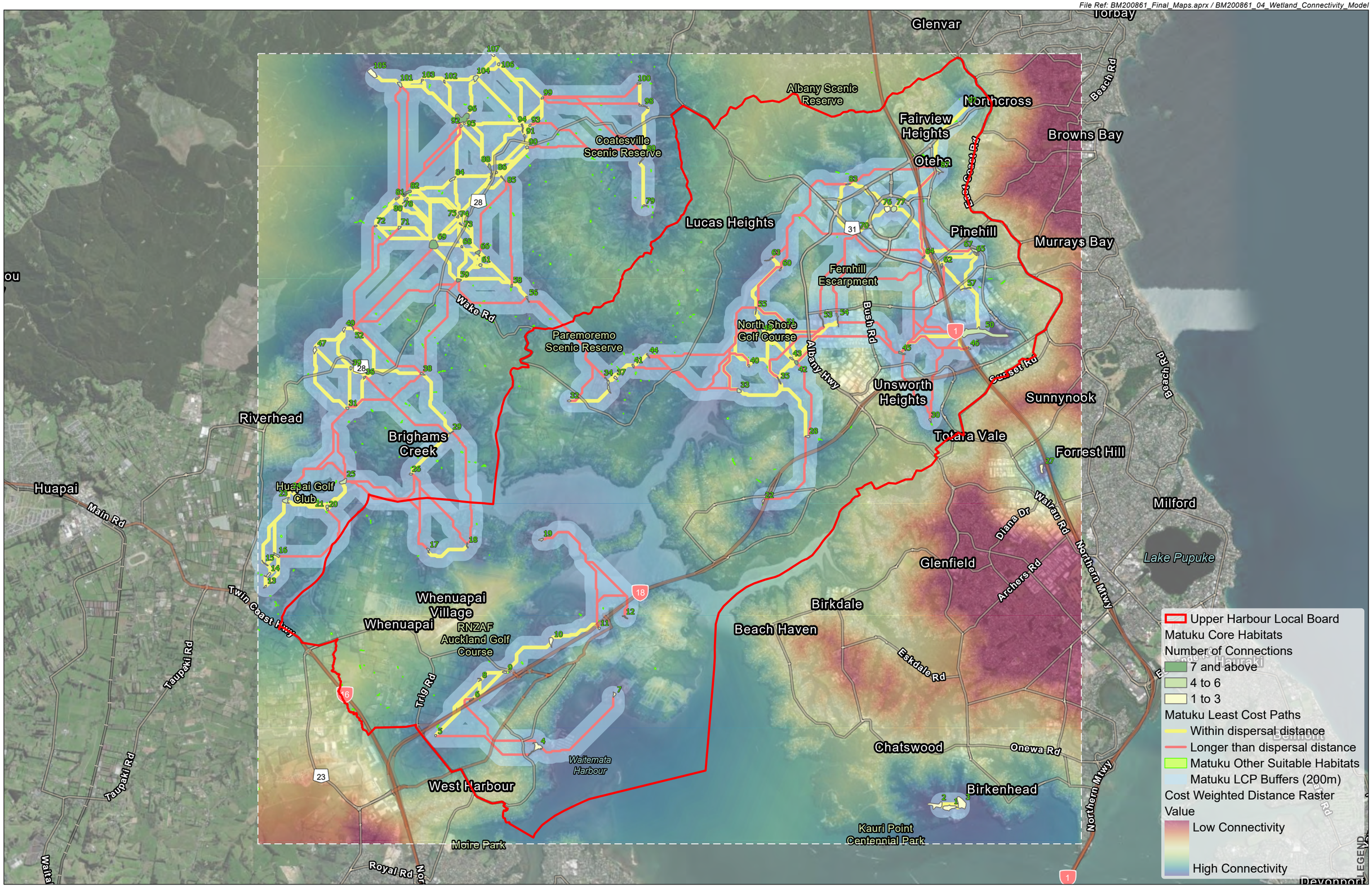
Estuarine Margin Connectivity Model

Date: 07 July 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate.Heaphy@boffamiskell.co.nz | Drawn: SGa | Checked: KHe

Map 3



Boffa Miskell

www.boffamiskell.co.nz

0 1 2 km

1:60,000 @ A3

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

Projection: NZGD 2000 New Zealand Transverse Mercator

UPPER HARBOUR ECOLOGICAL CONNECTIVITY STRATEGY

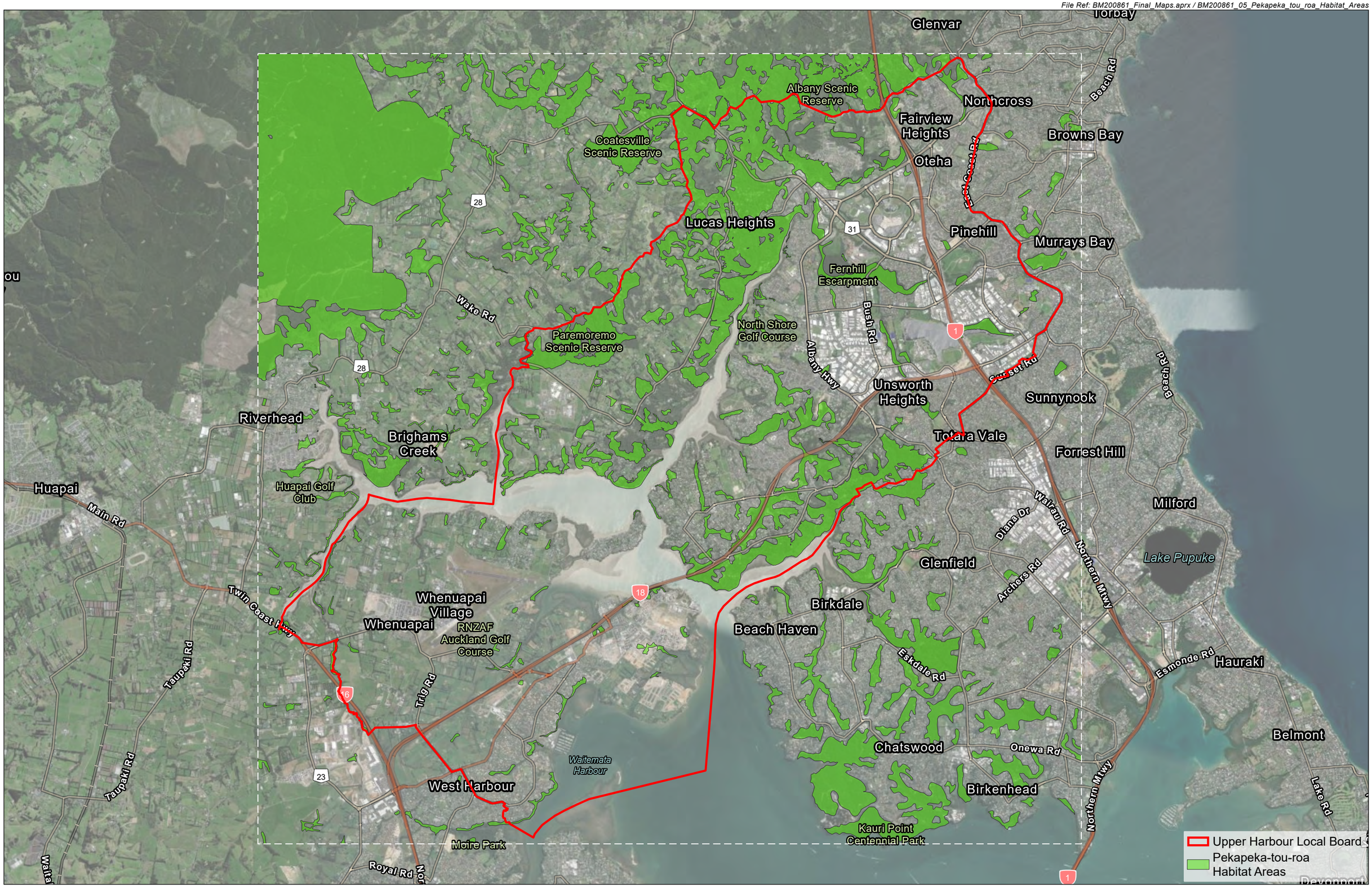
Wetland Connectivity Model

Date: 07 July 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate.Heaphy@boffamiskell.co.nz | Drawn: SGa | Checked: KHe

Map 4



Boffa Miskell

www.boffamiskell.co.nz

0 1 2 km

1:60,000 @ A3

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

Projection: NZGD 2000 New Zealand Transverse Mercator

UPPER HARBOUR ECOLOGICAL CONNECTIVITY STRATEGY

Pekapeka-tou-roa Habitat Areas

Date: 07 July 2021 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: Kate.Heaphy@boffamiskell.co.nz | Drawn: SGa | Checked: KHe

Map 5

Mammalian predator control

Introduced mammalian predators are one of the key threats to many native species, including all four umbrella species. Undertaking intensive mammalian predator control across the full extent of Upper Harbour is ideal, and one of the most effective management actions to improve connectivity.

Given limited resources, priority areas for control are the core habitats for forests, wetlands, and the coastal margin, prioritised for each ecosystem by number of core habitat connections (colour-coded on the Interactive Map). Core habitats of all ecosystem types are likely important breeding and/or feeding grounds for their associated species, have potential to act as refuges from predation and source populations that will spread into the surrounding landscape as connectivity increases, and reduce the overall resistance of the landscape (i.e. reduce the risk of movement by providing safe stepping-stone habitats).

It is also important to undertake predator control in buffer zones around each core habitat to prevent predator reinvasion. At minimum, control should be undertaken within at least 500 m around all core habitats, which will help minimise rat reinvasion. For wide-ranging predators such as stoats, at least a 1 km buffer zone of predator control is recommended, and ideally up to 3 km or more (in particular around the coastal margin, habitat which is both a preferred movement pathway of predators and also home to vulnerable ground-nesting native birds). Overall, where predator control across the full extent of Upper Harbour is not yet in place, the larger the buffer, the better.

Movement pathways of predators should be a key target when planning trap locations to increase the effectiveness of the control network. Forest corridors, the coastal margin, waterways, roads, and tracks, are often routes used by mammalian predators to move or disperse across the landscape. Although major roads may act as a barrier to mammalian predator movement and reinvasion, walkways, tracks, and some roads provide easy movement pathways both for mammalian predators and people servicing traps, so control along these features can be highly cost-effective.

This connectivity strategy is a tool that should be used in conjunction with historic pest control and monitoring data, and Auckland Council’s pest control guidelines, to inform where to prioritise pest control at a finer scale. Reviewing historic data can provide valuable information on hotspots with high catch rates, seasonal trends, and the effectiveness of particular management actions, trap types and lure types. For this reason, maintaining accurate and precise data records, using a data management software such as TrapNZ or CatchIT, is crucial. Ideally, annual reviews of predator control and monitoring data should be undertaken to identify, identify gaps in the control network and potential invasion corridors, and continually optimise control locations and methods.

Target species for control are rats, weasels, stoats, ferrets, possums, hedgehogs, and unowned 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 all pest species are on

the Tiaki Tāmaki Makaurau conservation pest search website. A list of traps that have passed (and failed) humane testing for each target species can be found on the Bionet website. Auckland Council's Pest animal control guidelines for the Auckland region also contains useful advices and tips for maximum success of pest animal control operations.

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 mammalian predators. Mustelids 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.

As well as the protection of biodiversity values, widespread and sustained predator control also helps to achieve Pest Free Auckland and Predator Free 2050 eradication objectives. Multiple predator control-focussed community group initiatives are already underway, including in many local reserves. For example, the recent Rail Trail Project aims to trap the coastal estuarine margin around Upper Harbour to better protect vulnerable species including mohu-pererū, pūweto, torea and kuaka.

If not already, Pest Free groups and pest animal management projects are encouraged to add their efforts to the community group directory through Tiaki Tāmaki Makaurau / Conservation Auckland website, to show where pest animal control is currently occurring and remaining gaps still requiring control. Comprehensive guides and resources to establish an effective pest animal control network is provided in the Useful Links section.

Pest plant control

Undertaking pest plant control has numerous benefits, in particular as a way to enhance the quality of core habitats. Although there is little evidence for pest plant control to increase connectivity, it has potential to increase the native dominance of ecosystems and allow native plants an opportunity to thrive, with provision of more natural habitat and potentially food sources for native species, minimising the spread of pest plants by birds.

Pest plant control should occur across the full extent of Upper Harbour, including both on public and private land. Given limited resources, pest plant control should occur first in the priority core habitats and then other core habitats for kererū identified in the forest connectivity model. Upper Harbour residents are encouraged to 'be a good neighbour' and get rid of pest plants from their gardens. When removing pest plants from streams and riparian margins, always start up stream, as seeds and rhizomes may be carried downstream.

Target species for control are those listed in the Auckland Regional Pest Management Plan. If you time and resources are limited, prioritise targeting the worst environmental weeds,

in particular in core habitats and within buffer zones around the modelled linkages for the umbrella species. A shortened, high-priority list of environmental pest plants, and the recommended methods of control for each, is included in a guide published by Forest & Bird. More information on pest species is provided on the Tiaki Tāmaki Makaurau conservation pest search website. See the Useful Links section on the online StoryMap for links to other handy resources.

Buffer planting (forest, riparian and wetland margins)

Upper Harbour has extensive coastline, scattered wetland/ freshwater ponds, and multiple small streams. First fencing these areas to exclude stock, and then revegetating riparian or buffer zones (i.e. around forest patches, along streambanks, around wetlands, and around estuary/coastal margins) is one of the most effective ways to enhance these valuable habitats.

Linear plantings (a long strip of planting, often along linear features such as stream banks and habitat boundaries) can form ecological corridors utilised by many native species (especially streams and coastal margins). These areas can also act as important habitat depending on the width and vegetation present. Buffer plantings help to reduce edge effects in the central habitat, and can facilitate movement into the surrounding landscape by decreasing the amount of high-resistant landcover. Buffer plantings are generally recommended to be at least 10 m either side (see Auckland Council's Wetland Restoration Guide), although the larger the better to create habitat, and all plants should be eco-sourced (see Auckland Council Ecosourcing guidelines). Riparian planting helps to prevent erosion, sediment runoff, filter out pollution prior to entering waterways, and improve both water flows and water quality.

Wetland and riparian planting in Upper Harbour has potential to create important habitat for inanga. Adult inanga migrate downstream to spawn in vegetation flooded by spring high tides. Spawning sites are typically stream banks covered by tidal freshwater at the upper limit of saltwater influence in dense native and exotic grasses and sedges, however, adults will not deposit eggs on short, grazed pasture (Mitchell, 1990). As much of the coastal riparian margin in Upper Harbour is under private ownership, cooperation with landowners is required to create and enhance habitats that support inanga spawning, along with other native species which depend on freshwater habitats in Upper Harbour, such as giant kokapu.(Boffa Miskell Ltd, 2010).

Priority areas for buffer planting are in, and immediately adjacent to, core habitats for mohu-pererū as per the Estuarine Margin Connectivity Model, and core habitats for matuku as per the Wetland Connectivity Model following on-the-ground verification. Pekapeka-tou-roa often use streams and other linear features such as coastal margins and shelterbelts when foraging. Protecting tall, mature trees in these areas, and planting new specimens where appropriate, may also help improve connectivity for this species.

As with any complex restoration project, specialist advice should be sought prior to commencing. Auckland Council's detailed, step-by-step guide to riparian planting is included in the Useful Links section, along with other helpful resources.

Creating and enhancing forest habitat

Creating and strengthening functional linkages between core habitats can be achieved using either ecological corridors or stepping stones (See Section 1 and Fig. 1). Many areas in Upper Harbour are currently undergoing intensive development and urbanisation, and incorporating suitable habitat into these designs will yield great benefit for native species.

Given limited resources, there are two priorities for creating forest habitat:

1. Within the buffer zones around current and potential linkages between core patches (yellow and pink lines respectively on the kererū least-cost paths layers).
2. In areas of that are currently difficult for the selected umbrella species to move through (white and red areas of the kererū CWD layer).

Restoration should occur with an ecosystem focus, in line with the Ecosystem Restoration Guide currently under development by Auckland Council. Replanting plans in these areas must consider the original ecosystem type of that area, plant appropriate species for the context, show a preference for native species, include plant with specific species in mind (e.g. puriri and kowhai as a food sources for kererū, tui, and korimako), be eco-sourced, and adopt a long-term vision (i.e. not just plant species that will mature in 5-10 years).

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 habitat through pest animal and plant control, and/ or creating new or supplementary habitat by planting suitable native species.

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 pest animal and pest plant control, landowners can contribute to connectivity by:

- Planting hedgerows and shelterbelts, and using vegetation to enhance 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 kererū, tui and korimako around the property.

Planting suitable native trees in backyards, and planning developments with a focus on habitat provision, will also help to achieve the objectives of the Urban Ngahere Strategy.

Expert advice should be sought to select appropriate species for individual locations. Refer to the Useful Links section and the Tiaki Tāmaki Makaurau / Conservation Auckland

website for more information on plant species selection, ecosourcing for particular ecosystems, and where to seek more specific advice.

Utilising transport infrastructure as ecological corridors

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 corridors that both facilitate movement of native wildlife between core habitats and provide potential habitat.

Recommendations to transform transport infrastructure into effective ecological corridors include:

- 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 corridor, and connect larger habitat patches that exist adjacent or near the route (i.e. corridors 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. kererū and fantail/ piwakawaka). 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 kererū 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 corridor, based on its particular location and surrounding habitat.

Planning projects to improve 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 for overall structural connectivity.

To align with this Strategy, species of focus should include kererū for forest ecosystems, and mohu-pererū for coastal estuarine ecosystems. Actions for other species can also be undertaken, such as for pekapeka-tou-roa or particular threatened species.

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 Upper Harbour. Native species (diversity and relative abundance) should increase over time.
- All community are encouraged to partake in the annual Great Kereru Count, usually occurring in the last week of September each year. Observations can be uploaded via the i-Naturalist website.
- Predator monitoring, such as chew card indices for rats, possums and/or mustelids (particularly in core habitats).
- Other useful project-specific measures, such as area of habitat created/restored.

Refer to the Useful Links section for more information on planning successful restoration projects.

Conservation groups are strongly recommended to add their project to the Tiaki Tāmaki Makaurau Conservation Auckland website to help identify where gaps are being filled and where further work is still required (Link in the Useful Links section). The website also has options to contact groups in your area to help collaboration and if people are interested in joining/connecting.

How to effectively plan projects 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 kererū
- Improve quality of estuarine margins for mohu-pererū
- Protect remnant habitats for pekapeka-tou-roa
- Actions for other key indicator species

2. Choose an area

- To identify **exisiting areas requiring protection and enhancement**, refer to the **habitat and least-cost paths layers** of the Forest, Coastal Estuarine and Wetland Connectivity Models. The habitat maps for pekapeka-tou-roa also identify potential tall-stature, mature forest habitat for protection

- To identify **new areas requiring habitat creation and connection**, look for the **white and red areas on the kererū cost-weighted distance (CWD) layer** on the Forest Connectivity Model

3. Select management action(s)

To improve existing habitat patches:

1. Undertake predator and pest plant control
2. Fence waterways (stock exclusion)
3. Replanting along riparian margins and buffer zones (along waterways, along the coastline and around wetlands)
4. Disturbance control (especially from people and dogs)

To improve connectivity between habitat patches and in high-resistant areas:

1. Add in small, managed, stepping stone habitats
2. Create ecological corridors of high-quality, suitable habitat (e.g. by planting along riparian margins and buffer zones, enhancing fences and shelterbelts)
4. Planting suitable native plants in local parks and private gardens

4. Select measure(s) of success

- Select measures of success at start of project and assess at set time intervals.

For example:

- Increase in diversity and abundance of native species (e.g. via 5-min bird counts of kererū, and/or other indicator species)
- Increase in landcover of a native habitat type that is replanted
- Decrease in predator numbers (e.g. via chew card index for rats, mustelids and/or possums)

5. Record the project on the Tiaki Tāmaki Makaurau database

7 Useful Links

Refer to the Tiaki Tāmaki Makaurau Conservation Auckland website for up-to-date conservation information for your area and how to be involved, along with an interactive map to explore te taiao (the environment), the natural taonga (treasures) of the landscape, and other data relevant to conservation.

Iwi engagement

Before starting any conservation project, it is important to familiarise yourself with the mana whenua of the area you will be working within, and any nearby areas of cultural significance (refer to the Cultural Values layer on the Interactive Map).

- Engaging with Mana Whenua
- Lessons for Successful Mana Whenua Engagement
- What is Matauranga Māori?
- Māori and Biodiversity
- Understanding the World through Whakapapa
- Kaitiakitanga
- Ngā Rerenga o Te Tiriti (for Community Groups)
- Te Tiriti o Waitangi

The mandated mana whenua for Upper Harbour is Ngāti Manuhiri, please visit their website or contact kaitiaki@ngatimanuhiri.iwi.nz for guidance on how to engage. Also see the Auckland Council mana whenua directory for a list of mana whenua and their contact information for your area of interest.

Additional information on the connectivity analysis methods:

- Linkage Mapper – connectivity software information.

Useful pest animal control resources:

- Pest animal control guidelines for the Auckland region - Simple techniques for maximum success in pest animal control in Tāmaki Makaurau/Auckland.
- Auckland Council Biosecurity – Pest plant, pest animal and general biosecurity information on the Auckland Council website.
- Auckland Council Pest Search - Search for pest organisms in Auckland.
- Predator Free NZ – collection of useful resources for effective predator (rats, possums, and mustelids).
- DOC's Practical Guide to Trapping – How-to guides, tools, and tips for effective trapping.
- BioNet – Tools, information, and best practice protocols for pest management.
- For more specific advice on pest management actions, contact pestfree@aucklandcouncil.govt.nz.

Useful pest plant control resources:

- WeedBusters – information on pest plant identification and control.
- Forest & Bird Weed Control Guide – Information sheet on pest plant identification and appropriate control techniques.

- Guide to ecosourcing plants - Information of sourcing native plants from local seed for local use.

Habitat restoration resources:

- Auckland Council's Native forest restoration guide - How to restore forest ecosystems.
- Auckland Council's Wetland restoration guide – How to restore wetlands.
- Auckland Council's riparian planting guide – How to successfully restore riparian habitat.
- Ecosourcing plants – Sourcing native plants from local seed for local use.
- Selecting native plant species for Auckland – A guide to selecting appropriate species for planting.
- Auckland Council is currently developing an Ecosystem Restoration Guide for native ecosystems in Tāmaki Makaurau/Auckland.

Health & Safety:

- PF2050 Health & Safety guide for staff and volunteers – General information to help keep everyone safe during predator management activities.
- Keep Kauri Standing – General information on kauri dieback on management protocols if you are working in an area with kauri present.

Add a Project

Please fill out Auckland Council's community group survey form if you would like to add your conservation project, group, or area to Auckland Council's Tiaki Tāmaki Makaurau Conservation database (survey form opens in a new window). Your responses will help to fill in and identify remaining gaps between projects.

Note the layers in this Strategy provide a snapshot of community activity as at June 2021. Refer to Refer to Auckland Council's Tiaki Tāmaki Makaurau map for up-to-date conservation project locations.

8 References

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Appendix 1: Auckland Council prioritisation of Upper Harbour reserves

Ecological prioritisation of selected reserves within Upper Harbour from Auckland Council. The top 10 reserves and any reserves with an ecological corridor function >1 (bolded, n = 12) were used to inform prioritisation recommendations for Upper Harbour in this Strategy. EV = Ecological Value. Note different scales were given for each criteria. Specific describes and justifications for each score are not detailed in this Strategy.

Park Name	EV flora	EV fauna	Restoration outcomes	Previous mgmt.	Size	Shape	Ecol. Corridors	Restoration efforts	Total score
Albany Heights Scenic Reserve	**15**	**15**	**15**	**0**	**6**	**6**	**5**	**6**	**68**
Oteha Scenic Reserve	**15**	**10**	**10**	**0**	**6**	**4**	**10**	**6**	**61**
Pāremoremo Scenic Reserve	**15**	**10**	**15**	**0**	**6**	**6**	**0**	**6**	**58**
Lucas Creek Scenic Reserve	**15**	**10**	**15**	**0**	**4**	**6**	**0**	**6**	**56**
Te Wharau Scenic Reserve	**15**	**10**	**10**	**0**	**2**	**6**	**5**	**6**	**54**
Redfern Nature Reserve	**10**	**5**	**15**	**0**	**4**	**4**	**5**	**4**	**51**
Albany Heights Reserve	**10**	**10**	**10**	**0**	**4**	**4**	**5**	**6**	**49**
Three Streams Reserve	**15**	**10**	**10**	**0**	**4**	**4**	**0**	**4**	**47**
Gills Reserve	**10**	**5**	**5**	**0**	**4**	**6**	**10**	**4**	**44**
Kereru Reserve	**10**	**5**	**10**	**0**	**2**	**4**	**5**	**4**	**40**
Dene Court Reserve	10	5	10	0	2	6	0	4	37
Chatham Reserve	10	10	5	0	2	4	0	4	35
Lady Phoenix Reserve	5	10	5	0	4	6	5	4	35
Unsworth Reserve	10	10	5	0	4	2	0	2	33
Kell Park	**5**	**5**	**0**	**0**	**2**	**2**	**10**	**4**	**28**
Schnapper Rock Reserve	5	5	5	0	2	6	0	4	27
Kingfisher Esplanade Reserve	5	5	0	0	2	6	0	2	20
Taihinui Historical Reserve	0	5	5	0	4	2	0	2	18
Luckens Reserve	5	0	0	0	4	6	0	2	17

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