Manaaki Whenua
Landcare Research

Spatial prioritisation to inform indigenous biodiversity management in the Otago region

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Spatial prioritisation to inform indigenous biodiversity management in the Otago region

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Summary

Project and client

- Otago Regional Council (ORC) completed the first step in its spatial prioritisation of sites for active biodiversity management across Otago in 2020 using Zonation software to identify a representative proportion of the full range of indigenous biodiversity in the region.
- The current project reviews the priority sites for terrestrial biodiversity identified via Zonation, drawing on specialist knowledge of the Otago region and its ecosystems and taxa to recommend refinements that ensure the network includes sites with high biodiversity values.

Objectives

- To describe a framework of criteria for ensuring inclusion of high-value sites in a network of priority sites for biodiversity management.
- To produce a set of guidelines for further assessment of and updates to the spatial layer of priority sites.
- To identify the key knowledge gaps for indigenous biodiversity in the Otago region that will inform future surveys, research, and management.

Methods

- We held two workshops with specialists familiar with Otago ecosystems to: (1) develop criteria for identifying sites to include within a priority site network; (2) review and suggest refinements to a candidate network of priority sites.
- We used the specialist input from the workshops in addition to other resources to develop a set of guidelines and practical steps for refining the priority site network to capture high-value sites.

Results

- Uniqueness and vulnerability were the key criteria agreed among specialists for identifying priority sites for biodiversity management in addition to the criteria of representativeness and large, contiguous sites that were predominantly used in the initial spatial prioritisation via Zonation. Sites meeting these criteria will include naturally uncommon ecosystems, 'unnaturally rare' (once common) ecosystems, populations of species endemic to Otago, and threatened species populations.
- Biodiversity values identified as missing from the candidate priority site network ('biodiversity gaps') included naturally uncommon ecosystems, and significant habitats of regionally endemic threatened taxa or severely threatened taxa. Improved surveying and mapping of these ecosystems and habitats were identified as important knowledge gaps.
- Based on the general criteria and biodiversity gaps identified above, we developed a set of criteria for three tiers of priority that would support refinement and

implementation of the priority site network, ensuring high-value sites are captured in the network:

  - First tier: threatened naturally uncommon ecosystems, habitats of threatened taxa endemic to Otago, and habitats of Nationally Critical species
  - Second tier: all other naturally uncommon ecosystems and 'unnaturally rare' ecosystems, particularly those that are most depleted
  - Third tier: all other ecosystem types and species' habitats, with an emphasis on sites with multiple biodiversity values that also meet other criteria as described.
- We produced a framework of guidelines and series of practical steps for refining the candidate priority site network to add high-value sites as identified using our criteria while balancing the total network area to maintain feasibility of implementing active management.

Conclusions

- Specialist input from two workshops informed development of criteria and a framework of guidelines to refine a network of priority sites for active management of biodiversity in Otago to ensure it includes high-value sites.
- The knowledge gaps identified in this report will help to inform future biodiversity surveys, inventories, and research.

Recommendations

- We recommend biodiversity values in the first and second tiers of priority should be fully captured in the priority site network, where practicable, due to their high biodiversity values combined with high vulnerability. We recommend that decisions to reduce area of the total network following additions of high-value sites consider: (1) removal of sites with no known indigenous biodiversity values; (2) potential trade-offs amongst sites with similar biodiversity values that, for example, contribute differently to geographical representation across the network or are more or less vulnerable to threats.
- We recommend a series of practical steps that the ORC can take to include high-value sites that meet the criteria of the first and second tiers of priority in the final network of priority sites for active management of biodiversity.
- Specialists from the workshops raised two additional recommendations that should be considered during implementation of the priority site network.
  - Establish a process for integrating the outputs of biodiversity site prioritisation in coastal/marine, freshwater, and terrestrial domains.
  - Employ management planning and approaches that consider the surrounding landscape of, and the threats it poses to, each priority site.

1 Introduction

Despite recent conservation gains for many species, indigenous biodiversity in New Zealand continues to face multiple threats that will lead to its continued decline if these are not actively managed (Department of Conservation 2020). A strategic direction and biodiversity think piece produced by Te Uru Kahika – Regional and Unitary Councils Aotearoa suggests five strategic shifts that could enable regional councils to contribute more effectively to biodiversity management (Willis 2017) given their mandated function to maintain biodiversity under the 2003 amendment to the Resource Management Act (Willis 2014). The think piece notes that regional councils have a particular role to play in active management due to the combination of: (1) their demonstrated ability to partner with a wide range of stakeholders, including the Department of Conservation (DOC), in operational programmes; (2) the tenure-neutral focus of the operational programmes they implement or support, which can complement biodiversity management undertaken on public conservation land (Willis 2017).

A key part of the third suggested shift – 'Better information for better management' – involves developing a consistent and systematic spatial prioritisation of sites for active management of biodiversity that all councils, and other biodiversity managers, can implement (Willis 2017). The aim of this prioritisation is to encompass 'a full and representative range of habitats and ecosystems' within each region. Such prioritisation would therefore include sites containing rare and threatened species and ecosystems but extend beyond focusing solely on these components of a region's biodiversity. Additionally, such a prioritisation of sites for active management is different to regulatory protection of 'significant natural areas' designated under legislation, although some sites may be identified in both processes.

According to Willis' 2017 think piece, consistent and systematic spatial prioritisation of sites for active management requires using a single approach (e.g. a single decision-support tool) under consistent settings, which would require the same types of data to be available for use within that tool (Willis 2017). Consistent prioritisation also relies on using a consistent classification of ecosystems into types, as well as consistent threat classification of those ecosystems (Willis 2017). Limitations persist in both the availability of mapped data and fit-for-purpose nationwide ecosystem classification systems, but progress can be made in using available tools and data in a systematic way across the regions to identify networks of priority sites for active biodiversity management (hereafter, 'priority sites'). In this report we outline the process used for Otago's terrestrial ecosystems with a particular focus on generating spatial outputs of high-value biodiversity sites to inform management operations. The framework developed to identify and evaluate potential sites to include within the spatial network of priority sites will also enable future improvements in knowledge of indigenous biodiversity in Otago to be incorporated in the network in a robust, systematic way.

2 Background

To achieve the Willis (2017) think piece's recommendation of prioritising sites, some regional councils have adopted the Zonation software as a decision-support tool, because it was already in use by DOC and certain regional councils (Willis 2017). As Zonation is a decision-support tool, which relies on its data inputs and model settings to produce a candidate network of priority sites, its output is indicative of a spatial network that represents the full range of ecosystems within a region. An evaluation of this output is needed to identify potential misclassification of ecosystem types or gaps in its coverage of biodiversity values. For example, the Bay of Plenty Regional Council added sites to the region's priority site network to capture habitats of threatened species that were not included in the candidate sites with high ecosystem values identified by Zonation (see Case Study 3 in Willis 2017).

Otago Regional Council (ORC) completed the first stage of this spatial prioritisation process in 2020, using Zonation to identify a candidate network of priority sites for terrestrial biodiversity that captured 30% of the remaining indigenous-dominated ecosystems in the Otago region (according to input data) and equated to 19% of the region's pre-human indigenous terrestrial vegetation cover (Leathwick 2020). The target capture of 30% of the remaining indigenous ecosystems represents a theoretical threshold under which biodiversity loss can accelerate (as demonstrated by, for example, Andrén [1994]) and aligns with targets set by other regional councils (e.g. Hawke's Bay[1]).

The input data included current land cover classifications from the New Zealand Land Cover Database version 5.0 (LCDB5; Landcare Research New Zealand Ltd 2020) and a spatial layer predicting the potential terrestrial ecosystem cover across the region (Lloyd et al. 2020b). These layers were intersected to enable current land cover to be classified into ecosystem types (using the Singers and Rogers [2014] ecosystem classification system) and to calculate remaining extent of each ecosystem type. In general, the Zonation approach sought to capture a greater proportion of the remaining cover of ecosystems which had been most reduced in their historical extent (Leathwick 2020), similar to the approach taken for Bay of Plenty's spatial prioritisation of sites (see Case Study 3 in Willis 2017). Additional weighting of certain locations of ecosystem types was done using a spatial layer that described significant habitats of a range of threatened and at risk fauna (Lloyd et al. 2020a).

Leathwick's report describing the Zonation approach and results noted that it relied on existing, broad-scale data and that the ecosystem composition of individual sites within the candidate network proposed should be reviewed and verified (Leathwick 2020). Such a review would also provide the opportunity to check whether sites with high biodiversity values were missing from the candidate priority site network due to certain limitations. A strength of the candidate priority site network was its ability to capture ecosystem types that were well resolved in the data inputs, but certain issues were likely to arise for other ecosystem types and species' habitats. First, misclassification of ecosystem types and

[1] https://www.hbrc.govt.nz/environment/biodiversity/

inaccurate delineation of ecosystem boundaries can occur with LCDB, including difficulties in distinguishing indigenous- vs. exotic-dominated vegetation in grasslands. Second, the Singers and Rogers (2014) ecosystem classification system lacks a thorough treatment of seral types and naturally uncommon ecosystems, both of which can provide high biodiversity values in Otago. Finally, although a spatial layer of select faunal habitat informed the Zonation approach, habitats of other taxa (including plants) were not included.

The focus of the current project was to lead a review of this candidate network of terrestrial priority sites to ensure sites with high biodiversity values were included and spatial outputs could be updated to support implementation of biodiversity management. The Zonation approach was also used to identify priority sites for freshwater ecosystems in the same report (Leathwick 2020). Coastal and marine biodiversity sites for Otago are being identified through separate processes.

This review of the initial spatial prioritisation output produced via Zonation (Leathwick 2020) aimed to: (1) enable the ORC to use the priority site network to inform its biodiversity management operations and funding (which includes biosecurity operations); (2) to align these with the efforts of key partners and stakeholders by promoting shared application of the priority site network in decisions about biodiversity or biosecurity management interventions and funding allocation. The review involved incorporating knowledge unavailable to the Zonation process, including mapped locations of naturally uncommon ecosystems and specialist knowledge of habitats of threatened taxa. All parties understood that new information will become available in the future and environmental change will continue to occur, so the ability to update the priority site network accordingly is critical to operationalising it.

3 Objectives

- To describe a framework of criteria for ensuring inclusion of high-value sites in a network of priority sites for biodiversity management.
- To produce a set of guidelines for further assessment of and updates to the spatial layer of priority sites.
- To identify the key knowledge gaps for indigenous biodiversity in the Otago region that will inform future surveys, research, and management.

4 Methods

We held two workshops to receive input from specialists familiar with Otago ecosystems to meet the project's objectives. To inform discussion at each of the workshops, we generated an interactive online map with the candidate priority site network produced via Zonation and a series of other available data layers, including land cover (LCDB5), potential ecosystem cover (Lloyd et al. 2020b) and locations of certain ecosystem types (e.g. coastal ecosystems; Brough et al. 2022). Examination of the candidate priority site

network focused on ecological criteria, drawing on the specialists' knowledge of the Otago region and its ecosystems and taxa. We will describe each workshop in more detail below.

We used the specialist input from the workshops in addition to other resources to develop a set of guidelines and practical steps for refining the priority site network to capture high-value sites.

4.1 Broad review of candidate priority sites to identify key gaps (workshop 1)

We invited a panel of 11 specialists from Manaaki Whenua – Landcare Research (MWLR), DOC, and environmental consultancies with a range of taxonomic and ecological expertise to attend the first workshop. We communicated the workshop's aims to the panel as:

- reviewing and refining a candidate list of priority sites across Otago that capture its full range of indigenous biodiversity and that can inform conservation decisions and management efforts to maintain and enhance biodiversity in the region
- documenting the criteria and process used by the panel to develop a list of priority sites using the information currently available, which will inform next steps, including:
  - future work needed to fill identified knowledge gaps
  - a framework for regular review of the priority sites as new information becomes available and environmental change occurs.

We provided background information to participants before the workshop, including its aims, scope, and terms of reference, as well as suggestions for how to prepare. This included providing examples of criteria that could be adapted for a framework to determine the final network of priority sites. These examples included:

- criteria for designating significant natural areas presented in the exposure draft of the National Policy Statement on Indigenous Biodiversity (Ministry for the Environment 2022): these included representativeness, diversity and pattern, rarity and distinctiveness, and ecological context
- instances of terrestrial ecosystems or habitats and ecological processes that are most important to protect from negative effects in order to maintain indigenous biodiversity as described in Table 1 of Walker et al. (2021)
- threat classifications of 'naturally uncommon ecosystems' (Holdaway et al. 2012) and threatened environments within the region; for example, Land Environments of New Zealand (LENZ) classes with <20% indigenous cover remaining (Walker et al. 2015)
- sites containing significant populations of species in certain categories of the New Zealand Threat Classification System, as well as regional endemics and regional threat classifications

- overlap with priority sites identified through other assessment systems, such as DOC's priority Ecosystem Management Units (EMUs) and Species Management Units (SMUs).

After the workshop we summarised the discussion by themes. We present these in the Results section of this report.

4.2 Focused session to refine spatial network of priority sites (workshop 2)

The aim of the second workshop was to develop a process by which the spatial network of candidate priority sites identified by Zonation could be refined with additional mapped data and expert knowledge of on-the-ground biodiversity values to best meet the criteria developed in the first workshop. This focused session involved three specialists with expertise in Otago ecosystems, who examined coastal, wetland, and inland dryland ecosystems to provide examples for candidate site polygons that adequately captured biodiversity values, incompletely captured them, or did not contain known biodiversity values. The specialists also identified apparent biodiversity gaps in these areas, i.e. particular sites with significant biodiversity values that were not included in the network of candidate sites.

5 Results

The specialist panel at the first workshop discussed criteria for identifying priority sites for biodiversity management, as well as tiers of priority for refining the candidate priority site network to capture sites with high biodiversity values that will enable the ORC to meet its goals of maintaining biodiversity in Otago.

Specialists present at both workshops identified gaps in the biodiversity values captured by the candidate list of priority sites identified by the Zonation approach. A suite of mapping approaches were suggested to assess how the candidate sites meet the proposed criteria and the extent to which the candidate sites capture the ecosystems and sites identified as apparent gaps. Specialists at the second workshop identified more specific examples. Specialists at both workshops discussed which knowledge gaps would be most important to fill to support management of the region's biodiversity.

We used the workshop discussion and other resources to develop a framework of guidelines and series of practical steps that we recommend be taken to refine the priority site network to capture sites with high biodiversity values.

Finally, specialists at both workshops provided two additional recommendations for implementation of biodiversity management across the priority sites.

5.1 Developing criteria for prioritising sites for biodiversity management

The first workshop's specialist panel discussed the broader context of the remaining biodiversity in the Otago region with the aim of creating useful general criteria for

ensuring the full range of biodiversity was captured in the final network of priority sites. We also considered how a tier system could support a focus on high-value biodiversity sites (including those that represent national as well as regional priorities) when refining the priority site network and implementing management across sites. However, the panel noted that potential biodiversity gains from management efforts should be evaluated for *all* priority sites – given that small investment can lead to large gains for some ecosystems and species.

The panel noted that Otago probably has a greater diversity of ecosystems than any other New Zealand region. They also noted that several ecosystem types, including wetlands and moraines, can contain a range of biodiversity given their different origins, climatic context, and other environmental and historical factors. The panel agreed that the selection of priority sites should be informed by both a landscape-scale ecosystem approach and a species habitat approach. This would include considering maintaining natural processes and the capacity for ecosystems to function, as well as including sites that can provide a home for each component of the region's biodiversity – even when these sites are not in pristine condition (e.g. non-native species are abundant).

Uniqueness and vulnerability were also key themes of the discussion for selecting priority sites. Certain ecosystems, such as some types of naturally uncommon ecosystems, are primarily or exclusively found in Otago, and other ecosystems are characteristic of Otago. It would also be important to include habitats of species endemic to Otago, or whose only extant populations occur in Otago, in a network of priority sites. Vulnerability can relate to these unique characteristics of Otago's biodiversity, but also relates to the threats in the surrounding landscape. Thus, threat status (for both ecosystems and species) was also an important component to consider for these general criteria.

The proposed set of general criteria for identifying priority sites is summarised below.

- Representativeness: the final network of sites are representative of the region as a whole, including geographical and ecological representativeness.
- Size: large, intact systems and contiguous sites are included.
- Uniqueness and vulnerability:
    - all naturally uncommon ecosystems are included
    - all fragments and remnants of 'unnaturally' rare (once common) ecosystems are included
    - ecosystems and habitats of species that are endemic to, or have strongholds in, Otago are represented in the final network of priority sites
    - sites containing populations of threatened species are represented in the final network of priority sites
    - the surrounding landscape and threats (i.e. vulnerability and risk of loss of a site or ecosystem) are considered when selecting priority sites among multiple options for an ecosystem or species.

The workshop panel also discussed a set of criteria for identifying tiers of priority within the network of sites. We have further developed the descriptions of these tiers to explain their intent in supporting refinement and implementation of the priority set network.

Applying these tiers aims to ensure that sites with high biodiversity values will be captured in updates to the priority site network. As such, they focus on ecosystems and habitats where biodiversity protection and management are most needed to prevent further declines, including due to their vulnerability and to the difficulty of restoring them (sensu Walker et al. 2021).

- The first tier includes threatened naturally uncommon ecosystems (Holdaway et al. 2012), habitats of threatened taxa endemic to Otago, and habitats of Nationally Critical species. Biodiversity loss in this tier could equate to loss from New Zealand as a whole, thus these regional priorities align closely with national biodiversity priorities.
- The second tier includes all other naturally uncommon ecosystems and 'unnaturally rare' ecosystems, particularly those that are most depleted from their historical extents. For example, ecosystems with less than 30% of their historical extent remaining might be categorised as 'unnaturally rare' and those with less than 10% remaining as 'most depleted' (using thresholds of loss suggested in the Threatened Environments Classification [Walker et al. 2015] and 'Endangered' categories of the IUCN red list risk assessment for ecosystems [Keith et al. 2013]).
- The third tier includes all other ecosystem types and species' habitats, with an emphasis on sites with multiple biodiversity values that also meet other described criteria. For example, sites with greater vulnerability to biodiversity loss, such as sites in land environments with less than 20% indigenous vegetation cover remaining or indigenous ecosystems and habitats in lowland areas (as described in Walker et al. 2021), would benefit particularly from active management.

5.2 Identifying gaps and refining polygons to capture high biodiversity values

Refining the spatial network of priority sites involves assessing which biodiversity values are captured – and which are missed – by the current network (i.e. what biodiversity 'gaps' exist in the network). We discussed these points at a conceptual and whole-region level with specialists at both workshops, and at a more focused and operational level at the second workshop. We will first summarise the main conceptual points made around biodiversity gaps apparent in the candidate network of priority sites (Section 5.2.1).

Second, in Section 5.2.2, we will discuss the operational considerations involved in refining the candidate network of sites to both capture biodiversity values that were missed and to remove sites (or parts of delineated sites) with no biodiversity values and severely limited potential for critical ecosystem processes to function. By 'ecosystem processes', we mean those properties that generate an ecosystem type and provide the basis for the associated flora and fauna to occur there (e.g. hydrological and geological processes inherent to wetland and dune ecosystems, respectively). The delineation of mapped polygons for most individual sites will probably need some refinement to best match on-the-ground ecosystem boundaries and for management to be effective and easily implemented. For example, specialists recommended minimising the amount of polygon 'edge' where feasible and eliminating unnecessary 'holes' in the middle of several polygons due to the patchiness of some ecosystem or land cover types. We do not discuss this aspect of refining polygon boundaries further in this report.

Finally, in Section 5.2.3, we will describe knowledge gaps in ecosystem and species distributions and mapping that will be important to address to support refinement of the priority site network.

5.2.1 Apparent biodiversity gaps in the candidate priority site network

Given the criteria for selecting priority sites as proposed at the first workshop, specialists discussed which ecosystem types and species populations appeared to be captured within the candidate priority site network versus which were missing. At the first workshop the discussion focused on naturally uncommon ecosystems and sites where significant populations of severely threatened species or species endemic to Otago are known to occur. At the second workshop the discussion focused on biodiversity values likely to be missed in coastal areas and in the dry interior of Otago. Specialists also noted that certain 'unnaturally' rare ecosystems – e.g. mataī–tōtara forest, and upland conifer forest that contains Hall's tōtara (*Podocarpus laetus*), mountain celery pine (*Phyllocladus alpinus*) and bog pine (*Halocaprus bidwillii*) – and areas with biodiversity values dispersed throughout a modified landscape (e.g. the Macraes Ecological District) may be under-represented within the candidate sites.

Certain categories of naturally uncommon ecosystems, such as coastal turfs, were largely captured by the candidate priority sites, with only a few missed sites that should be included in the final network of priority sites (e.g. Tunnel Beach in the case of coastal turfs). Other categories were largely missing from the candidate sites, such as limestone and inland saline environments. Finally, certain ecosystem types were captured well by the candidate sites in some parts of Otago but were missing from other areas of the region (e.g. ephemeral wetlands).

When focusing on coastal ecosystems, specialists noted that certain habitat types might be more likely to be misclassified by aerial imagery given they are at the terrestrial-marine boundary (e.g. dunes and salt marshes) or are vertical habitats (e.g. coastal cliffs), as well as often having a small extent. When focusing on the dry interior of Otago, specialists noted that the candidate site network appeared to have much less coverage of lowland areas than was representative of the biodiversity values occurring there. This might be due to the small size of indigenous ecosystem remnants (e.g. forest patches in gullies that sometimes were not mapped as indigenous in the input data) or the dispersed biodiversity values within the modified landscape.

Habitats and large populations of many threatened species or species endemic to Otago were captured by the candidate priority sites (e.g. all moth species listed as 'Threatened' by Hoare et al. 2015). If not captured already, they would be captured in the final network of priority sites if all naturally uncommon ecosystems were included; for example, the Threatened – Nationally Endangered Cromwell chafer beetle (*Prodontria lewisi*) (Leschen et al. 2012) and the Threatened – Nationally Critical Pisa Flats woollyhead (*Craspedia argentea*) (listed as '*Craspedia* (a) CHR 511522; Clutha River' in de Lange et al. 2017, p. 28).

There were some known occurrences of threatened species endemic to Otago or Nationally Critical species that appeared not to be captured by the candidate sites. For example, the candidate sites may not fully capture the habitat of the Nationally Critical

green skink (*Oligosoma chloronoton* [Hitchmough et al. 2021]) where it is known to occur in Otago, but further surveying is needed to identify if additional populations are present. Specialists noted three Nationally Critical forget-me-nots (*Myosotis* spp. [de Lange et al. 2017]) as another example where known occurrences appeared to be incompletely captured by the candidate sites. This gap would remain even with addition of naturally uncommon ecosystems to the priority site network because these species occur in other ecosystem types. Our specialists noted that reassessing gaps in the priority site network for known sites of threatened Otago endemics or severely threatened species, especially sites located outside naturally uncommon ecosystems, is particularly needed after threat classifications are updated or new mapping of species occurrences becomes available.

5.2.2 Illustrative examples for evaluating and refining site polygons

Specialists at the second workshop discussed scenarios in which polygons from the candidate priority site network incompletely captured biodiversity values at a location or did not capture known biodiversity values (either within the entire polygon or only part of it). The discussion focused on coastal and dry interior ecosystems of Otago and involved specific feedback on a number of polygons in the candidate priority site network. In this section of the report we provide illustrative examples of scenarios where a polygon might be extended, reduced in size, or removed from the priority site network based on the biodiversity values it captures. Our specialists also noted that reductions in size of large polygons with biodiversity values likely to be over-represented across the priority site network or within certain parts of Otago could accommodate addition of areas containing high biodiversity values which have been missed or under-represented in the network. In other words, a 'swap' could be conducted of biodiversity values that are well represented or less vulnerable with areas missed by the site network but meeting the criteria for high priority (i.e. tiers one to three) described in Section 5.1.

Specialists identified polygon boundaries for certain priority sites that could be extended to capture mapped biodiversity values that were not included in the input data for the Zonation analysis and to better match ecosystem boundaries on the ground. For example, one coastal candidate site does not fully capture the dune habitats and wetlands (both naturally uncommon ecosystems) that have been mapped by the ORC.

Specialists also identified polygons for certain priority sites that could be reduced in area to remove a part of the polygon that may not contain biodiversity values. For example, the same coastal candidate site mentioned in the previous paragraph also captured a large area identified as 'Low-producing grassland' by LCDB5 that the specialists did not expect to contain indigenous biodiversity. Further ground-truthing could be used to confirm this assessment.

Finally, specialists identified some polygons that could be removed from the priority site network because they contain no biodiversity values. This could be due to misclassification of the land cover or species present at the site. In some cases, there is an opportunity to relocate the polygon to a nearby site with indigenous biodiversity. For example, there is a small candidate site that covers a patch of macrocarpa (i.e. an exotic tree) surrounding a house, while directly west of it is a patch of indigenous bush not captured within the candidate priority site network.

5.2.3 Identifying key knowledge gaps

Specialists in the first workshop identified several knowledge gaps that indicate where focused surveys and mapping could most usefully inform the delineation of priority sites in Otago. This includes improved mapping of many naturally uncommon ecosystems, such as limestone ecosystems, and assessing whether certain categories of naturally uncommon ecosystems, such as subterranean river gravels, occur in Otago.

Better mapping of threatened species occurrences (including for species identified as Data Deficient in the National Threat Classification System) and habitats was also identified by specialists as a gap. Finally, they suggested that additional surveying of particular ecological districts was important where these districts have potentially high biodiversity values while also having high vulnerability and relatively low coverage by the candidate priority sites.

5.3 Recommended guidelines and practical steps for refining the priority site network

We used the developed criteria and assessment of biodiversity and knowledge gaps to create a framework of guidelines and series of practical steps for refining the priority set network to capture high-biodiversity values. These guidelines and practical steps build on the representation of all ecosystems present in Otago within the candidate priority site network produced by Zonation (Leathwick 2020) by: (1) suggesting additions or expansions to the candidate sites to fill biodiversity gaps; (2) suggesting reductions to or removal of candidate sites to maintain a focus on the purpose of spatially prioritising sites for active management of biodiversity in Otago and implementing this management. The priority site network will work in tandem with regulatory mechanisms for biodiversity maintenance (e.g. delineation of Significant Natural Areas). However, feasible implementation of its purpose of active management, including decisions to support biodiversity management efforts of partner organisations and groups (e.g. through community funding mechanisms), will require focusing on a subset of Otago's remaining indigenous biodiversity rather than its full extent (e.g. the 30% target used to develop the candidate priority site network; Leathwick et al. 2020). For this reason, our guidelines and practical steps include suggested reductions and removals as well as additions and expansions to the candidate priority site network.

5.3.1 Conceptual guidelines

These guidelines draw predominantly on the criteria for tiers of priority (Section 5.1) to address the main biodiversity gaps (Section 5.2) in the candidate priority site network. The tiers of priority also provide a general guide and justification for the total area (and proportion of remaining extent) of each ecosystem or habitat type to include within the priority site network to meet its goal of maintaining biodiversity. For example, the network should capture the entire current extent of ecosystems and habitats in the first tier, where practicable. The network should also capture a greater proportion of the current extent of ecosystem or habitat types that have been most reduced from their historical extent and/or have the most restricted current extent; this aligns with established criteria for

vulnerability that are meant to help inform conservation and management planning (e.g. IUCN red list for ecosystems [Keith et al. 2013]; New Zealand Threatened Environment Classification [Walker et al. 2015]). This approach that produces disproportionate representation of remaining cover of rare and threatened biodiversity values (i.e. ecosystems or species) was noted in the think piece suggesting the implementation of the spatial prioritisation of sites across the regions (Willis 2017). It was also used in the Zonation approach that produced the candidate priority site network for Otago (Leathwick 2020). For example, the proportion of remaining ecosystem cover captured in the candidate priority site network ranges from an average of approximately 96% for ecosystems estimated to currently occupy less than 1,000 ha in Otago to approximately 20% for the most extensive remaining indigenous ecosystem (estimated to currently occupy more than 440,000 ha; Leathwick et al. 2020).

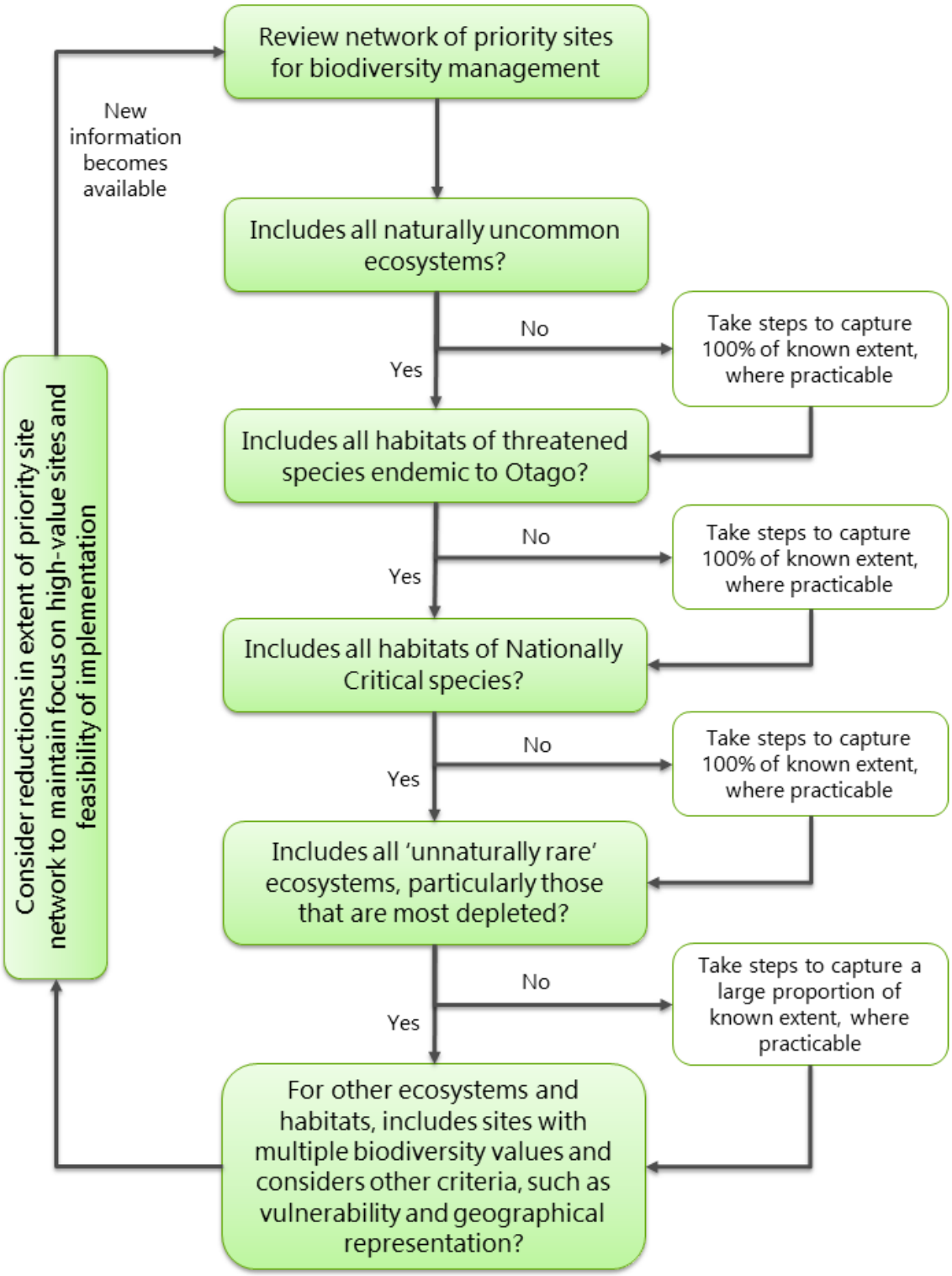

Figure 1. A framework of guidelines for refining the network of priority sites for management of biodiversity in the Otago region.

Figure 1 shows a visual framework for these guidelines. This project described an approach to review the priority site network using specialist input and knowledge of unmapped biodiversity values in Otago. Future reviews could employ a combination of spatial analysis with mapped biodiversity data and additional specialist input to determine

which biodiversity values are captured or missed following each refinement of the network.

We recommend biodiversity values in the first and second tiers of priority should be fully captured in the priority site network, where practicable, due to their high biodiversity values combined with high vulnerability. Scenarios where this is not practicable may include, for example, sites where unnaturally uncommon ecosystems are present but not functional or with limited opportunities for biodiversity management (e.g. in built environments). Other such scenarios could include those 'unnaturally rare' ecosystems that are not the most depleted and/or that currently occupy a relatively large area. As a hypothetical example, given two ecosystems with less than 10% of their historical extent remaining, the priority site network might capture the complete extent of the ecosystem that currently occupies less than 1,000 ha but only capture 50% of the ecosystem that currently occupies more than 10,000 ha.

Filling the biodiversity gaps identified in this report to ensure the priority site network captures sites with high biodiversity values will increase the total area of the site network. This increase in area, potentially coupled with an increase in number of sites, will reduce the feasibility of planning and implementing management operations to maintain biodiversity across the priority site network. We therefore include explicit recommendations to consider how to reduce the total area of the network following any additions of high-value sites.

The reduction(s) can include removing sites with no known indigenous biodiversity values (as determined during each review of the priority site network). They could also include taking into consideration potential trade-offs amongst sites with similar biodiversity values that, for example, contribute more or less to an ecosystem's geographical representation within the network or that are more or less vulnerable to threats. Ecosystem types of the greatest extent (or very large priority sites clustered in one part of the region) could also be considered for reduction to help meet the other criteria described, particularly where this type of refinement would emphasise the active management purpose for the priority site network.

5.3.2 Practical steps

Producing a fully mapped and vetted spatial layer of priority sites for the Otago region will require multiple additional steps. However, progress on these can occur alongside work to fill the key knowledge gaps we have described to enable the ORC to take actions to enhance known and mapped biodiversity values. The listed steps represent iterative processes because new information is expected to become available, as shown in Figure 1.

Naturally uncommon ecosystems fall within the first and second tiers of priority we describe. These ecosystems have been broadly defined (Williams et al. 2007) and their national threat status assessed (Holdaway et al. 2012), which provides a starting point for assigning them to each priority tier. Some of these ecosystems have been mapped according to these definitions using field-based data (e.g. dune systems), while systematic mapping of others remains to be done. Evaluating and clarifying the definitions of naturally uncommon ecosystems to enable such systematic mapping is an active area of

research. We recommend the ORC takes the following steps to include these high-value sites.

- Join spatial layers for mapped naturally uncommon ecosystems, according to current definitions, to the priority site network to ensure they are captured fully within the network.
- Use revised definitions for naturally uncommon ecosystem types, as they are produced, to support systematic mapping of those ecosystems.
- Update the priority site network once new mapping becomes available to include those naturally uncommon ecosystem sites within the network.

Habitats of threatened species endemic to the Otago region and of Nationally Critical species fall within the first tier of priority. Some occurrences for these species are known, but new information is likely to become available (e.g. as new occurrences are observed, taxonomic relationships are revised, or threat classifications are updated). Moreover, some species' habitats may encompass a greater area or range of ecosystem types than indicated by their occurrences only, particularly for species that are highly mobile or have complex life cycles that use different habitats at different life stages. We recommend the ORC takes the following steps to include these high-value sites.

- Collate known occurrences of Otago-endemic species currently classified as threatened and of all species currently classified as Nationally Critical. If there is uncertainty about whether threatened species are endemic to Otago, we recommend undertaking consultation with specialists with appropriate taxonomic expertise.
- Overlay the priority site network spatial layer with mapped occurrences of these species to identify any occurrences that lie outside the network. An appropriate area around these occurrences should be added to the priority site network to capture habitats of these species, as described in the next bullet point.
- Establish agreed definitions of habitat for these species, which can then be mapped to determine whether any part of this habitat lies outside the priority site network. This will be most important for where species occurrences lie outside the priority site network, but also important for species that may use multiple habitat types.

'Unnaturally rare' ecosystems fall within the second tier of priority and are represented in the candidate priority site network produced by Zonation (Leathwick 2020). Further assessment of their extent and representation within the priority site network can be conducted as new tools become available, such as the recently released Ecosystem Restoration Map produced by Eco-Index.[2] Such investigation should start with those ecosystems most depleted from their historical extent and/or most limited in their current extent using available data and quantified estimates (e.g. Lloyd et al. 2020b, Leathwick 2020). Making reductions in the total area of the priority site network to balance any additions can involve reducing the extent of or completely removing sites that: (1) do not clearly meet the criteria presented here; (2) capture similar biodiversity values to other sites that better meet other criteria (as described in Section 5.3.1). We recommend the

[2] https://eco-index.nz/ecosystem-restoration-map

ORC takes the following initial steps to identify sites or partial sites that contain no known indigenous biodiversity values as candidates for removal from the priority site network.

- Produce a spatial layer of polygons that have no overlap with biodiversity values mapped from sources other than satellite imagery (e.g. with the available spatial layers used to inform the two workshops described here). Then ask specialists with on-the-ground knowledge of those locations if they know of biodiversity values present in those locations (i.e. conduct a desktop exercise similar to the second workshop described in this report, but with a short-list of polygons for assessment).
- Flag the polygons identified by specialists as lacking clear biodiversity values for removal or follow-up, depending on whether further ground-truthing was noted as needed to verify their assessment.
- Conduct opportunistic ground-truthing of sites flagged as unlikely to contain biodiversity values, where feasible, while operational tasks are being undertaken in or near these sites by council staff, contractors, or partners.

5.4 Additional recommendations for implementation

Specialists from the workshops raised two additional recommendations that should be considered during implementation of the priority site network.

- Establish a process for integrating the outputs of biodiversity site prioritisation in coastal/marine, freshwater, and terrestrial domains.
- Employ management planning and approaches that consider the surrounding landscape of, and the threats it poses to, each priority site.

6 Conclusions

We used specialist input from two workshops, as well as published sources, to develop a recommended framework of guidelines and practical steps that the ORC can use to refine the candidate priority site network produced via Zonation (Leathwick 2020) to ensure it includes sites with high biodiversity values.

The criteria we developed will help support implementation of the priority site network as well as focusing the refinement of the network on high-value sites. The knowledge gaps identified will help to inform future biodiversity surveys, inventories, and research, as well as refinement of the priority site network.

Our additional recommendations will help to inform the implementation of biodiversity management in the region, including how the terrestrial biodiversity priorities identified in this project should be integrated with coastal and marine, wetland, and freshwater biodiversity priorities that will be identified in separate processes.

Overall, the specialist input and guidelines developed will support the ORC in achieving the purpose of this spatial prioritisation of sites for active biodiversity management (as described in Willis 2017) and its goals of maintaining and enhancing biodiversity in the

Otago region. This work will complement other activities for biodiversity protection and management, including those conducted under regulatory mechanisms.

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