Bioeconomy Science Institute™
Maiangi Taiao

A current ecosystem map for Aotearoa New Zealand

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Project and client

The Ministry for the Environment commissioned the Bioeconomy Science Institute, in collaboration with Earth Sciences New Zealand, Lincoln University, and the New Zealand Institute for Public Health and Forensic Science, to produce a current ecosystem map of the International Union for Conservation of Nature Global Ecosystem Typology (IUCN GET) Level 3 ecosystem functional groups (EFGs) present in New Zealand.

Objective

To create a current ecosystem map depicting the present-day national distribution of EFGs across six domains in New Zealand: terrestrial, wetlands, rivers, lakes, groundwater, and marine.

Methods

In order to produce a nationwide current ecosystem map across all six ecological domains we applied a composite mapping approach that integrated multiple spatial data sources in varying formats. This method allowed us to draw together point, polygon, and raster data sets from across the domains and use them collectively to identify and map the EFGs present in New Zealand.

Domain teams led the mapping for their respective environments, following a common workflow: assess available data sets, align domain classifications with the EFGs, and produce spatial layers. Once mapped, EFGs were compiled into a stacked raster data set, with each layer representing an individual EFG. The final national product was standardised to a 100 × 100 m resolution to meet Global Ecosystem Atlas requirements. The resultant maps were uploaded to the Land Resource Information System portal[1] for wider access and use, and to the Global Ecosystem Atlas.[2]

Conclusions

The current ecosystem map provides the first national-scale view of EFGs in New Zealand. Although the global nature of these classes means the map is relatively coarse, the project represents an important initial step towards aligning ecosystem concepts and spatial boundaries across domains. It also highlighted gaps and inconsistencies in current data sets, New Zealand typologies, and the IUCN GET framework.

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[1] https://lris.scinfo.org.nz/data/

[2] https://globalecosystemsatlas.org

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Recommendations

We recommend making several improvements to this first version of the current ecosystem map:

- Continue to refine New Zealand’s domain typologies, particularly at the finer IUCN GET Level 6, to allow construction of ecosystem maps that are more suitable for national and regional-scale use. We recommend that these finer-resolution maps be developed from the bottom up, based on detailed domain knowledge. Future updates to the current ecosystem map can then be produced by aggregating these Level 6 maps into broader Level 3 EFGs.
- Provide feedback to the IUCN GET Scientific Committee on EFGs that require clearer quantitative definitions or that do not adequately represent New Zealand ecosystems.
- Address existing data gaps, extend mapping coverage to offshore islands and the full Exclusive Economic Zone, and resolve boundary gaps and overlaps between domains to improve completeness and spatial consistency in future versions of the current ecosystem map.

1 Introduction

Maps of ecosystems are vital tools for biodiversity planning, resource management, and monitoring and reporting changes in ecosystem distribution over time and space. Ecosystem maps are different from, and complementary to, land-cover and land-use maps. Land-cover maps may represent the structural elements of ecosystems and vegetation (e.g. identifying areas with native forest), but not their functional or biotic components. Land-use maps are typically anthropogenic in their focus on land-based human activities, such as forestry and agriculture. An ecosystem map represents the biotic, functional, and structural components of ecosystems, and thereby illustrates the extent and occurrence of various ecosystems. New Zealand has land-cover and land-use maps, but there is a need to produce a current ecosystem map that is aligned with international best practice and is suitable for domestic application.

The International Union for Conservation of Nature Global Ecosystem Typology (IUCN GET) is a globally comprehensive ecosystem classification framework, which aims for consistency across biological domains (Keith et al. 2022). As a classification framework it distinguishes between ecosystem types by defining six hierarchical levels. Within Levels 1–3 the IUCN GET provides extensive metadata for each of the units. The units in Levels 4–6 are not yet enumerated, and instead these lower levels provide a framework to enable national or subnational ecosystem typologies to contribute to and integrate with the IUCN GET. The IUCN GET has been adopted internationally and will be used for reporting on several Global Biodiversity Framework headline indicators in the upcoming New Zealand reporting to the Convention on Biological Diversity.

The IUCN GET ecosystem functional groups (EFGs, Level 3) are groups of related ecosystems within a biome that share common ecological drivers that shape similar ecosystem properties. There are 110 EFGs, 15 of which are anthropogenic. Examples of EFGs in New Zealand include T2.3 ‘Oceanic cool temperate rainforests’, M1.2 ‘Marine kelp forests’, and F1.1 ‘Permanent upland streams’.

Although the IUCN GET has indicative maps of the EFGs, these are incomplete and imprecise for New Zealand. Mapping these EFGs using existing domain data sets would enable us to see where these ecosystems occur. While this map would probably be at too coarse a resolution to be used for regional biodiversity management or planning, it would be useful to inform future national-scale conservation and spatial planning. It could also be used to direct ecosystem mapping at finer resolutions. The map would also facilitate buy-in to the National Ecosystem Typologies programme led by the Ministry for the Environment.

Finally, creating a map of the EFGs in New Zealand would directly contribute to New Zealand’s 7th National Report to the Convention on Biological Diversity, as several of the Convention’s Global Biodiversity Framework headline indicators use a national ecosystem map of the IUCN GET EFGs.

2 Objectives

The overall aim of this project was to create a current ecosystem map of the present-day spatial distribution of the IUCN GET EFGs in New Zealand. This project was ambitious in its scope because the current ecosystem map is at a national scale and spans six domains: terrestrial, wetlands, rivers, lakes, groundwater, and marine ecosystems.

The project's specific objectives were to:

1. map IUCN GET EFGs in New Zealand using existing domain data sets
2. upload spatial layers to the Land Resource Information System portal and the Global Ecosystem Atlas.

The collection of additional data or revisions to existing New Zealand typologies was beyond the scope of this project.

3 Methods and results

To create a nationwide current ecosystem map across the six domains we used a composite approach, with many input layers from multiple data sources. We used this approach because across the domains there were many data sources and different types of data available (point, polygon, and raster data) at different spatial scales. Developing a composite map of these data layers allowed us to compile these different data sources into a map of the EFGs present in New Zealand.

Each domain team led the mapping of the EFGs in their domain and followed the same general steps:

1. explore and assess potential existing sources of data
2. align domain typologies (complete 'crosswalks')[3] with the EFGs
3. map the EFGs and resolving spatial boundary issues between EFGs within but not between domains.

EFGs were mapped to the smallest possible spatial resolution of the input data.

Once all EFGs that had data available were mapped, they were compiled into a stacked raster, with each raster layer representing a separate EFG present in New Zealand. These final raster layers were at a 100 m × 100 m spatial resolution, following the requirements of the Global Ecosystem Atlas.

Below we describe the methods followed for each domain, along with caveats, data gaps, and recommendations for further action. We also detail the steps taken to complete the final stacked raster output.

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[3] 'Crosswalking' is the systematic alignment of ecosystem types across different typologies to identify conceptual equivalents, partial overlaps, and key distinctions, thereby supporting translation and integration between typologies.

3.1 Terrestrial

3.1.1 Data sources (explored and used)

We used the Land Cover Database (LCDB, version 6.0; Bioeconomy Science Institute 2025) as the foundational layer for this mapping. It provides a practical starting point for national-scale mapping because it offers a standardised set of land-cover classes with national coverage and is updated on a regular cycle (approximately 5-yearly). Although the LCDB does not capture all ecosystem variation and can contain localised inaccuracies, it is the most comprehensive national baseline available for implementing a transparent and repeatable crosswalk and map of EFGs. We undertook the mapping across New Zealand's terrestrial domain at the extent of the Land Environments of New Zealand (i.e. the three main islands and surrounding inshore islands; Leathwick et al. 2002), which aligns with the coverage of most national terrestrial spatial layers used in this project.

In addition to the LCDB, we used a small set of ancillary variables derived from other spatial layers to provide environmental and geographical context where the LCDB alone could not distinguish between multiple plausible EFG assignments. We then used these inputs within a rules-based assignment, whereby the LCDB supplies the starting land-cover class for each cell and the ancillary variables provide additional information that allows us to distinguish between different EFGs.

We used the following ancillary variables.

- **Warm temperate forest:** We generated a warm temperate forest layer (McCarthy & McGlone 2025) for this project by combining mapped areas of warm temperate rain forests from Grubb et al. 2013 and the major phytogeographic boundary separating the northern North Island described by McGlone (1985; his Figure 2).
- **Above treeline:** We defined 'above treeline' using the Environmental Limiting Factors spatial layer (Ministry for the Environment 2012), which classifies TREELINE = 1 as above treeline. This variable also aligns with the treeline concept used in the LCDB to support the delineation of alpine classes.
- **Sand substrate:** We defined areas with a sand substrate using the New Zealand Land Resource Inventory (LRI; Bioeconomy Science Institute 2024) TOPROCK lithology codes (Wb, Us, Us', est). We augmented this with QMAP (GNS Science 2012) for Stewart Island / Rakiura, where LRI coverage is incomplete, classifying polygons with MAIN_ROCK = 'sand' south of NZTM2000 northing 4,830,000 mN.
- **Inland:** We defined inland areas as locations more than 5 km from the coast. We derived this using the NZ Coastlines and Islands spatial layer (Land Information New Zealand 2025a), generating a 5 km coastal buffer with the st_buffer function in the *sf R* package (Pebesma 2018). We selected the 5 km threshold to align with the distance used in the IUCN's global mapping approach for the MT2.1 'Coastal shrublands and grasslands' EFG.[4]
- **LUM high producing:** We defined areas of high-producing grassland using the LUCAS NZ Land Use Map (Ministry for the Environment 2020), classifying areas with LUCID_2020 = '75 - Grassland - High producing'.
- **Salt spray:** We defined areas where plant growth is influenced by salt spray using the Environmental Limiting Factors spatial layer (Ministry for the Environment 2012), classifying where SALT_SPRAY = 1.

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[4] https://global-ecosystems.org/explore/groups/MT2.1

- **Alluvial substrate:** We defined alluvial substrate areas using the LRI (Bioeconomy Science Institute 2024) TOPROCK lithology codes (riv, est, lak).

3.1.2 Crosswalking methods

We developed a crosswalk between the LCDB and the IUCN GET, but note that these two classification systems describe the landscape in different ways. LCDB provides land-cover classes that often reflect the dominant physiognomy (e.g. vegetation structure) and land use, whereas the IUCN GET defines ecosystems primarily based on function and environment. We therefore assigned each LCDB class to the EFG(s) that best matched its conceptual scope using the ancillary variables, rather than attempting to split individual LCDB classes among different EFGs. The spatial coverage of EFGs within LCDB classes can, however, be derived from the map.

We treated novel and anthropogenic ecosystems in a way that is consistent with the functional intent of the IUCN GET framework. Specifically, we mapped non-native or highly modified land covers according to their functional affinity with an EFG, recognising that many EFG definitions are largely independent of native/non-native status, because the overriding focus is ecosystem function. This meant that production systems and built environments were crosswalked directly to the most appropriate anthropogenic EFGs, while novel vegetation mixtures were assigned to EFGs that best reflected their dominant physiognomy, environmental setting, and ecological dynamics. We used ancillary variables (described in section 3.1.1 and Appendix 1) to resolve cases where an LCDB class could crosswalk to more than one EFG by considering environmental context (e.g. coastal vs inland, alpine vs non-alpine). Finally, we recorded the rationale for key decisions to ensure the crosswalk is clear and the results are transparent, reproduceable, and revisable.

3.1.3 Mapping methods

We adopted a raster-based approach to apply classification rules consistently across New Zealand's terrestrial domain. This approach reduces slivers and gaps that can occur when polygons are mismatched and greatly improves processing efficiency for large data sets. To create the base layer we converted LCDB polygons to a raster at 100 m (1 ha) resolution. For each raster cell we assigned the LCDB class that covered the greatest proportion of its area. We then implemented this conversion in R using the exact_extract function from the *exactextractr* R package (Baston 2025) to ensure accurate representation of dominant land cover. All terrestrial mapping was done in R 4.5.1 (R Core Team 2025).

We excluded areas identified as wetlands in the LCDB before applying any classification rules. For all remaining areas, we classified cells into EFGs using a rules-based framework, excluding LCDB classes corresponding to other domains (e.g. Lake or Pond, Mangrove). This approach provides transparency and reproducibility, and a framework from which future refinements can be developed. As part of refining the rules, we recorded conflicts (cases where applying the rules resulted in allocating more than one EFG to a cell) and null (where no rules applied to a cell) metrics. These checks ensured the final map was complete and free of unresolved issues.

Explanation of rule decisions

We developed mapping rules to reflect the ecological principles and vegetation structure of the EFGs. Assignments were first based on LCDB classes, with modifiers applied (using our ancillary variables) where necessary to capture environmental gradients. Following are some examples.

- Forest LCDB classes were assigned to the two forest EFGs present in New Zealand: T2.3 ‘Oceanic cool temperate rainforests’ and T2.4 ‘Warm temperate laurophyll forests’, based on our warm temperate forest ancillary variable.
- Grasslands were split between alpine and temperate tussock grassland EFGs (T6.4 ‘Temperate alpine grasslands and shrublands’ and T4.5 ‘Temperate subhumid grasslands’) based on treeline position; MT2.1 ‘Coastal shrublands and grasslands’ based on the presence on sandy substrates and the likely influence of salt spray; and T7.2 ‘Sown livestock pastures’ and T7.5 ‘Derived semi-natural pastures and old fields’ based on a combination of the LCDB class and the LUCAS NZ Land Use Map.
- Exotic forests, harvested areas, and orchards were assigned to T7.3 ‘Plantations’, while croplands were mapped to T7.1 ‘Annual croplands’. Surface mines, built-up areas, and transport infrastructure were assigned to T7.4 ‘Urban and industrial ecosystems’.
- Exposed substrates from the terrestrial domain such as sand, gravel, and rock were mapped to dune, rocky or alpine classes (MT2.1 ‘Coastal shrublands and grasslands’, T3.4 ‘Young rocky pavements, lava flows and screes’, T6.2 ‘Polar/alpine cliffs, screes, outcrops and lava flows’) depending on treeline position, and distance to coast.

We provide a full summary of our rules in Appendix 1.

3.1.4 Caveats

The terrestrial map inherits several important limitations from the input data, particularly the LCDB. Although it provides the best available nationally consistent baseline for land cover, its thematic classes do not always align cleanly with the EFGs, and it can lag behind recent land-cover change. For example, areas that have transitioned from less intensively managed grassland to high-producing grassland may not yet be mapped as such (Walker et al. 2006). Conversely, some grasslands showing high vigour on fertile or moist soils may be classified as high-producing grassland even where intensive management is absent (Thompson et al. 2004). LCDB also tends to under-detect structural transitions, such as gradual woody encroachment into grasslands.

We recognise this latter limitation, but it is less problematic for the relevant EFG assignment (T7.5 ‘Derived semi-natural pastures and old fields’), which is sufficiently broad in concept to accommodate a woody component. T7.5 also allows for a mix of native and non-native species, which probably reflects much of the area mapped to this EFG. Some grassland areas, particularly those with a limited history of management, may, however, be more appropriately aligned with T4.5 ‘Temperate subhumid grasslands’. Unfortunately, we lack the required spatial data (e.g. mapped structural and compositional data) to make this delineation. There were also difficulties mapping rocky terrestrial EFGs. We could not reliably distinguish areas mapped as Gravel and Rock in the LCDB that functionally belong to freshwater EFGs (e.g. river banks and rocky islands) from terrestrial areas. To address this, we used landform proxies (e.g. maps of alluvial substrates), but some areas adjacent to rivers remain incorrectly mapped.

We encountered two main sources of uncertainty during the crosswalk from the LCDB to the EFGs. First, some EFGs require conceptual interpretation when applied in a New Zealand context, particularly those defined by broad abiotic settings (e.g. the two forest EFGs found in New Zealand) or global ‘typical’ expressions that do not map neatly onto local ecosystems (e.g. T3.3 ‘Cool temperate heathlands’). Second, several LCDB classes can plausibly correspond to more than one EFG (e.g. the LCDB class Low Producing Grassland corresponds to five EFGs; see Appendix 1). Also, individual EFGs can occur in multiple LCDB classes (e.g. MT2.1 ‘Coastal shrublands and grasslands’ corresponds to several LCDB classes). This many-to-many relationship complicates the crosswalk, meaning that some assignments represent best-fit compromises rather than unequivocal mappings.

Additional caveats arise from the mapping to a 100 m raster. A pixel-based approach improves consistency and processing efficiency, but it can be less locally accurate than polygon-based mapping, because we assigned each cell a single dominant value, even where the underlying landscape may be heterogeneous. This generalisation alters boundaries and reduces the representation of narrow features and small patches. These effects are most pronounced in environments with fine-grained mosaics or linear structures, where the map tends to reflect dominant cover rather than the full range of components present within and between cells.

Several limitations relate to schema fit rather than data quality. The shrubland EFGs emphasise heathland-like systems, which align with some wetland shrubland ecosystems but do not always correspond well to New Zealand's widespread low-woody ecosystems. This affects confidence in representing ecosystems captured by LCDB classes such as Manuka and/or Kanuka, Mixed Exotic Shrubland, Matagouri or Grey Scrub, Gorse and/or Broom, and woody variants of Fernland and Flaxland, none of which have an obvious one-to-one match with the heath-focused EFGs. Forest EFGs pose a different challenge: many are framed primarily by abiotic factors, whereas major ecological differences in New Zealand forests often also align with broad biogeographic gradients (McGlone 1985). We addressed this by mapping EFGs based on a bioclimatic representation sourced from published sources (McGlone 1985; Grubb et al. 2013), but preferably mapping would be achieved via nationally consistent forest type maps crosswalked to the EFGs.

Finally, areas we mapped as T7.5 'Derived semi-natural pastures and old fields' should be interpreted with care. Although this class sits within T7 'Intensive land-use biome' in the IUCN GET framework, areas mapped as this EFG can be highly relevant for native biodiversity in New Zealand, including providing habitat for native species and facilitating secondary woody succession to indigenous forest. The map can therefore support broad-scale assessment of derived ecosystems that retain conservation value. It is important to stress that its place within a biome described as having 'Intensive' land use does not imply low ecological importance.

3.1.5 Gaps

The most important gaps arise where we lack nationally consistent layers required to map certain EFGs, even where those ecosystems are ecologically significant. MT1.3 'Sandy shorelines' provides a clear example where we do not have a reliable nationwide spatial layer that distinguishes these substrates in a way that supports rule-based assignment, and this limitation is compounded by the use of a 100 m resolution raster. Most shoreline environments occur as long, narrow strips that fall below the effective width of a grid cell, so even with improved inputs a 100 m raster will under-represent or fragment these systems.

We also could not include the Department of Conservation (DOC) Naturally Uncommon Ecosystems (NUE) layer because of data-sharing limitations. This prevented us from mapping many spatially restricted ecosystems the LCDB does not capture. Our map also omits or under-represents several EFGs because they are not accommodated by current spatial data or do not fit well within the current crosswalk structure. This includes the shrubland and heathland EFGs (T3.2 'Seasonally dry temperate heath and shrublands' and T3.3 'Cool temperate heathlands'), although some areas of these were mapped in the Wetland domain. Another potential under-representation includes T4.4 'Temperate woodlands', which probably occurs in New Zealand but we were unable to map it reliably. In addition, we could not identify an obvious EFG that describes exposed, non-inundated dunes. Although ecologically distinct from vegetated dunes and sandy shorelines, the IUCN GET lacks an EFG to represent them.

There are also geographical coverage gaps. We could not map offshore islands, the subantarctic islands, or the Chatham Islands because the necessary spatial data were not available in a consistent form for those areas.

Finally, the IUCN GET framework lacks an obvious EFG for drier variants of T2.3 ‘Oceanic cool temperate rainforests’ (e.g. South Island lowland beech forests), because the IUCN definition includes a large water surplus (see McCarthy & Wiser 2024). Whereas New Zealand forests fall along a continuum that includes relatively drier settings, this definition means the map cannot represent those forest types. This is a conceptual limitation, and it highlights a potential area for future refinement to the IUCN GET.

3.1.6 Recommendations specific to this domain

- Work with New Zealand terrestrial domain experts and the IUCN GET Scientific Committee to refine EFGs that do not translate cleanly to New Zealand, or facilitate the definition of new EFGs, especially for low-woody shrublands and ‘drier’ forest expressions that currently lack representation in the framework.
- Update this version of the terrestrial map as new versions of the LCDB (or improved national land-cover products) become available.
- Investigate whether alternative or additional ancillary variables could be used to improve the separation of many-to-many LCDB/EFG crosswalks, particularly for forest–shrubland–grassland transitions, forest types, and alpine/lowland differentiation (e.g. improved maps of woody cover, disturbance proxies, and more direct coastal influence maps).
- Prioritise the development or acquisition of nationally consistent shoreline substrate layers (sandy/muddy/rocky) and assess whether a supplementary higher-resolution coastal workflow is needed to represent long, narrow features that are systematically lost at 100 m resolution.
- Work with the Rivers domain team to ensure ecosystems adjacent to rivers are correctly mapped.
- Negotiate access to the DOC NUE layer or develop a permission-safe derivative/aggregation that can be used to improve representation of spatially restricted ecosystem types.
- Develop guidance for end-users on interpreting T7.5 ‘Derived semi-natural pastures and old fields’ in a New Zealand context, emphasising its conservation relevance and expected internal heterogeneity despite its placement within T7 ‘Intensive land-use biome’.
- Extend mapping coverage to offshore islands, the Chatham Islands, and the subantarctic islands once consistent supporting layers become available.
- Maintain a formal ‘gap register’ of classes likely to be absent or under-represented (e.g. T3 ‘Shrublands and shrubby woodlands biome’, T4.4 ‘Temperate woodlands’, MT1 ‘Shorelines biome’), and link each gap to the specific data or schema improvement required to address it in subsequent versions.

3.2 Wetlands

3.2.1 Data sources (explored and used)

We used LCDB as the foundational layer for this mapping due to its national coverage and its ability to provide a consistent method of delineating non-wetland terrestrial systems (covered by the Terrestrial domain) and estuarine and marine systems (more appropriately covered by the Marine and Estuarine domain). We refer the reader to the advantages and disadvantages of the LCDB discussed under the Terrestrial domain, section 3.1.1.

There is one disadvantage to using the LCDB specific to wetlands: the LCDB contains no wetland class information (i.e. bog, fen, swamp are not attributed – the layer just maps 'wetlands' without further details), and the breadth of the vegetation classes means that it cannot be used as a stand-alone source of information. This notwithstanding, the LCDB was used to select the areas of New Zealand considered to be wetland EFGs. This was achieved using the attributes 'Wetland_23' (whether a polygon was considered to be a wetland in 2023, the most recent timestep), selected where the attribute value was 'yes', and 'Onshore_23' (whether a polygon was considered to be within the coastline of New Zealand), selected where the attribute value was 'yes'. Only polygons that satisfied both conditions were selected.

Non-wetland polygons were considered more appropriately dealt with by the Terrestrial domain, while offshore polygons were considered more appropriately dealt with by the Marine and Estuarine domain. From our selected polygons, those that were LCDB class Herbaceous Saline Vegetation were excluded from our data set, as these were considered likely to be estuarine areas that are within the coastline of New Zealand (e.g. Ōkārito Lagoon). We rasterised the final resulting polygons using a parent raster of the same extent and with the same characteristics as that of the Terrestrial domain to maximise complementarity and minimise overlap and underlap.

We then considered how to allocate wetland class[5] to our selected LCDB polygons. We explored using the 'current' (early 2000s) and historical (nominally 1280 AD) wetland layers described in Ausseil et al. (2008, 2011) to assign New Zealand wetland classes to the LCDB. Both Ausseil et al. layers include a wetland class attribute; the historical layer is greater in extent because it includes areas considered to be wetlands prior to human arrival that have subsequently been lost. However, neither layer covered what we considered to be an acceptable proportion of our selected LCDB wetlands: the most extensive historical layer still left c. 25% of wetlands without a class attribute. Therefore, we proceeded to reimplement the principles of Ausseil et al. for all LCDB wetland polygons. Below we list the data sets used and the purpose for which they were used.

- **Vegetation and wetlands**
  - The LCDB was used for wetland polygons and most current vegetation (e.g. to separate forested from non-forested EFGs).
  - The Land Resource Inventory (LRI; Manaaki Whenua – Landcare Research 2010b, 2023a) was used for vegetation data corresponding to those used by Ausseil et al. 2008 and was used to identify red tussock and alpine herbfields.
- **Soil and drainage characteristics**
  - The Fundamental Soil Layer (FSL; Manaaki Whenua – Landcare Research 2010a, 2023b), all attributes, was used, along with an internally held data set, to cover Stewart Island / Rakiura, for which otherwise there would be no data. These data

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[5] Per Johnson & Gerbeaux 2004, e.g. bog, fen, swamp

describe key variables such as whether a soil is mineral or organic, and the drainage class.
  - The soil pH layer for New Zealand (McCarthy et al. 2021) was used, as soil pH is often used to identify wetland classes that tend to have more acidic soils, such as bogs and New Zealand fens.
- **Elevation and slope data** were used, both of which were taken from McCarthy et al. 2021, to infer whether a wetland is high elevation (which reduces the likelihood of swamps – smaller catchments) or is on sloping ground (slope is positively correlated with seepages), per Ausseil et al.
- **River and lake proximity data**, using the Land Information New Zealand 1:250,000 river polygons (Land Information New Zealand 2025d) and river centrelines (Land Information New Zealand 2025c) layers, and the Land Information New Zealand 1:250,000 lake polygon layer (Land Information New Zealand 2025b), were useful to reduce the likelihood of bogs and fens, as per Ausseil et al. (2008), as marshes and swamps fed by surface water are considered more likely.

These data layers were combined with expert opinion and reference to the Ausseil et al. documentation to create a likelihood layer for each wetland class. (The rule set is provided in Appendix 2.) As per Ausseil et al. (2008), the likelihood values for each wetland class for each raster cell are multiplied to calculate a likelihood value for each raster cell, for each wetland class. Each raster cell was assigned to the wetland class that had the greatest likelihood. This meant that LCDB polygons could be composed of more than one wetland class. This is considered to be ecologically realistic (e.g. a marsh grading into a swamp, or a fen on the outer perimeter of a bog). The last task remaining was a conversion of New Zealand wetland classes into EFGs.

3.2.2 Crosswalking methods

We applied a refined crosswalk to the initial one set out in Burge 2025, following discussions with New Zealand and Australian experts who had been involved with the creation of the IUCN GET typology. This prompted improvements to how we treated pākihi and gumland, and fens. Most pākihi and gumland vegetation is largely analogous to the EFG T3.3 ‘Cool temperate heathlands’, except those on organic (peat) soils, and therefore by default we placed pākihi and gumland in T3.3. Those on peat soils were retained within TF1.6 ‘Boreal, temperate, and montane peat bogs’. New Zealand fens are typically ‘poor’ fens, with low nutrients and pH, and therefore also best accommodated in TF1.6. The EFGs separate forested and non-forested wetlands, whereas in New Zealand forested and non-forested wetlands may occur within the same New Zealand wetland class. To accommodate this, our final rule converted any cell that contained vegetation mapped by LCDB as forest to TF1.2 ‘Subtropical-temperate forested wetlands’. These rules are set out in Table 1.

Table 1. Rule set for converting New Zealand wetland classes to EFGs. Cell colours are used to identify similar rules; row colours indicate similar realms

Original map class value	TF3.3 'Cool temperate heathlands'	TF1.2 'Subtropical/temperate forested wetlands'	TF1.3 'Permanent marshes'	TF1.4 'Seasonal floodplain marshes'	TF1.6 'Boreal, temperate and montane peat bogs'
Bog		YES where LCDB class indicates forest			By default
Fen		YES where LCDB class indicates forest			By default
Marsh		YES where LCDB class indicates forest		By default	
Swamp		YES where LCDB class indicates forest	By default		
Seepage		YES where LCDB class indicates forest	By default		
Pākihi	By default	YES where LCDB class indicates forest			YES where soil is organic. Does not override forest rule
Gumland	By default	YES where LCDB class indicates forest			YES where soil is organic. Does not override forest rule

Note: The EFGs TF1.1, TF1.5, and TF1.7 are not considered to be present in New Zealand so are not listed.

3.2.3 Mapping methods

The relevant information from all input vector layers was rasterised and input raster layers reprojected to a common 100 m spatial grid. A fuzzy multi-criteria evaluation approach (Jiang & Eastman 2000) was used to apply the principles of Ausseil et al. to combine the relevant input layer into national-scale layers of probability for each wetland class. The wetland class with the highest possibility was then assigned to each 100 m cell identified as a terrestrial wetland by the LCDB. The whole analytical process was implemented in Python (Python Software Foundation 2025) code using the *GDAL* (GDAL/OGR contributors 2023), *NumPy* (Harris et al. 2020), *SciPy* (Virtanen et al. 2020), and *RichDEM* (Barnes 2016) packages.

3.2.4 Caveats

We made several design decisions in creating the wetland EFG map, which we highlight here for future consideration, and then summarise the caveats to the current approach.

Our overall approach was to make the extent of wetlands in New Zealand using a ‘parent’ layer (LCDB) that reduced overlaps and gaps for non-wetland terrestrial ecosystems, and allowed a consistent delineation between coastal systems and palustrine systems. This design choice has some important implications: although the LCDB is very effective at mapping change over time in known ecosystems, it is not necessarily a spatially comprehensive stocktake of the extent of ecosystem types, such as wetlands. This is demonstrated by the difference between the Ausseil et al. (2008, 2011) current wetland layer and the LCDB wetland layers (see also Dymond et al. 2021), and additional wetlands found during regional council mapping that are not mapped within the LCDB (Bartlam & Burge 2024).

An alternative approach would be to compile all mapped wetland layers, which would maximise the spatial extent covered but also introduce several issues. The first is that sampling effort on mapping wetlands is likely to be uneven across the country: some regional councils have mapped catchments in their regions down to 0.05 ha while others have not, and although there is a requirement to map inland, natural, wetlands to 0.05 ha minimum size by 2030, this requirement does not include wetlands on public conservation land.[6] The second issue is which data sources to follow where one maps a wetland and another maps a terrestrial ecosystem. This would be particularly problematic if we had followed the generous, international definition of wetlands that includes marine areas up to 6 m deep at low tide, rivers, and lakes.[7] In some cases, multiple EFGs may truly co-occur or co-exist due to the way they are defined (see, for example, Lundquist et al. 2024). However, we foresee that in many others, ‘overlap’ may occur due to data of different quality, provenance, spatial scale, or time period, where in reality there is only one ‘correct’ EFG present. At the national scale the only tractable solution will be coarse rules to choose which EFGs to prioritise over others, where required.

We chose to assign New Zealand wetland class values (per Johnson & Gerbeaux 2004) and then use ancillary data to help convert these to Level 3 EFGs. In the future, once the occurrence of Level 3 EFGs is better understood and mapped using field observations in New Zealand, it might be preferable to map Level 3 EFGs directly using relevant covariates rather than via New Zealand wetland classes.[8]

Given the absence of wetland class attributes in the LCDB, we assigned a New Zealand wetland class for each polygon using a modelling approach rather than field observations or manual interpretation of desktop layers. Our modelling approach followed the reasoning and principles in Ausseil et al. 2008, 2011, but we note that field validation at the time showed that marshes and swamps, and fens and bogs, were pairs of wetland classes that were poorly distinguished. Our results are likely to similarly suffer, but errors with respect to bogs and fens have little impact here, as both are assigned to the same EFG. In disaggregating forested wetlands from other wetland classes we had to choose which LCDB classes would be indicative of forest. We chose to include classes that were clearly forest (e.g. LCDB Indigenous Forest and Exotic Forest) but also LCDB

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[6] National Policy Statement for Freshwater Management 2020.

[7] Convention on Wetlands, an intergovernmental treaty for the conservation and wise use of wetlands and their resources (see http://www.ramsar.org).

[8] Particularly as a number of New Zealand wetland classes were split between several EFGs.

classes Manuka and/or Kanuka, and Broadleaved Indigenous Hardwoods that may include shrublands.

All source data included were at the national scale; for example, the FSL soils data are at the 1:50,000 scale, whereas the LCDB is designed to match the scale and accuracy of the 1:50,000 topographic database. A 1:50,000 scale means that users are advised to zoom in no further than 1:50,000 on a geographical information system. As our raster has 100 × 100 m cells, a portrait map on A4 (e.g. 20 × 20 cm) would contain 10,000 pixels: this is the scale at which the map should be interpreted.

3.2.5 Gaps

We identified the following gaps that arise because of the data sources available and the analytical steps undertaken.

- Because the LCDB has a minimum polygon size of 1 ha it misses small wetlands. As a result these small wetlands are also missing from the output data set.
- Wetlands in general are likely to be under-represented, even where they appear in the source data set, as a 1 ha wetland may be ‘spread’ across several raster cells, meaning it may not appear in any of them in the final output.
- Insufficient data precluded mapping of the Chatham Islands.
- Our reliance on non-peer-reviewed soils data for Stewart Island / Rakiura (held by the Bioeconomy Science Institute) weakens the robustness of our inference as to wetland classes on Stewart Island / Rakiura. The relevant soils data should be reviewed and made publicly available in the future if resourcing allows.
- We classified all polygons mapped as wetlands in the LCDB where they met our criteria. However, we note the existence of F3 ‘Artificial wetlands biome’.[9] The EFGs within this biome are unlikely to fall within what LCDB mapped as wetlands and were considered more likely to fall within the remit of the estuaries (F3.4 ‘Freshwater aquafarms’) and lakes (EFGs F3.1 ‘Large reservoirs’ and F3.2 ‘Constructed lacustrine wetlands’) domains. Biome F3 includes drains and canals, which are discussed in the Rivers section of this report (section 3.3). Here we simply note that the lack of a comprehensive data set for drains, which make up part of F3.5 ‘Canals, ditches and drains’, is documented (Burge et al. 2023), and that mapping of canals is inconsistent in extant data sets.
- Our approach to modelling wetland class has not been ground-truthed. Observed (either via desktop or field methods) wetland class would be a superior method to assess EFGs, but the scope and time available for this work dictated that we model wetland class and then create rules for converting these classes to EFGs.
- Regional wetland mapping data sets, which incorporate observations of wetland class and smaller wetlands, were unable to be incorporated alongside LCDB data due to the project’s scope.

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[9] Comprising: F3.1 ‘Large reservoirs’, F3.2 ‘Constructed lacustrine wetlands’, F3.3 ‘Rice paddies’, F3.4 ‘Freshwater aquafarms’, and F3.5 ‘Canals, ditches and drains’.

3.2.6 Recommendations specific to this domain

We provide recommendations firstly for an improved, future Level 3 EFG map, and then recommendations that might be considered to progress an IUCN GET Level 6 ‘Subglobal ecosystem types’ map.

Improvements to a level 3 EFG map

- **Improve the source data for mapping extent:** The terrestrial-freshwater palustrine wetlands biome would be best mapped by a national-scale map of current wetland extent that includes wetland class as an attribute. This would not only improve our mapping, but would also improve national-scale reporting on wetland ecosystems, which vary enormously among wetland classes (McGlone 2009). Such a layer could build on current coarser mapping that lacks a wetland class attribute (LCDB), regional council mapping, or other wetland maps, or it could be an entirely new product to ensure even detection effort. Such a layer could also be incorporated into the LCDB at an appropriate spatial resolution.
- **Improve the modelling of EFG classes:** We undertook a modelled approach to assigning wetland class to LCDB polygons within the constraints of the project’s scope. Improvements could include rule refinement, or testing resulting attribution against other data sets, such as council mapping. We incorporated unpublished soils data to extend the wetland domain coverage to Stewart Island / Rakiura to match the extent of the terrestrial domain. These data would preferably be reviewed and released publicly to increase the robustness of the Stewart Island / Rakiura mapping. Finally, once EFGs are better understood and applied within New Zealand, consideration could be given to mapping them directly, rather than mapping wetland classes as a proxy for EFGs, which requires additional rules-based steps to disambiguate New Zealand wetland classes.
- **Create a more precise map instead of the current coarse raster map to improve extent estimates:** For New Zealand use, an improved map of Level 3 EFG extent could be created that comprises either polygons or a finer-grain raster (e.g. 25 m cells instead of 100 m, meaning the area of each cell would be 625 m^2 or 0.06 ha, compared to 10,000 m^2 or 1 ha). This would allow incorporation of small wetlands that have been mapped. This should be achievable because the source wetland mapping data are polygons, and future source data are also likely to be polygons. However, unless wetland class attributes become available through other data sources, the wetland class will still need to be modelled and current data sets are relatively coarse, which may impose a limit on the increased level of precision achievable with respect to wetland type. At a national scale it is computationally more efficient to model with raster, and the current model is based on a raster workflow. The raster model could be revised (and improved), and could be applied to a polygon layer of wetlands or a finer raster-scale layer, which would better represent the extent of Level 3 wetland EFGs in New Zealand.

Next steps towards a Level 6 ‘Subglobal ecosystem types’ map

Progress towards a Level 6 map requires that Level 6 units be defined by New Zealand wetlands and for a map of those units to be created. While Level 6 units nest conceptually within Level 3 units, we do not consider that any attempt to ‘disaggregate’ the current Level 3 map is advisable. Many Level 6 communities will be smaller than the spatial grain used to create the Level 3 map and therefore would be missed entirely in a disaggregation attempt. Furthermore, due to the necessity of modelling Level 3 units (described above) rather than using observations, it is highly likely the map will be inaccurate in places, although we did not have the opportunity in this project to quantify the inaccuracy. Therefore, the recommended action towards a cohesive pair of Level 3 and Level 6 maps is to progress defining and then mapping Level 6 ecosystem units, and then *aggregate* those units into a Level 3 map. At the same time, we recommend ongoing efforts to recognise and address overlaps and gaps of coverage among and within domains.

3.3 Rivers

A range of river typologies are currently in use in New Zealand. Franklin and Booker (2024) evaluated how well two of the most commonly used typologies, the River Environment Classification (REC) and Freshwater Environments of New Zealand (FWENZ), map to the EFGs. They concluded that while some classes in both typologies could be crosswalked to the EFGs moderately well, there was significant ambiguity and uncertainty in aligning class definitions, meaning that neither typology was a strong candidate for the basis of national mapping and reporting. Franklin and Booker (2024) concluded that neither REC nor FWENZ was strongly aligned with the principles for a national ecosystem typology and recommended exploring the development of a new national ecosystem typology for rivers.

Considering the conclusions of Franklin and Booker, and the work programme currently underway exploring the future development of a national ecosystem typology for rivers in New Zealand, a pragmatic decision was made directly map the IUCN GET river EFGs based on readily available environmental attributes, rather than by crosswalking an existing typology to the IUCN typology.

3.3.1 Data sources (explored and used)

There are two main forms of data required for generating the national map of river EFGs:

- a digital representation of the national river network
- environmental attributes mapped to the river network that can be used as the basis for delineating EFGs.

River network

We considered two main options for the digital representation of the national river network onto which the EFGs would be mapped: the LINZ Topo50 NZ River Centrelines and the New Zealand Digital River Network v2.4 (DN2.4). While the LINZ Topo50 River Centrelines are generally considered more geographically accurate, DN2.4 has been widely used as the basis for mapping environmental attributes onto the national river network. DN2.4 was therefore selected as the preferred option.

We note that Earth Sciences New Zealand is currently leading a project funded by the Ministry for the Environment to develop a new, standardised and updateable national digital river network. However, the timeline for our project did not align with the delivery dates for the new national digital river network, so we did not consider the new digital river network for this project.

Environmental attributes

To generate maps of the EFGs from the Rivers domain we required maps of environmental attributes across the river network that could potentially be used to delineate the different EFGs. There is a wide range of derived and estimated environmental attributes associated with DN2.4, including information on catchment area, elevation, slope, and stream order; estimates of different flow metrics, wetted width, and substrate composition; and derived climatological attributes (e.g.

temperature and rainfall metrics). Many of these environmental attributes are available either as attributes associated with the REC[10] or via NZ River Maps[11] (Whitehead & Booker 2019, 2020).

3.3.2 Crosswalking methods

Franklin and Booker (2024) previously concluded that only two EFGs from the Rivers domain are likely to be present in New Zealand:

- F1.1 ‘Permanent upland streams’
- F1.2 ‘Permanent lowland rivers’.

Consequently, our focus was on deriving a reproducible and transparent process for delineating these two classes across the New Zealand river network.

F1.1 ‘Permanent upland streams’

This class is described as ‘small rivers or streams in mountainous or hilly areas characterised by steep gradients and fast flow’ (Kingsford, MacNally, Giller, Rains, Kelly-Quinn et al. 2022). They are considered high-energy environments, often with coarse substrates and a riffle-pool habitat structure.

F1.2 ‘Permanent lowland rivers’

This class is described as ‘lowland rivers with slow continuous flows up to 10,000 m^3/s, common at low elevations (Kingsford, MacNally, Giller, Rains, Arthington et al. 2022). They are distinguished by shallow gradients, low turbulence, low to moderate water velocities, and moderate flow volumes, and are dominated by depositional processes.

Delineation

While stream order is prominent as a descriptor for differentiating classes F1.1 and F1.2 in Kingsford, MacNally, Giller, Rains, Kelly-Quinn et al. 2022 and Kingsford, MacNally, Giller, Rains, Arthington et al. 2022, our view was that this was a poor basis for delineating these classes in New Zealand. This is primarily because there are many examples of streams of order 1–3 (suggested to delineate permanent upland streams) in lowland, shallow-gradient areas. Therefore, these streams, while often relatively small, are functionally more consistent with the low-energy, depositional characteristics of the lowland rivers EFG (F1.2).

Instead, we identified stream gradient as being a primary differentiator between the two EFGs. Stream gradient has a strong influence on channel morphology, hydraulic characteristics, and sediment transport process, and hence stream ecosystem structure and function (Buffington & Montgomery 2022), which is consistent with the separation of steep-gradient, high-energy, erosional streams (F1.1) from shallow-gradient, low-energy, depositional streams/rivers (F1.2). There are also precedents for using stream gradient as a basis for delineating river types (e.g. Rosgen 1994; Buffington & Montgomery 2022). Stream gradient was therefore considered a more mechanistic delineator compared to a simplistic, elevation-based classification of upland versus lowland that is better aligned with the functional descriptions of the classes.

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[10] https://data-niwa.opendata.arcgis.com/maps/3a4b6cc2c1c74fbb8ddbe25df28e410c/about

[11] https://shiny.niwa.co.nz/nzrivermaps/

Based on Rosgen 1994, we selected a stream slope threshold of 2% to delineate steep-gradient, high-energy streams (F1.1) from shallow-gradient, low-energy streams (F1.2).

3.3.3 Mapping methods

DN2.4 consists of c. 500,000 river reaches with an average reach length of c. 700 m. Mean stream slope was derived for each river reach (nzsegment) based on the upstream and downstream elevation, and the length of each reach. Each nzsegment was then classified as 'steep' (>2%; F1.1) or 'shallow' (≤2%; F1.2) gradient.

All rivers were mapped as line features due to the absence of mapped polygon features for most rivers and streams in New Zealand. As a surrogate for stream extent, predicted river width at median flow (Booker 2010) is provided for each nzsegment.

3.3.4 Caveats

As previously discussed, and highlighted in Franklin & Booker 2024, there was no strong candidate among current river typologies in use in New Zealand for crosswalking to the river EFGs. Consequently, we chose to use a direct delineation approach to generate national maps of river EFGs. This is beneficial because it avoids the ambiguity of crosswalking between typologies, but it also means there is no direct way to align the map of EFGs with existing river typologies in New Zealand.

Our EFG delineation is specific to the current version of the digital river network (DN2.4), which is derived from a 30 m digital elevation model (DEM). DN2.4 will be superseded in 2026 by the new freshwater digital network currently under development for the Ministry for the Environment, which is based on a finer-resolution DEM. This will result in changes to the shape of the digital representation of the river network and the precision of the upstream/downstream elevations associated with each reach. Stream slope for each segment will be refined and will result in a different (although likely very similar) reach-scale map of the EFGs in New Zealand.

Classification and mapping were undertaken at the individual stream reach (nzsegment) level. This means the two classes are not necessarily contiguous within a catchment, and consecutive reaches can switch back and forth between classes as stream gradient varies across the landscape. Broadly speaking, however, F1.1 'Permanent upland streams' occur predominantly in higher-elevation hill and mountainous areas, while F1.2 'Permanent lowland streams' are primarily found in low-elevation areas. We chose not to apply a smoothing approach that might lead to a more contiguous grouping of classes within a catchment because:

- the EFGs are defined functionally, so if local stream gradient is presumed to be the primary driver of local stream form and function, then classifying streams at the reach scale is consistent with reflecting local stream function
- implementing a smoothing function would require arbitrary decisions to be made on the spatial extent of the smoothing, whether the smoothing extends upstream and/or downstream of the reach, and how to apply smoothing at stream confluences.

If a more contiguous grouping of classes were considered desirable, a range of smoothing options could be explored.

The ecosystem map generated in this project is a line feature so it is not suitable for accurately quantifying the spatial extent (area) of river ecosystems. Estimated wetted width at median flow based on statistical models has been integrated into the mapping layer as a surrogate for estimating area. However, it should be noted that the spatial extent of a river is not necessarily defined by its wetted area, which varies temporally with river flow. Polygon features are available for a limited number of larger rivers in the LINZ Topo50 series, and we understand that work has recently been completed by the University of Canterbury to map the spatial extent of braided rivers. However, there remain considerable gaps in our ability to deliver polygon features of the river network at a national scale.

We also note that the river EFG map has been developed in isolation from the maps of other domain EFGs. It was out of scope of this project to check topology between domains (e.g. where rivers transition to estuaries).

3.3.5 Gaps

We have generated the current map of river EFGs based on the assumption that only two EFGs (F1.1 and F1.2) are likely to be present in New Zealand. There is high certainty that the vast majority of New Zealand rivers will fall into these two classes, but there could be localised occurrence of ‘freeze-thaw rivers and streams’ (F1.3). There is also some ambiguity as to where naturally intermittent streams should be classified; for example, should they be considered ‘seasonal’ streams/rivers (F1.4/F1.5)? We are unaware of readily available data that could be used to simply identify and confirm the presence/absence of these river types.

F3.5 ‘Canals, ditches and drains’ was not mapped as part of this project. These artificial streams are often low gradient and are characterised by high uniformity of physical habitat (Kingsford, Robson et al. 2022). They often support a low diversity of species and can be highly degraded, but can also function as novel habitats that provide a refuge for native biota in some circumstances.

Currently, the network of canals, ditches and drains in New Zealand is not well mapped, restricting our ability to delineate them.

3.3.6 Recommendations specific to this domain

- Collaborate with the IUCN team to refine the qualitative definitions of the river types (F1.1–1.7) to remove inconsistencies and improve delineation.
- Update the EFG map to the new freshwater digital river network once this becomes available.
- Investigate whether there are alternative or additional environmental attributes that could be used as the basis for more effectively delineating river classes.
- Check whether ‘freeze-thaw’ and ‘seasonal’ classes are legitimately absent using temperature modelling and flow regime modelling, respectively.
- Explore the need to generate a river polygon feature rather than a line feature for mapping the spatial extent of river ecosystems, especially for braided river systems.
- Check the overlap between boundaries caused by misalignment of mapping with other ecosystem domains (terrestrial, estuarine, lakes, wetlands, artificial).
- Work with the Ministry for the Environment technical working groups to develop a local river ecosystem typology that can be mapped to the EFGs.

3.4 Lakes

3.4.1 Data sources (explored and used)

We primarily used two key data sources. The first was a data set generated in 2024 that documents the number of lakes larger than 1 ha in New Zealand (Schallenberg et al. 2024). This data set represents an update of lakes from the original Freshwater Ecosystems of New Zealand (FENZ) database (Leathwick et al. 2010). In addition to confirming the number of lakes, the updated data set includes data and information on each lake, such as surface area, geomorphological classification, and indicators of whether it is ephemeral. This database is hosted by the Ministry for the Environment and is available both as a spreadsheet and as a GIS layer containing lake polygons and associated metadata.

The second data source used was metadata generated by Earth Sciences New Zealand, as described in Booker & Snelder 2025. This data set provides newly derived metadata for lakes (excluding artificially constructed lakes) identified in Schallenberg et al. 2024. Although the database includes information on a wide range of attributes, such as predicted solar radiation, catchment size, and land use, the only attribute used in the present analysis was predicted winter air temperature at each lake.

In addition to these two data sources, we used expert judgement to identify FM1.3 ‘Intermittently closed and open lakes and lagoons’ (ICOLLs) and F2.7 ‘Ephemeral salt lakes’ (see section 3.4.2).

3.4.2 Crosswalking methods

The Lakes biome (F2) sits within the core realm of Freshwater in the IUCN GET system. This includes 10 relevant ecosystem functional groups:

- F2.1 ‘Large permanent freshwater lakes’
- F2.2 ‘Small permanent freshwater lakes’
- F2.3 ‘Seasonal freshwater lakes’
- F2.4 ‘Freeze-thaw freshwater lakes’
- F2.5 ‘Ephemeral freshwater lakes’
- F2.6 ‘Permanent salt and soda lakes’
- F2.7 ‘Ephemeral salt lakes’
- F2.8 ‘Artesian springs and oases’
- F2.9 ‘Geothermal pools and wetlands’
- F2.10 ‘Subglacial lakes’.

Two other ecosystem functional groups relevant to lakes in New Zealand are included in F3 ‘Artificial wetlands biome’ within the core realm Freshwater:

- F3.1 ‘Large reservoirs’
- F3.2 ‘Constructed lacustrine wetlands’.

Also, within the realm Freshwater Marine (FM) and FM1 ‘Semi-confined transitional waters biome’ there is one relevant EFG:

- FM1.3 ‘Intermittently closed and open lakes and lagoons’.

We excluded from analysis three EFGs because they are unlikely to occur in New Zealand:

- F2.3 ‘Seasonal freshwater lakes’ – based on the IUCN GET system definition these are considered unlikely to occur in New Zealand, although there may be some cross-over between this functional group and F2.5 ‘Ephemeral lakes’.
- F2.6 ‘Permanent salt and soda lakes’ – based on the IUCN GET system definition these are considered highly unlikely to occur in New Zealand
- F2.10 ‘Subglacial lakes’.

We had insufficient empirical or modelled information to assign any lakes / water bodies to the following two ecosystem functional groups and therefore excluded them from further analysis:

- F2.8 ‘Artesian springs and oases’
- F2.9 ‘Geothermal pools and wetlands’.

Crosswalking, in the traditional sense of aligning two ecosystem typologies, was not possible for lakes in New Zealand. The original FENZ database (Leathwick et al. 2010) includes a single lake typology, but the basis on which this typology was derived could not be clearly established by the authors of the present report. A previous investigation found that it does not provide a sufficiently transparent or robust framework to crosswalk the lake types defined in the New Zealand typology to the functional groups defined within the IUCN GET system (Wood & Schallenberg 2024).

We therefore adopted an alternative approach whereby each lake was assigned directly to one of the relevant EFGs using existing data, including both empirical measurements and modelled estimates.

Criteria used when allocating lakes across multiple functional groups

Some lakes fit the definition of multiple EFGs. While the IUCN GET provides guidance on crosswalking to the typology, some of the definitions of the EFGs within the lake’s biome overlap (e.g. F2.1 ‘Large permanent freshwater lakes’ and F3.1 ‘Large reservoirs’). Therefore we developed and applied the criteria outlined in Table 2. These assignments are somewhat arbitrary, however, and we recommend that clear guidance be developed by the IUCN GET team and New Zealand experts to ensure consistency across biomes.

Table 2. Description of approach used for assigning lakes to EFGs

Value/ratio	Rational
1	This value was used when a lake aligned with only one EFG
0.7:0.3	This ratio was used when a lake primarily aligned with one EFG, but due to other influencing factors also belonged to a secondary group. For example, large glacial lakes in the South Island that have been modified for hydropower are primarily F2.1 'Large permanent freshwater lakes' formed by glacial processes (0.7), but they are also classified as F3.1 'Large reservoirs' (0.3). Another example is high-alpine lakes where predicted air temperatures are below 0°C, suggesting classification as F2.4 'Freeze–thaw freshwater lakes' (0.3). However, in terms of size and biology, these lakes are predominantly F2.2 'Small permanent freshwater lakes' (0.7).
0.5: 0.5	This ratio was used when there was an approximately equal contribution of two functional groups. For example, some F2.1 'Large permanent freshwater lakes' (0.5) are also classified as FM1.3 'Intermittently closed and open lakes and lagoons' (0.5). Similarly, many smaller FM1.3 'Intermittently closed and open lakes and lagoons' (0.5) were also classified as F2.2 'Small permanent freshwater lakes' (0.5).
0.4: 0.3: 0.3	This three-way split was applied when a lake could reasonably be classified into three functional groups. The highest weighting (0.4) was assigned to the most prominent group. For example, some F2.2 'Small permanent freshwater lakes' (0.4) were also classified as F2.4 'Freeze–thaw freshwater lakes' (0.3) and F2.5 'Ephemeral freshwater lakes' (0.3).

Assignment of lakes to EFGs

A database containing information on 5,265 lakes larger than 1 ha was assembled by combining data from Schallenberg et al. 2024 and Booker & Snelder 2025. The approach described below was then applied to assign lakes to EFGs.

1 **F2.1 'Large permanent freshwater lakes'.** Lakes were first sorted by surface area and then by geomorphic class. Lakes with a surface area greater than 100 km² were assigned to F2.1 'Large permanent freshwater lakes'. There were only three lakes in this group: Lake Taupō, Lake Wakatipu, and Lake Wānaka.

2 **F2.1 'Large permanent freshwater lakes' (modified by dams or water control structures).** Lakes that would otherwise fall within F2.1 'Large permanent freshwater lakes' but have been modified through the addition of dams or water control gates on their outlets (typically for hydropower generation), such as Lakes Pukaki and Te Anau, were apportioned between functional groups: 0.7 to F2.1 'Large permanent freshwater lakes' and 0.3 to F3.1 'Large reservoirs'. There were two exceptions: (1) Lake Taupō, which, despite the presence of outlet control gates was retained entirely within F2.1 'Large permanent freshwater lakes', as these modifications were not considered sufficient to warrant partial reclassification as F3.1 'Large reservoirs', based on our expert judgement, and (2) Lake Wakatipu, where there is a low control sill/weir at the Kawarau River outlet, but this does not actively regulate flow and it is hydrologically close to natural.

3 **F3.1 'Large reservoirs'.** Lakes whose geomorphic classification included 'Artificial' (meaning man-made or significantly modified from their natural state) were sorted by surface area. Some lakes have a hybrid geomorphology; for example, Lake Ōhau is classified as both 'Glacial' and 'Artificial', as it was primarily formed by glacial processes, but its outlet has been dammed, resulting in significant modifications to its water level and fluctuations. Lakes with a surface area greater than 50 km² were included in this EFG. There was only one lake that was classified entirely into this EFG (Lake Benmore). Two lakes that were allocated to both F3.1 'Large reservoirs' and F2.2 'Small permanent freshwater lakes' are Lake Ōhau and Lake Tekapo.

4 **FM1.3 ‘Intermittently closed and open lakes and lagoons’ (ICOLLs).** These are lakes that are connected to the sea intermittently, meaning their mouths can open or close naturally due to sandbar formation or erosion. Water exchange with the ocean occurs only intermittently, often controlled by river inflow, tides, or storm events. There is some uncertainty regarding the precise definition of an ICOLL; for example, how long or how often the mouth must remain open for a lake to be classified as such. Identification of ICOLLs therefore requires assessment of historical imagery and/or monitoring records, along with consultation with local authorities and other stakeholders to determine appropriate opening durations and frequencies. While this approach has been undertaken in some regions, to our knowledge it has not been applied consistently at a national scale. Conducting such a comprehensive assessment was beyond the scope of this project. For this study we conducted a preliminary assessment to identify possible ICOLLs. Some prominent ICOLLs are well known, such as Te Whanga Lagoon and Lake Ellesmere / Te Waihora, but for smaller or lesser-known lakes we used the ARC-GIS lake layer from Schallenberg et al. 2024 and satellite imagery to assess all lakes within approximately 1 km of the coast. We looked for evidence of openings, such as a stream channel, a narrow sandbar, or visible openings on satellite imagery available through Google Earth. This was not an exhaustive search, and so the confidence associated with these identifications is low (see description of confidence below). No lakes were classified solely within this EFG; all were allocated to multiple EFGs (see below).

5 **FM1.3 ‘Intermittently closed and open lakes and lagoons’ and F2.1 ‘Large permanent lakes’.** F2.1 ‘Large permanent freshwater lakes’ that were identified as ICOLLs were allocated to both EFGs. Two lakes met this criterion: Te Whanga Lagoon and Lake Ellesmere / Te Waihora.

6 **FM1.3 ‘Intermittently closed and open lakes and lagoons’ (Other).** The remaining ICOLLs were classified using three different approaches.

- Lakes that were also identified as small, naturally formed lakes were allocated to both ICOLLs and F2.2 ‘Small permanent freshwater lakes’.
- Lakes identified as ICOLLs where the geomorphic class was artificial were allocated to both ICOLLs and F3.2 ‘Constructed lacustrine wetlands’.
- Eleven lakes were allocated to three EFGs, as these lakes were probably naturally formed small lakes (F2.2 ‘Small permanent freshwater lakes’ functioned as ICOLLs, and had also been modified to some extent to be partially F3.2 ‘Constructed lacustrine wetlands’). Weightings follow the example in Table 2, with the highest weighting given to the EFG F2.2 ‘Small permanent freshwater lakes’.

7 **F2.4 ‘Freeze-thaw freshwater lakes’ and F2.2 ‘Small permanent freshwater lakes’**. Lakes with a predicted winter air temperature of 0°C or less were identified. All of these were naturally formed lakes. These lakes were allocated to two functional groups: F2.4 ‘Freeze–thaw freshwater lakes’ (weight of 0.3) and F2.2 ‘Small permanent freshwater lakes’ (weight of 0.7). The rationale for this uneven allocation is that, although winter air temperatures suggest the potential for freeze–thaw processes, these lakes remain permanent waterbodies (there was one exception where the lake was ephemeral, see below). Consequently, lake size, permanence, and biological characteristics were considered more influential than seasonal freeze–thaw dynamics.

8 **F2.5 ‘Ephemeral freshwater lakes’**. Ephemeral lakes were identified in Schallenberg et al. 2024 using a time series of satellite imagery. All these lakes were allocated to multiple EFGs. Usually they were allocated to two EFGs, most commonly F2.2 ‘Small permanent freshwater lakes’ and F3.2 ‘Constructed lacustrine wetlands’. There were three types of three-way allocations, each to different combinations of EFGs (weightings shown in brackets):

  - F2.2 ‘Small permanent freshwater lakes’ (0.4), F2.4 ‘Freeze–thaw freshwater lakes’ (0.3), and F2.5 ‘Ephemeral freshwater lakes’ (0.3)
  - F2.2 ‘Small permanent freshwater lakes’ (0.4), F3.2 ‘Constructed lacustrine wetlands’ (0.3), and F2.5 ‘Ephemeral freshwater lakes’ (0.3)
  - F2.2 ‘Small permanent freshwater lakes’ (0.3), F2.7 ‘Ephemeral salt lakes’ (0.4), and F2.5 ‘Ephemeral freshwater lakes’ (0.3).

9. **F2.7 ‘Ephemeral salt lakes’.** Expert knowledge was used to identify these lakes. The only prominent salt lake described in New Zealand is Sutton Salt Lake (Middlemarch, Otago). This lake was formed through repeated cycles of evaporation and refilling. Rainfall delivers marine-derived salts and eroded minerals into the basin, while strong winds and a pronounced rain-shadow effect promote rapid evaporation, leading to a high salt concentration. Sutton Salt Lake may not fully conform to this EFG because it is uncertain whether it is ephemeral, but it is likely to become ephemeral during extreme drought conditions. Satellite imagery, used in conjunction with Arc GIS shapefiles from Schallenberg et al. 2024, were used to identify five additional small lakes near Sutton Salt Lake that are considered likely to be F2.7 ‘Ephemeral salt lakes’. These lakes were allocated to both F2.7 ‘Ephemeral salt lakes’ and F2.2 ‘Small permanent freshwater lakes’.
10. **F3.2 ‘Constructed lacustrine wetlands’.** The remaining lakes were sorted by geomorphic class. Using expert knowledge, lakes categorised as ‘Artificial’ were either assigned entirely to this functional group or split 0.3:0.7 between this EFG and F2.2 ‘Small permanent freshwater lakes’.
11. **F2.1 ‘Small permanent freshwater lakes’.** All remaining lakes were assigned to this EFG.

3.4.3 Mapping methods

All lakes have a FENZ identification number. Once the EFG assignments described above were completed, the FENZ numbers in the new database were matched to the corresponding FENZ numbers in the Arc GIS layer from Schallenberg et al. 2024 for mapping.

3.4.4 Caveats

The limitations of the data used in the assignment steps are summarised in Table 3. We also provide a summary of the confidence in EFG assignments, with scores ranging from low (1) to high (5). A score of 5 indicates high confidence that all lakes within an EFG have been correctly assigned.

Table 3. Data limitations associated with the assignment steps and confidence levels for EFG classification (high = 5, low = 1)

EFG	Caveats	Confidence
F2.1 ‘Large permanent freshwater lakes’	No caveats/limitations. We are confident that large permanent freshwater lakes have been correctly assigned.	5
F2.2 ‘Small permanent freshwater lakes’	There are a large number of these lakes, and their classification is based primarily on surface area and geomorphic class, as described in Schallenberg et al. 2024. The authors of that report note that assigning geomorphic classes was often challenging, and that given the national scale and number of lakes a detailed assessment was not possible. Consequently, they state that the current classifications should be considered preliminary, and site visits with in-depth investigations are needed for robust geomorphic assignments. For this reason, we have assigned moderate confidence to our assignments.	4
F2.4 ‘Freeze-thaw freshwater lakes’	There is currently no information on ice cover for lakes in New Zealand. For the assignments we used a predicted mean winter air temperature for each lake, obtained from the updated FENZ database (Booker & Snelder 2025). This value is derived from national climate models and spatial data sets and linked to each lake in the FENZ GIS layer. These values are modelled or interpolated rather than measured directly. We then assumed that lakes with a predicted air temperature of 0°C or less were likely to experience ice cover. This is a simplification, because ice formation is influenced by factors such as lake size, depth, wind exposure, shading, and inflows. Thus, while winter air temperature provides a useful proxy, it does not capture the full complexity of ice dynamics, and results should be interpreted with caution. We note that the IUCN GET system description states that all lakes with minimum temperature below 0°C are included in this EFG, but we assume this is a measured water temperature (rather than a predicted air temperature as used in our assignments).	3
F2.5 ‘Ephemeral freshwater lakes’	The recent update of the FENZ lake database (Schallenberg et al. 2024) provides an indication of whether a lake was likely to be ephemeral, based on recent satellite imagery. However, the authors of that report note that this assessment relied on satellite imagery, which provides only snapshots in time. Lakes were classified as ephemeral if they contained little or no water during parts of the year, based on the previous 5 years of available imagery. It is therefore likely that not all ephemeral lakes have been captured in the database. While we have moderately high confidence (4) in the classification of the lakes that were identified, we have low confidence that all relevant ephemeral lakes have been captured nationally.	4
F2.7 ‘Ephemeral salt lakes’	As noted above, there is uncertainty in the classification of these lakes as ephemeral, and we did not observe (via satellite imagery) them as dry. We are confident in assigning Sutton Lake as a salt lake, but have lower confidence in the nearby lakes, as this assessment was based solely on satellite imagery. To our knowledge, no other salt lakes besides Sutton Lake have been described in New Zealand.	4
F3.1 ‘Large reservoirs’	No caveats/limitations. We are confident that all large reservoirs have been correctly assigned.	5
F3.2 ‘Constructed lacustrine wetlands’	There are many of these lakes, and their classification is based primarily on surface area and geomorphic class, as described in Schallenberg et al. 2024 (see F2.2 for challenges with geomorphic classification).	4
FM1.3 ‘Intermittently closed and open lakes and lagoons’	Identification of this EFG requires assessment of historical imagery or monitoring records. To our knowledge this has not been done consistently at a national scale, and a comprehensive assessment was beyond the scope of this project. For this study we conducted a preliminary assessment by identifying lakes within c. 1 km of the coast and looking for evidence of openings, such as stream channels or narrow sandbars. This was not exhaustive, and we suggest only moderate confidence in these assignments.	3

In addition to the above, a further caveat is that the FENZ database includes only lentic waterbodies larger than 1 ha. Some waterbodies within the ‘Lakes’ biome, such as F2.8 ‘Artesian springs and oases’ and F2.9 ‘Geothermal pools and wetlands’, are often much smaller than this threshold, as are some F2.2 ‘Small permanent freshwater lakes’ and F2.5 ‘Ephemeral freshwater lakes’, and therefore have not been mapped. A LINZ layer for small ponds exists and includes approximately 50,000 waterbodies that may contain relevant information, but incorporation of this layer was beyond the scope of this work.

3.4.5 Gaps

Freeze-thaw freshwater lakes. There is currently no information on ice cover for lakes in New Zealand. It is likely this could be obtained from historical satellite imagery. This would be useful because it would provide a baseline to assess future impacts of climate change on the extent and duration of ice cover.

Ephemeral freshwater lakes. There is currently no comprehensive national information on ephemeral lakes in New Zealand. Existing assessments, such as those in the FENZ database, rely on limited satellite imagery, which provides only snapshots in time and may not capture all periods when lakes dry out. A full assessment would probably require analysis of satellite imagery over multiple years, which would be time-consuming unless automated. However, this would also provide a useful baseline to assess the future impacts of climate change.

Ephemeral salt lakes. There is very limited knowledge of salt lakes in New Zealand, with Sutton Salt Lake being the only well-documented example. Other small lakes near Sutton Salt Lake are presumed to be salt lakes but have not been assessed. Site visits are recommended to improve understanding of these systems, given they are an uncommon ecosystem type in New Zealand. In addition, there are no data on whether these lakes are ephemeral. Based on their small size and location in a dry, arid region it is likely they are, but assessment of historical satellite imagery would be required to confirm this.

Intermittently closed and open lakes and lagoons. Knowledge of which coastal lakes in New Zealand are ICOLLs is limited, and no comprehensive national assessment has been conducted. Identification requires assessment of historical imagery and monitoring records, and we recommend that a detailed analysis be undertaken. Further efforts are also needed to develop a clear definition of ICOLLs, including the duration and timing of openings required to classify a lake as an ICOLL, both in New Zealand and within IUCN GET.

Geothermal pools and wetlands. Geothermal lakes, pools, and wetlands occur in New Zealand, but this information is not officially recorded in FENZ or other national lake databases. Also, many of the waterbodies that fit this category are likely to be smaller than 1 ha, which is the minimum area used to classify a lake in FENZ. It is possible that some of these sites have been mapped by research teams working on thermal habitats across New Zealand,[12] and these groups should be approached for further information on these habitats.

Artesian springs and oases. Some lakes in New Zealand, such as groundwater-fed dune lakes, may fit this category. Knowledge of purely groundwater-fed lakes is very limited, and this information is not included in any national databases. Also, many of the waterbodies that fit this category are likely to be smaller than 1 ha, which is the minimum area used to classify a lake in FENZ.

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[12] E.g. https://1000springs.org.nz

3.4.6 Recommendations specific to this domain

We have moderate to good confidence in the assignment of lakes to EFGs. For the purpose of mapping lake numbers and surface areas within these groups at a national scale this is probably sufficient. However, we caution against using these assignments for lake-level or perhaps even regional-scale assessments due to the uncertainties outlined above.

To improve certainty, the following steps are recommended.

- Develop standardised and transparent criteria for splitting lakes across multiple EFGs, and provide clear guidance for future assignments to ensure consistency.
- Collect data on ice cover and ephemeral lakes using satellite imagery.
- Conduct comprehensive national assessments of salt lakes and ICOLLs using multi-year satellite imagery and historical monitoring records (if available).
- Undertake targeted field surveys, particularly for ephemeral salt lakes, to validate satellite-based classifications.
- Consider assessing EFGs excluded from this analysis, such as F2.8 ‘Artesian springs and oases’ and F2.9 ‘Geothermal pools and wetlands’, which are known to occur but were not included in the current assessment.

While this exercise has been useful for contributing information to international reporting, it should not be regarded as a lake typology for New Zealand, and it is likely to have limited direct value for lake management.

3.5 Groundwater

There are currently no groundwater ecosystem typologies in wide use in New Zealand. In the absence of these, typologies used by different users to classify hydrogeological systems, including groundwater, were evaluated. Evaluations were made against a set of end-user principles (Sprague & Wiser 2024) and how well they map to the IUCN GET (Houghton et al. 2024).

While several of the typologies assessed are hierarchical, none of the currently used classification systems are suitable for use as part of a national ecosystem typology. This is partly due to the lack of data across all groundwater systems. To achieve this, consistent national-scale investment is required, including the development of a new national typology using a range of environmental and anthropogenic features to classify groundwater ecosystems into smaller regional subgroups. We have identified some potential useful data sets for future updates.

For the purposes of this project, hydrogeological units (White et al. 2019) were used rather than crosswalking an existing typology to the IUCN GET. The hydrogeological units provide nationally consistent geological data that can be integrated with other data sets of chemical, lithological, environmental, or biological data in the future.

3.5.1 Data sources (explored and used)

The New Zealand Hydrogeological Units data set (stacked North Island and South Island; 31.01.2025 release) was used as the foundational layer for groundwater mapping. It provides a nationally consistent framework of overlapping polygons representing the three-dimensional structure of aquifers across New Zealand. The classification also incorporates recently identified uncommon aquifers from Greater Wellington and Auckland, including fractured basalt and coarse sand systems (Bolton et al. 2025; Weaver et al., 2024).

Groundwater ecosystems are most effectively delineated using aquifer boundaries, which offer a mappable and hydrologically meaningful spatial unit. However, because ecological processes operate at finer scales within aquifers, these hydrogeological units should be interpreted as system-level ecological proxies rather than direct ecological equivalents.

We also considered other data sets that will be useful for providing finer resolution than the New Zealand Hydrogeological Units (i.e. regional sub-groups, IUCN GET Levels 5 or 6) for future efforts:

- predicted groundwater redox state in New Zealand – predicted from a range of physical variables associated with the well locations and available in nationwide geospatial data sets with variable depths, although there is some geographical bias
- groundwater quality indicators – quantitative chemistry data with ordinal trends, although there is biased geographical coverage that is inconsistent across measured parameters
- New Zealand Groundwater Atlas – groundwater recharge, groundwater–surface-water exchange, and groundwater flow. It includes spatial and temporal data, although scales vary.

These supplementary data sets were not included here in the spatial mapping of groundwater ecosystems. This includes useful point-based/localised data sets, which would be difficult to translate into 100 m rasters:

- groundwater quality indicators
- New Zealand Groundwater Atlas
- New Zealand uncommon aquifers
- Hutt Aquifer system groundwater diversity.

3.5.2 Data sources (explored and currently unused)

For EFGs other than SF1.2, spatial data in general are limited (see Table 4). SF1.1 ‘Underground streams and pools’ and S1.1 ‘Aerobic caves’ have moderate spatial data available, primarily derived from regional karst studies, cave inventories, and speleological mapping. While these systems are reasonably well located geographically, data sets are often fragmented and lack national integration (DOC 2001, 2007).

Data sets that may prove useful for mapping these EFGs in the future include:

- speleological surveys and/or regional cave ecology work
- DOC science reports
- the 1000 Springs microbial biogeography project.

In contrast, SF2.1 ‘Water pipes and subterranean canals’ are well mapped as infrastructure assets but are rarely described as ecological or environmental systems within national data sets. SF2.2 ‘Flooded mines and other voids’ are typically identified through geological and geophysical investigations rather than systematic environmental inventories, resulting in limited spatial synthesis despite clear evidence of their presence (e.g. Beetham et al. 2004; Tonkin & Taylor 2005; Sutter & Barounis 2020).

Data sets that may prove useful for mapping these functional groups in the future include:

- municipal infrastructure data sets
- regional mine remediation studies
- council hazard reports.

S1.2 ‘Endolithic systems’ remain the least characterised, with presumably a number that are subterranean. However, there appears to be little direct mapping or system-level description currently available in New Zealand literature, meaning their distribution is largely unknown and can only be inferred from analogous settings (Gaylarde et al. 2006).

Overall, the evidence indicates that while hydrogeological and geothermal systems benefit from relatively mature national data sets, several subterranean classifications (particularly engineered, post-industrial, and specific groundwater environments) remain poorly synthesised at a systems level, suggesting that the full extent of New Zealand’s subsurface environments is not yet comprehensively mapped.

Table 4. Summary of groundwater and associated EFGs and primary data sets available to map these groups in New Zealand

Level 1 realm	Level 2 biome	ID	Level 3 EFG	EFG present	Data available to map EFG	Data source
Subterranean-Freshwater	Subterranean freshwaters	SF1.1	Underground streams and pools	Yes	Partial	https://subsite2.waikatoregion.govt.nz/assets/WRC/TR202203.pdf https://data.linz.govt.nz/layer/50253-nz-cave-points-topo-150k https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/subterranean-or-semi-subterranean/caves-and-cracks-in-karst
Subterranean-Freshwater	Subterranean freshwaters	SF1.2	Groundwater ecosystems	Yes	Yes, but requires further work to link to functional characteristics.	National Groundwater Monitoring Programme Envirolink projects; Ministry for the Environment projects*
Subterranean-Freshwater	Anthropogenic subterranean freshwaters	SF2.1	Water pipes and subterranean canals	Yes	Yes	Held by councils.
Subterranean-Freshwater	Anthropogenic subterranean freshwaters bio	SF2.2	Flooded mines and other voids	Yes	Partial	Held by councils.
Associated groups						
Subterranean	Subterranean lithic	S1.1	Aerobic caves	Yes	Partial	https://data.linz.govt.nz/layer/50253-nz-cave-points-topo-150k Speleological surveys; regional cave ecology work
Subterranean	Subterranean lithic	S1.2	Endolithic systems	Yes	Partial	Gaylarde et al. 2006
Subterranean	Anthropogenic subterranean voids	S2.1	Anthropogenic subterranean voids	Yes	No	
Freshwater	Lakes	F2.8	Artesian springs and oases	Yes	Partial	https://data.linz.govt.nz/layer/50356-nz-spring-points-topo-150k/ DOC science reports; Crown Research Institute (CRI) data sets
Freshwater	Lakes	F2.9	Geothermal pools and wetlands	Yes	Partial	1000 Springs microbial biogeography project; CRI data sets

* Additionally identified data sets (localised) that could be included in future iterations; see also Houghton et al. 2024.

3.5.3 Crosswalking methods

The New Zealand Hydrogeological Units data set was considered the most appropriate spatial proxy for SF1.2 ‘Groundwater ecosystems’. This particular EFG comprises approximately 90% of underground aquifer systems (see Table 5).

SF1.2 ‘Underground streams and pools’ and SF1.2 ‘Groundwater ecosystems’ sit within the core realm of Subterranean-Freshwater in the IUCN GET. This biome encompasses ecosystems associated with water stored and flowing beneath the Earth’s surface, typically within aquifers, karst systems, and other saturated geological formations.

SF2.1 ‘Water pipes and subterranean canals’ and SF2.2 ‘Flooded mines and other voids’ within the Artificial subterranean biome within the Subterranean-Freshwater realm) were not included in this project.

Several additional ecosystem functional groups associated with subsurface water occur outside the Subterranean-Freshwater realm in the IUCN GET. These include S1.1 ‘Aerobic caves’ and S1.2 ‘Endolithic systems’ within the Terrestrial subterranean realm; and F2.8 ‘Artesian springs and oases’ and F2.9 ‘Geothermal pools and wetlands’ within the Freshwater realm. While these systems may interact hydrologically with groundwater, they represent distinct ecosystem types under the IUCN GET framework. Spatial data describing the distribution and extent of these systems in New Zealand are limited or highly localised, making their inclusion on a national scale challenging.

We have tentatively defined New Zealand groundwater ecosystems using hydrogeological units, within the Subterranean-Freshwater realm, focused on SF1.2 ‘Groundwater ecosystems’.

Due to the absence of data sets that directly align with the IUCN GET, crosswalks and crosswalk ratios were generated through expert judgement, supported by available spatial data, hydrogeological frameworks, and domain knowledge (Table 5). These ratios represent the best available approximation under current data constraints and should therefore be interpreted with appropriate caution.

Table 5. Crosswalk of EFGs relevant to groundwater in New Zealand

Functional group	Description	SF1.1 'Underground streams and pools'	SF1.2 'Groundwater ecosystems'	SF2.1 'Water pipes and subterranean canals'	SF2.2 'Flooded mines and other voids'	S1.1 'Aerobic caves'	S1.2 'Endolithic systems'	F2.8 'Artesian springs and oases'	F2.9 'Geothermal pools and wetlands'
Artesian springs	Ecosystems formed by groundwater discharge at the surface under artesian pressure.[a]	0.1	0.1	-	-	-	-	0.7	0.1
Geothermal pools	Ecosystems associated with geothermal groundwater discharge at the surface, enriched with dissolved minerals, elevated temperatures.[b]	0.1	0.1	-	0.1	-	-	0.1	0.6
Underground (aquifer) ecosystems	Aquatic ecosystems within the saturated zones of aquifers and aquitards, in darkness, nutrient-limited conditions.[c]	-	0.9	-	-	-	-	0.1	-
Underground streams and caves	Flowing ecosystems within karstic geologies, lava tubes, cave networks, often enable connection between surface and groundwater systems.[d]	0.6	0.1	-	-	0.1	0.1	0.1	-

[a] These systems create localised wetland habitats. Constant water supplied under pressure from confined aquifers, typically mineral rich, with stable temperature and a small spatial extent. Continuous upwelling supports highly productive and potentially unique trophic networks. Specialised aquatic plants, mosses, microbial biofilms (mats), endemic invertebrates, reliance on spring and associated wetland by vertebrate fauna.

[b] Often warm to hot water, high mineral content (in particular silica, sulphur), variable pH range, often associated with geothermal fields and volcanic terrain. Thermophilic microbial communities that are highly specialised, specialised algae, mosses and vascular plants and macroinvertebrates.

[c] Stable temperature, often low oxygen, absence of light processes, variable water flow rates, mineral rich in certain aquifers. Presence of stygofauna, microbial communities adapted to oligotrophic conditions, absence of photosynthesis/photosynthetic organisms. Energy derived from dissolved organic matter and chemoautotrophy, slow nutrient turnover, biogeochemical cycling.

[d] Flowing ecosystems within karstic geologies, lava tubes, cave networks, often enable connection between surface and groundwater systems. Variable flow, absence of light, high humidity, intermittent nutrient inputs from the surface, carbonate or volcanic substrates. Troglobitic species, microbial biofilms/mats, detritus-based food webs, vertebrate defecation (e.g. bats) source of nutrients. Specialised adaptation to darkness and low energy; ecological connection between surface and underground realms

3.5.4 Mapping methods

SF1.2 ‘Groundwater ecosystems’ was mapped using New Zealand Hydrogeological Units, consisting of overlapping stacked polygons that represent aquifers, developed in a nationally consistent manner. Other hydrogeological units (i.e. aquitards, aquicludes, and basement) are included in the data set but not mapped. The data set was initially prepared for the Ministry for the Environment (White et al. 2019) and is now continually revised by Earth Sciences New Zealand as part of the Groundwater Strategic Science Investment Fund programme. During compilation, inferences and assumptions have been made about hydrogeological units at a regional scale (1:250,000) without validations using actual observations in some areas.

3.5.5 Caveats

- There is a lack of spatial sensitivity for the mapping because the underlying hydrogeological unit data set is based on a 1:250,000 scale. Regional data sets for specific ecosystems may have a more appropriate resolution but are hard to integrate with nationally consistent data.
- National monitoring groundwater bores, which validate hydrogeological units, are not evenly distributed and are often biased towards productive but less pristine wells.
- Remote sensing has been used to validate hydrogeological units only in certain regions.
- There are limitations to how the resulting map in this domain could be used because several known ecosystem types have not been mapped at this stage.

3.5.6 Gaps

We could not map the Chatham Islands, Stewart Island / Rakiura, offshore islands, or the subantarctic islands for SF1.2 ‘Groundwater ecosystems’ because the necessary spatial data are not available.

Nationally consistent spatial data are unavailable for several EFGs. Although cave maps exist for S1.1 ‘Aerobic caves’, they rarely differentiate cave oxygen regimes, limiting their use for ecosystem classification. F2.9 ‘Geothermal pools and wetlands’ and F2.8 ‘Artesian springs and oases’ also lack comprehensive national coverage, despite some regional mapping. SF1.1 ‘Underground streams and pools’, SF2.1 ‘Water pipes and subterranean canals’, SF2.2 ‘Flooded mines and other voids’, and S1.2 ‘Endolithic systems’ were not mapped due to insufficient data relevant to groundwater ecosystems. While infrastructure and mine information probably exists at local or regional levels, these data sets are fragmented and may be restricted due to their sensitivity, limiting their accessibility for ecological assessment and preventing consistent national-scale mapping.

3.5.7 Recommendations specific to this domain

This work has revealed the potential to realise and combine a number of existing data sets, and also highlighted gaps in the characterisation of groundwater typologies and maps. Our recommendations are as follows.

- Continue to work with New Zealand groundwater domain experts and the IUCN GET Scientific Committee to refine EFGs or suggest sub-groups.
- Continue to add data from different aquifer types in New Zealand (this was started with the inclusion of fractured basalt and coarse sand [Weaver et al. 2024] but needs to continue to include all aquifer types in New Zealand).
- Investigate whether alternative or additional environmental parameters can be used as the basis for effectively delineating sub-surface ecosystems (e.g. hydrochemistry, lithology or biological data).
- Develop a national biological data set to create functional regional sub-groups by building the ecological evidence needed to define how groundwater ecosystems function within groundwater hydrogeological units.
- Consider assessing EFGs excluded from this analysis owing to lack of nationally consistent data, such as S1.1 ‘Aerobic caves’, F2.8 ‘Artesian springs and oases’, and F2.9 ‘Geothermal pools and wetlands’, which are known to occur but were not included in the current assessment
- Check overlap between boundaries with other ecosystem domains (rivers, wetlands, terrestrial, artificial).
- Extend mapping coverage to Stewart Island / Rakiura, the Chatham Islands, offshore islands, and the subantarctic islands once consistent supporting layers become available.
- Create a more precise map to improve extent estimates, because underlying data sets currently rely on 1:250,000 scale, which we consider too broad for mapping groundwater ecosystems.

3.6 Marine and estuarine

New Zealand’s marine and estuarine ecosystems cover an extensive area of over 4 million km^2, approximately 15 times the total land area of New Zealand. The IUCN GET identifies 24 Marine EFGs and 16 additional Marine Transitional EFGs in its typology (Keith et al. 2022); three of these EFGs were confirmed by experts to not be present in New Zealand (M1.3 ‘Photic coral reefs’, M2.5 ‘Sea ice’, MFT1.1 ‘Coastal river deltas’) (Appendix 3). Due to the broad scope of data sets required to populate the marine and estuarine EFGs, and given the budget available, not all marine EFGs were mapped in this project. Based on an initial scoping analysis and ease of crosswalking to IUCN GET, 21 EFGs were selected for mapping. The rationale for the selection of groups to be mapped is described in the following sections, including exploration of data sets suitable to map all marine and marine transitional groups.

3.6.1 Data sources (explored and used)

Many marine and estuarine data sets were explored to inform the mapping of marine and marine transitional EFGs, and to determine which EFGs had sufficient and robust data sets to be mapped. Approaches and data sets were similar for some EFGs within each Level 2 biome (see sources detailed in Table 6 and Appendix 3). However, as discussed in Lundquist et al. 2024, the EFGs do not have a consistent hierarchical structure, nor are environment drivers used consistently within

IUCN GET Level 2 biomes for marine and marine transitional EFGs. As an example, the M1 'Marine shelf' biome includes EFGs defined by vegetation (e.g. seagrass meadows), by invertebrates (e.g. shellfish beds and reefs), by sediments (e.g. subtidal rocky reefs), and by hydrodynamic features (e.g. upwelling zones). In many cases a particular location could be defined by multiple EFGs; examples include features based on vegetation that also have sedimentary and hydrodynamic components, often corresponding to two or more EFGs applying to a particular location.

We structured our discussion of data sets used for mapping similar EFGs based on groups of EFGs defined by similar features:

- estuarine hydrodynamics (FM1 'Semi-confined transitional waters biome')
- flora (M1 'Marine shelf biome', MFT1 'Brackish tidal biome')
- fauna (MT2 'Supralittoral coastal biome', M1 'Marine shelf biome', M3 'Deep sea floors biome')
- sedimentary features (M1 'Marine shelf biome', MT1 'Shorelines biome')
- pelagic/water column features (M2 'Pelagic ocean waters biome', M1.9 'Upwelling zones' within M1 'Marine shelf biome')
- seafloor topographic features (M3 'Deep sea floors biome')
- anthropogenic features (M4 'Anthropogenic marine biome', MT3 'Anthropogenic shorelines biome').

Table 6. Summary of the 21 marine and marine transitional EFGs that were mapped in this contract, and their source data sets

Level 1 realm	Level 2 biome	ID	Level 3 EFG	Data sources used
Freshwater-Marine	Semi-confined transitional waters biome	FM1.1	Deepwater coastal inlets	Coastal Hydrosystems Classification (Hume et al. 2016)
		FM1.2	Permanently open riverine estuaries and bays	Coastal Hydrosystems Classification (Hume et al. 2016)
		FM1.3	Intermittently closed and open lakes and lagoons	Coastal Hydrosystems Classification (Hume et al. 2016)
Marine	Marine shelf biome	M1.1	Seagrass meadows	National blue carbon data set (Bulmer et al. 2024).
		M1.6	Subtidal rocky reefs	National rocky reef layer based primarily on data from navigational charts (DOC 2011). Assumed to be incomplete for deeper reefs.
Marine	Pelagic ocean waters biome	M2.1	Epipelagic ocean waters	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
		M2.2	Mesopelagic ocean water	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
		M2.3	Bathypelagic ocean waters	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
		M2.4	Abyssopelagic ocean waters	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
Marine	Deep sea floors biome	M3.1	Continental and island slopes	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).

Level 1 realm	Level 2 biome	ID	Level 3 EFG	Data sources used
		M3.2	Submarine canyons	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.3	Abyssal plains	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.4	Seamounts, ridges and plateaus	Seamounts – underwater topographic features (Clark et al. 2022); plateaus – digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.6	Hadal trenches and troughs	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.7	Chemosynthetic-based ecosystems	Global hydrothermal vent data set (Ramirez-Llodra & Baker 2006); cold methane seeps (Greinert et al. 2010). Best available but likely incomplete, as seafloor surveys regularly find new chemosynthetic features.
Marine	Anthropogenic marine biome	M4.1	Submerged artificial structures	Offshore platforms, submarine cables, submarine pipelines, shipwrecks compiled for Ministry for the Environment Naturalness data set, compiled from various sources (Lundquist et al. 2025).
		M4.2	Marine aquafarms	Aquaculture farms (finfish and shellfish) compiled for Ministry for the Environment Naturalness data set, compiled from various sources (Lundquist et al. 2025).
Marine-Freshwater-Terrestrial	Brackish tidal biome	MFT1.2	Intertidal forests and shrublands	National blue carbon data set (Bulmer et al. 2024).
		MFT1.3	Coastal saltmarshes and reedbeds	National blue carbon data set (Bulmer et al. 2024).
Marine-Terrestrial	Shorelines biome	MT1.1	Rocky shorelines	National rocky reef layer based primarily on data from navigational charts (DOC 2011). Assumed to be incomplete for deeper reefs.
Marine-Terrestrial	Supralittoral coastal biome	MT2.2	Large seabird and pinniped colonies	Data sets on seal and sea-lion breeding colonies and haul-out sites, and roosting and breeding seabird colonies compiled from central and regional government data sets for key ecological areas data sets (Stephenson et al. 2018; Lundquist, Stephenson et al. 2020).

EFGs defined by estuarine hydrodynamics

The primary source data set available to map EFGs in FM1 ‘Semi-confined transitional waters biome’ was estuaries classified according to the New Zealand Coastal Hydrosystems Classification (NZCHC) (Hume et al. 2016). This classification provided 11 classes, with 1–5 subclasses representing differences in geomorphological features in estuaries.

EFGs defined by flora

Coastal wetland EFGs defined by vegetation include M1.1 ‘Seagrass meadows’, MFT1.2 ‘Intertidal forests and shrublands’, and MFT1.3 ‘Coastal saltmarshes and reedbeds’, and multiple data sets were available to map these habitats. A national data set of mangrove forests, seagrass meadows and saltmarsh (Bulmer et al. 2024) was determined to be the most comprehensive and temporally recent, with consistent methods derived from satellite imagery used at a national scale to map distributions of mangrove forests, seagrass meadows, and coastal saltmarsh. Other data sets that were explored but not used to map coastal vegetation (see Appendix 3) include:

- point records or distributions of coastal vegetation (mangroves, seagrass) at national or regional scales surveyed at varying points in time (many of these have been compiled by DOC from regional council data sets as part of their Estuaries programme, and distributions at different points in time are available for some locations)
- wetland maps, including saline wetlands, which have been updated recently, with a focus on data available from terrestrial land-cover databases (Dymond et al. 2021), and both current and historical data sets are available.

Within M1 ‘Marine shelf biome’, two other EFGs are defined by flora (M1.1 ‘Kelp forests’ and M1.10 ‘Rhodolith/Maërl beds’), and data sets were explored to assess whether there were available data sets to map these groups. For both of these EFGs data sets were assessed as not sufficiently comprehensive or robust to provide adequate national-scale maps of these EFGs.

- Kelp forest mapping has occurred in some regions but has not been mapped comprehensively at a national scale (Tait et al. 2021; Tait & D’Archino 2024), so gaps in data (if uploaded to an international data set) could be misinterpreted as absences when kelp may be present at a location.
- Predictive models of habitat suitability have been developed for macroalgae at the genus level at both national and regional scales (Lundquist, Stephenson et al. 2020; Bennion et al. 2024), but these have not been ground-truthed, and model extrapolation is limited to rocky reef habitats. Predictive models do not include soft sediment-associated macroalgae or the calcified coralline algae that form rhodoliths / maërl beds.
- Point records are available for large kelps, but the data sets do not represent comprehensive sampling of New Zealand’s oceans (Lundquist, Stephenson et al. 2020).

EFGs defined by fauna

The EFG MT2.2 ‘Large seabird and pinniped colonies’ within MT2 ‘Supralittoral coastal biome’ is defined by the presence of fauna, and many data sets were available that can inform MT2.2. A recent compilation of regional and central government data sets on these colonies was performed for the key ecological areas programme of work by central government (Stephenson et al. 2018; Lundquist, Stephenson et al. 2020). This represents the most comprehensive data set currently available for both pinniped and seabird colonies and was used to map this EFG. Other data sets that were explored, and in many cases had been incorporated into the previously mentioned compilation (see Appendix 3), include:

- central government (Fisheries New Zealand National Aquatic Biodiversity Information System (NABIS) distributions) and further updates from DOC
- regional government significant ecological areas that included the presence of marine mammals and seabirds

- Birdlife International and New Zealand Forest & Bird's Important Bird Areas in New Zealand, which include broader pelagic foraging ecosystems so did not match the ecosystem described
- Naturally Uncommon Ecosystems data sets (seabird-burrowed soils, seabird guano deposits, and marine mammal haul outs; Wiser et al. 2013) – there were uncertainties with respect to permissions with the NUE data sets so these were not used.

Multiple EFGs in M1 'Marine shelf biome' and M3 'Deep sea floors biome' are defined based on the presence of invertebrate fauna, including M1.4 'Shellfish beds and reefs', M1.5 'Photo-limited marine animal forests', and M3.5 'Deepwater biogenic beds'. Many data sets were explored but were determined to be insufficient to allow comprehensive mapping of these three EFGs based on habitat-forming invertebrates. The types of data sets that were explored for biogenic habitats are described below.

- Expert knowledge of locations of these biogenic habitats has been compiled and mapped, although these maps are typically represented by broad polygons, are available only for some regions, and have not been ground-truthed (e.g. DOC & Ministry of Fisheries 2011; Lundquist, Tablada et al. 2020; Tablada et al. 2022).
- Local ecological knowledge of fishers has been mapped to indicate the historical presence of biogenic habitats in some regions (Jones et al. 2016).
- Predictive models of habitat suitability have been developed for biogenic habitats and for biogenic invertebrates at the genus level at both national and regional scales (Anderson et al. 2020; Lundquist, Stephenson et al. 2020; Stephenson et al. 2023; Bennion et al. 2024), but these have not been ground-truthed and are often based on a limited number of point records (<100).

EFGs defined by sedimentary features

Multiple EFGs within M1 'Marine shelf biome' and M3 'Deep sea floors biome' are defined by sedimentary features. We explored national data sets and assessed that while national sedimentary data sets are available, they do not directly correspond with the EFGs, with the exception of M1.6 'Subtidal rocky reefs' and MT1.1 'Rocky shorelines'. We describe sediment data layers below.

- A national rocky reef layer is available primarily based on reefs, as identified and mapped in navigational charts, and was determined to be adequate for mapping M1.6 'Subtidal rocky reefs' and MT1.1 'Rocky shorelines' (as referenced in DOC & Ministry of Fisheries 2011).
- Sedimentary data sets have been collated for both the continental shelf (Bostock et al. 2019b) and the continental slope and deep ocean (Bostock et al. 2019a). However, more analysis would be required to interpret and map EFGs based on available grain size distributions (% mud, % sand, % gravel, % carbonate) to develop maps of M1 'Marine shelf biome' EFGs (M1.7 'Subtidal sand beds', M1.8 'Subtidal mud plains'), and MT1 'Shorelines biome' EFGs (MT1.2 'Muddy shorelines', MT1.3 'Sandy shorelines', and MT1.4 'Boulder and cobble shores').

EFGs defined by pelagic / water column features

Four EFGs in M2 'Pelagic ocean waters biome' and one EFG in M1 'Marine shelf biome' are defined based on pelagic / water column features.

- For M2 'Pelagic ocean waters biome', a national bathymetric layer was determined to be suitable to derive the four pelagic groups based on water depth (Mitchell et al. 2012).
- No data sets were available to map upwelling zones, probably due to the spatial and temporal variability and complex hydrodynamic processes that drive upwelling in New Zealand's Exclusive Economic Zone (EEZ). Physical oceanographic data sets are available that could be used to inform the mapping of upwelling zones (e.g. environmental variables from the Earth Systems Models used in Bennion et al. 2024).

EFGs defined by seafloor topographic features

A number of national and international layers were available to inform maps of EFGs based on seafloor topographic features in M3 'Deep sea floors biome'. These included the following.

- National layers are available and have recently been updated to represent seamounts (underwater topographic features) (Clark et al. 2022), noting that this is only one type of feature within M3.4 'Seamounts, ridges and plateaus'.
- A global hydrothermal vent data set is available, which includes locations in New Zealand (Ramirez-Llodra & Baker 2006) to inform M3.7 'Chemosynthetic-based ecosystems'.
- A data set is available that documents point locations of cold methane seeps (Greinert et al. 2010) to inform M3.7 'Chemosynthetic-based ecosystems'.
- New chemosynthetic features are regularly discovered, and data sets of both hydrothermal vents and cold seeps are probably incomplete due to the limited sampling of the deep sea floor in New Zealand's EEZ.
- A global digital seafloor geomorphic analysis (Harris et al. 2014) provides mapped layers for the M3 'Deep sea floors biome' EFGs (M3.1 'Continental and island slope', M3.2 'Submarine canyons', M3.3 'Abyssal plains', ridges and plateaus within M3.4 'Seamounts, ridges and plateaus', and M3.6 'Hadal trenches and troughs').

EFGs defined by anthropogenic features

Multiple EFGs within M4 'Anthropogenic marine biome' and MT3 'Anthropogenic shorelines biome' are defined by anthropogenic features. Data sets were determined to be sufficiently complete to inform M4.1 'Submerged artificial structure' and M4.2 'Marine aquafarms', but not to inform MT3.1 'Artificial shorelines'. Data sets explored include the following.

- A recent project collated layers representing anthropogenic disturbances within New Zealand's marine estate (Lundquist et al. 2025). Available layers include:
  - finfish and shellfish aquaculture zones, which inform M4.2 'Marine aquafarms'
  - oil and gas structures, which inform M4.1 'Submerged artificial structures'
  - submarine cables, which inform M4.1 'Submerged artificial structures'
  - submarine pipelines, which inform M4.1 'Submerged artificial structures'
  - shipwrecks, which inform M4.1 'Submerged artificial structures'
  - ports and marinas, which inform MT3.1 'Artificial shorelines'
  - boat ramps, which inform MT3.1 'Artificial shorelines'

  - coastal roads, which inform MT3.1 ‘Artificial shorelines’.
- Other coastal/shoreline anthropogenic structures such as coastal hardening are poorly mapped in New Zealand (Lundquist et al. 2025), and ports and marinas are often represented by point locations and not the spatial extent of a facility.

3.6.2 Crosswalking methods

EFGs defined by estuarine hydrodynamics

New Zealand coastal hydrosystems (Hume et al. 2016) are primarily defined based on geomorphology, whereas the four corresponding EFGs span two transitional biomes (Freshwater-Marine: FM1.1 ‘Deepwater coastal inlets’, FM1.2 ‘Permanently open riverine estuaries and bays’, FM1.3 ‘Intermittently closed and open lakes and lagoons’; and Marine-Freshwater-Terrestrial: MFT1.1 ‘Coastal river deltas’). Expert assessment was that no coastal river deltas, as per the description in IUCN GET, are present in New Zealand.

The 26 classes/subclasses of New Zealand coastal hydrosystems primarily mapped onto FM1.2 and FM1.3 based on whether the class was permanent or intermittent, respectively. Three deeper hydrosystems mapped onto FM1.1 (Table 7). In some cases, coastal hydrosystems crosswalked to freshwater EFGs (e.g. damp sand plain lakes were considered conceptually to be most similar to the EFG of sand dunes and mapped accordingly). In contrast, beach streams (geomorphic class 4) and freshwater river mouths (geomorphic class 5) were defined in the New Zealand coastal hydrosystem classification as freshwater streams, but were crosswalked to FM1.2 because they are more appropriately classified as freshwater-dominated tidal streams rather than freshwater streams (with no saltwater influence).

Table 7. Crosswalk of New Zealand coastal hydrosystem geomorphic classes and subclasses to EFGs

Coastal hydrosystem geomorphic class	Subclass number and description	F2.5 ‘Ephemeral freshwater lakes’	F2.7 ‘Ephemeral salt lakes’	FM1.1 ‘Deepwater coastal inlets’	FM1.2 ‘Permanently open riverine estuaries and bays’	FM1.3 ‘Intermittently closed and open lakes and lagoons’
Damp sand plain lake	1	0.5	0.5			
Waituna-type lagoon	2A: Coastal plain depression					1
	2B: Valley basin					1
Hāpua-type lagoon	3A: Large hāpua-type lagoon					1
	3B: Medium hāpua-type lagoon					1
	3C: Small hāpua-type lagoon					1
	3D: Intermittent hāpua-type lagoon					1

Coastal hydrosystem geomorphic class	Subclass number and description	F2.5 ‘Ephemeral freshwater lakes’	F2.7 ‘Ephemeral salt lakes’	FM1.1 ‘Deepwater coastal inlets’	FM1.2 ‘Permanently open riverine estuaries and bays’	FM1.3 ‘Intermittently closed and open lakes and lagoons’
Beach stream	4A: Hillside stream				1	
	4B: Damp-sand plain stream				1	
	4C: Stream with pond					1
	4D: Stream with ribbon lagoon					1
	4E: Intermittent stream with ribbon lagoon					1
Freshwater river mouth	5A: Unrestricted				1	
	5B: Deltaic				1	
	5C: Barrier beach enclosed				1	
Tidal river mouth	6A: Unrestricted				1	
	6B: Spit enclosed				1	
	6C: Barrier beach enclosed				1	
	6D: Intermittent with ribbon lagoon					1
	6E: Deltaic				1	
Tidal lagoon	7A: Permanently open				1	
	7B: Intermittently closed					1
Shallow drowned valley	8				1	
Deep drowned valley	9			1		
Fjord	10			1		
Coastal embayment	11			1		

Note: MFT1.1 ‘Coastal river deltas’ are not considered to be present in New Zealand and are not included.

EFGs defined by flora

For many EFGs there were direct crosswalks to available data sets; for example, seagrass meadows, mangrove forest (intertidal forests and shrublands), and saltmarsh (coastal saltmarshes and reedbeds) (Table 8).

EFGs defined by fauna

Layers representing seabird and pinniped colonies, roosting and haul-out sites, in combination, were crosswalked to MT2.2 ‘Large seabird and pinniped colonies’ (Table 8).

EFGs defined by sedimentary features

A national rocky reef layer does exist, primarily based on known reefs from navigational charts, with approximately 90% of the data set crosswalking to M1.6 ‘Subtidal rocky reefs’ and 10% to MT1.1 ‘Rocky shorelines’ (Table 8).

EFGs defined by pelagic / water column features

Bathymetric layers were used to derive maps of each pelagic ocean water layer, with bathymetry clipped to 0–200 m depth to represent the epipelagic zone, 200–1,000 m to represent the mesopelagic zone, 1,000–4,000 m to represent the bathypelagic zone, and 4,000–6,000 m to represent the abyssopelagic zone (Table 8). Note that in deep waters all four pelagic zones would be present. We note that New Zealand’s oceans include depths beyond 6,000 m (i.e. the hadalpelagic zone), but this group is not included in the IUCN GET classification.

EFGs defined by seafloor topographic features

Seafloor geomorphic features generally crosswalked directly to EFGs, with some EFGs (e.g. M3.4 ‘Seamounts, ridges and plateaus’) representing multiple geomorphic features crosswalking to one EFG (Table 8).

EFGs defined by anthropogenic features

Anthropogenic data sets generally crosswalked directly to EFGs, typically with multiple anthropogenic layers crosswalking to one EFG (Table 8). Both finfish and shellfish aquaculture zones crosswalk to M4.2 ‘Marine aquafarms’). Oil and gas structures, submarine cables, submarine pipelines, and shipwrecks crosswalked to M4.1 ‘Submerged artificial structures’. Anthropogenic shoreline structure data sets are typically incomplete and were not mapped (MT3.1 ‘Artificial shorelines’) for this project. Ports, marinas, boat ramps, shoreline roads, and other shoreline reinforcements would be logically crosswalked to this EFG, although these features are not comprehensively mapped in New Zealand.

Table 8. Crosswalk of remaining source data sets to IUCN GET marine and marine transitional EFGs (Level 3)

Driving features	Data set	Crosswalk to IUCN GET Level 3 EFG
EFGs defined by flora	Blue carbon habitats: seagrass meadows	M1.1 ‘Seagrass meadows’
	Blue carbon habitats: mangrove forests	MFT1.2 ‘Intertidal forests and shrublands’
	Blue carbon habitats: saltmarsh	MFT1.3 ‘Coastal saltmarshes and reedbeds’
EFGs defined by fauna	Seabird breeding colonies and roosting sites	MT2.2 ‘Large seabird and pinniped colonies’
	Pinniped breeding colonies and haul-out sites	MT2.2 ‘Large seabird and pinniped colonies’
EFGs defined by sedimentary features	Rocky reef sediment layer – subtidal reefs	M1.6 ‘Subtidal rocky reefs’
	Rocky reef sediment layer – intertidal reefs	MT1.1 ‘Rocky shorelines’
EFGs defined by pelagic / water column features	Bathymetry: clipped to Epipelagic zone (0–200 m depth)	M2.1 ‘Epipelagic ocean waters’
	Bathymetry: clipped to Mesopelagic zone (200–1,000 m depth)	M2.2 ‘Mesopelagic ocean water’
	Bathymetry: clipped to Bathypelagic zone (1,000–4,000 m depth)	M2.3 ‘Bathypelagic ocean waters’
	Bathymetry: clipped to Abyssopelagic zone (4,000–6,000 m depth)	M2.4 ‘Abyssopelagic ocean waters’
EFGs defined by seafloor topographic features	Global digital seafloor geomorphic analysis (Harris et al. 2014): slopes	M3.1 ‘Continental and island slopes’
	Global digital seafloor geomorphic analysis (Harris et al. 2014): canyons	M3.2 ‘Submarine canyons’
	Global digital seafloor geomorphic analysis (Harris et al. 2014): abyssal plains	M3.3 ‘Abyssal plains’
	National underwater topographic features (Clark et al. 2022): seamounts	M3.4 ‘Seamounts, ridges and plateaus’
	Global digital seafloor geomorphic analysis (Harris et al. 2014): hadal trenches	M3.6 ‘Hadal trenches and troughs’
	Cold methane seeps (Greinert et al. 2010)	M3.7 ‘Chemosynthetic-based ecosystems’
	Global hydrothermal vent data set (Ramirez-Llodra & Baker 2006	M3.7 ‘Chemosynthetic-based ecosystems’
EFGs defined by anthropogenic features	Naturalness data set: offshore platforms	M4.1 ‘Submerged artificial structures’
	Naturalness data set: submarine cables	M4.1 ‘Submerged artificial structures’
	Naturalness data set: submarine pipelines	M4.1 ‘Submerged artificial structures’
	Naturalness data set: shipwrecks	M4.1 ‘Submerged artificial structures’
	Naturalness data set: finfish farms licences and permits	M4.2 ‘Marine aquafarms’
	Naturalness data set: shellfish farms licences and permits	M4.2 ‘Marine aquafarms’

3.6.3 Mapping methods

Most EFGs were directly aligned with existing data layers or with classifications within those data sets, thus required no further processing. For those EFGs that required further processing of existing data sets, the methods are described for each type of feature that defines similar groups of EFGs.

All layers were provided as raw data layers (shape files for point or polygon data, rasters) to provide the highest resolution available. We did not convert shape files to 100 × 100 m rasters because (i) rasters lose a lot of information (e.g. for mangroves or other EFGs distributed across a narrow depth zone), and (ii) for some layers 100 × 100 m would result in unmanageably large files (e.g. for the deep sea, where current data resolution is typically 1 km^2). We also note that in the marine biomes many EFGs result in overlapping layers; for example, where both a seafloor and a pelagic EFG exist, or where both vegetation, sediment, and other features that define individual EFGs are present at the same time. This overlap was noted in the initial examination of the appropriateness of IUCN GET for New Zealand for marine and marine transitional groups (Lundquist et al. 2024) and is one of many reasons that New Zealand marine stakeholders have selected the Coastal and Marine Ecological Classification Standard (CMECS) as the preferred classification framework for marine and estuarine ecosystems (see Collins 2024; Lundquist et al. 2024).

EFGs defined by estuarine hydrodynamics

Individual estuaries were allocated to classes and subclasses within the New Zealand Coastal Hydrosystem Classification, and were mapped onto crosswalked EFGs as per Table 8. Data are available as polygons.

EFGs defined by flora

Blue carbon data sets representing coastal wetlands were crosswalked onto EFGs as per Table 8, and were available as polygons.

EFGs defined by fauna

The marine key ecological areas combined data set was used to map the EFG MT2.2 ‘Large seabird and pinniped colonies’, because it represented the most up-to-date information from central and regional government (Table 8). One of the sub-data sets for this biome was altered slightly in order to remove the mainland elephant-seal-colony polygons, as elephant seals no longer breed on the mainland. Seabird and pinniped colonies were available as polygons and point records.

EFGs defined by pelagic / water column features

EFGs were derived from the national bathymetry raster and delineated by depth zones (Table 8). The epipelagic zone (0–200 m) spans the entire EEZ and required no clipping. The mesopelagic (200–1,000 m), bathypelagic (1,000–4,000 m), and abyssopelagic (4,000–6,000 m) zones occur only in progressively deeper waters, so the bathymetry raster was clipped to exclude areas shallower than 200 m, 1,000 m, and 4,000 m, respectively. Data were available in raster format (1 km^2).

EFGs defined by seafloor topographic features

Chemosynthetic ecosystems (cold seeps and hydrothermal vents) were taken directly from existing data sets. All other EFGs were derived from the Global Seafloor Geomorphic Features data set (Table 8). Abyssal plains were created by selecting Plains features within the Abyssal classification. Hadal trenches were created by selecting Trenches features within the Hadal base layer; no Hadal trough features were available. Continental and island slopes were derived by exporting the Slope base layer, and submarine canyons were derived by exporting the Canyons features. Cold seeps, hydrothermal vents, and seamounts were available as point data. Other data were available polygon shape files.

EFGs defined by anthropogenic features

Multiple data sets crosswalked to each anthropogenic EFG, as noted in Table 8. Data were available as polygon and point files.

3.6.4 Caveats

Limitations and caveats for most of these data sets have been discussed elsewhere. (See Stephenson et al. 2018 and Lundquist, Stephenson et al. 2020 for marine key ecological areas data sets; Lundquist et al. 2025 for anthropogenic data sets; Rowden et al. 2018 and Lundquist et al. 2024 for marine ecosystem classifications). Below we summarise key limitations with respect to robust mapping of EFGs.

EFGs defined by estuarine hydrodynamics

The New Zealand Coastal Hydrosystems Classification has been through multiple iterations (Hume et al. 2016) and is a comprehensive classification of all estuaries. With respect to IUCN GET it is primarily a many-to-one crosswalk, with IUCN GET including only four relevant geomorphic categories for estuaries, and the New Zealand Coastal Hydrosystems Classification providing 26 classes and subclasses.

EFGs defined by flora

For coastal wetlands the selected maps were from a national exercise that used satellite remote sensing to map three wetland types (M1.1 ‘Seagrass meadows’, MFT1.2 ‘Intertidal forests and shrublands’ [mangrove forests], and MFT1.3 ‘Coastal saltmarshes and reedbeds’ [saltmarsh] [Bulmer et al. 2024]). These layers represent a static point in time and should be updated regularly. Ministry for the Environment monitoring guidance suggests repeat sampling at sub-decadal scales for mangroves and saltmarsh (see details for particular habitats in Lohrer et al. 2024); seagrass is known to be more temporally variable, and any decreases could prompt a re-survey. The analysis resulting in these layers was performed at a national scale, with high uncertainty noted for seagrass meadows. The maps for these EFGs could be improved through finer-scale analyses to provide improved regional- and national-scale maps of distributions of wetland habitats.

EFGs defined by fauna

Layers representing seabird and pinniped colonies, and roosting and haul-out sites, are from disparate international, national, and regional sources. These data were compiled for the key ecological areas programme (Stephenson et al. 2018; Lundquist, Stephenson et al. 2020), so the combined data set is the most comprehensive available, but includes some inaccuracies and out-of-date data (e.g. elephant seal colonies are no longer present in Otago and Southland). Source data are also a mix of point records and polygons, and typically do not provide information on abundance, or on temporal occupancy of locations. Identifiers based on species present have been developed for each record (Lundquist, Stephenson et al. 2020).

Important bird area polygons are also available for New Zealand and complement locations of bird colonies that are available within central and regional government data sets. Important bird areas include broader areas of foraging in addition to the terrestrial habitats in which these colonies are found; we included only identified terrestrial locations of colonies within the EFG mapping, and not broader foraging areas. Three vertebrate-induced layers are also included within the NUE suite (Wiser et al. 2013). Note, however, that this data set has not been updated to reflect additional records compiled by Lundquist, Stephenson et al. (2020), particularly with respect to occurrences provided by regional councils, which are often missing from central government data sets on seabirds and pinniped colonies.

EFGs defined by sedimentary features

The national rocky reef layer is primarily based on known reefs from navigational charts, and it has known inaccuracies where mapping of the geospatial layer is poorly aligned with reefs as viewed in aerial images, and in its limited identification of deep reefs (DOC & Ministry of Fisheries 2011; SLR Consulting New Zealand, 2024). Updating of this layer is in progress, particularly with respect to identifying deep reefs that are less likely to be identified on navigational charts (SLR Consulting New Zealand 2024).

EFGs defined by pelagic / water column features

New Zealand's oceans include depths beyond 6,000 m (i.e. the hadalpelagic zone), but this group is not included in the IUCN GET classification. Overlap with hadal trenches and troughs is likely, although these EFGs are for deep-sea-floor ecosystems and do not include deep pelagic zones.

EFGs defined by seafloor topographic features

Data on chemosynthetic ecosystems (cold seeps and hydrothermal vents) are based on limited survey effort of New Zealand's EEZ and are likely to increase with further surveys. Seamounts have been more extensively mapped, including using bathymetric analysis. Feature data are typically provided as point records, so mapped polygons could provide a more accurate representation.

EFGs defined by anthropogenic features

Anthropogenic data sets are available for many features (aquaculture, oil and gas structures, submarine cables, submarine pipelines, and shipwrecks), though most data are available as point records, which may not represent the extent of these anthropogenic habitats. Aquaculture farms, in particular, are often provided as licence areas and/or future permitted areas, but the full area may not be used, or industry may rotate locations (e.g. salmon pens).

While maps of aquaculture licences are available from the Ministry for Primary Industries, regional councils typically host the most up-to-date data sets. The data set used for this mapping was developed in 2022, based on records confirmed across both national and regional government and updated for Lundquist et al. (2025). Lundquist et al. (2025) also discussed potential approaches to more accurately map these anthropogenic uses and ensure they are based on current permitting/licensing information and usage. Shoreline anthropogenic features have the most limited data to support mapping. Many of these features could be easily updated (i.e. through mapping the extents of ports and marinas; see recommendations in Lundquist et al. 2025).

3.6.5 Gaps

A key gap in our ability to map marine ecosystems in New Zealand is for habitat-forming fauna and flora (M1.2 ‘Kelp forests’, M1.4 ‘Shellfish beds and reefs’, M1.5 ‘Photo-limited marine animal forests’, M1.10 ‘Rhodolith/Maërl beds’, or M3.5 ‘Deepwater biogenic beds’). Approaches for mapping kelp forest have been developed and applied at regional scales, and could be applied at a national scale (Tait et al. 2021). Regular updates would be useful, because kelp forests are sensitive to climate change and heatwaves, and exhibit seasonality (Tait & D’Archino 2024).

Subtidal biogenic habitats are poorly mapped across New Zealand, but they are regularly noted as important habitat for seafloor ecosystem functioning and for providing habitat for juveniles of important commercial, recreational, and customary fisheries. In some locations expert knowledge of locations of these biogenic habitats has been compiled, but typically data sets are occurrence only and not based on systematic surveys. Predictive modelling approaches in combination with ground-truthing exercises could be used to confirm which modelling approaches are most appropriate to fill gaps in knowledge of distributions of these ecosystems; for example, models developed by Bennion et al. (2024) are in the process of being ground-truthed through systematic surveys of seafloor communities in the Hauraki Gulf.

A second key gap is caused by using pre-existing sedimentary layers to inform EFGs defined by sediments. While national sediment layers exist for New Zealand’s oceans (Bostock et al. 2019a,b), these do not directly translate to the IUCN GET EFGs and would require further discussion by the marine ecosystem typology group to assess how to classify sedimentary layers (% mud, % sand, % gravel, % carbonate) into EFGs of muddy shorelines, sandy shorelines, and boulder and cobble shores for MT1 ‘Shorelines biome’ (MT1.2, MT1.3, and MT1.4, respectively), and M1.7 ‘Subtidal sand beds’ and M1.8 ‘Subtidal mud plains’ for M1 ‘Marine shelf biome’.

These national-scale layers are also of limited use for mapping intertidal/shoreline EFGs. Instead, intertidal sediment data would need to be collated from other sources (mostly regional councils) to obtain the accuracy/resolution required. Similarly, a consistent definition of intertidal habitat types is needed; marine and coastal scientists in regional councils are in discussion about the need for harmonising definitions of intertidal and subtidal habitats within a national framework.

Finally, subtidal and deep sea sediment maps are often based on a limited number of sampling points and the mapped data sets have large areas with no data available. This means that values in many areas are statistically interpolated, creating unrealistic results based on point records in areas of limited sampling. Thus, our recommendation is to not include these maps in the IUCN record without further discussion. We note that once layers are uploaded it may be years or decades before they are updated (if ever).

Additional gaps in marine and marine transitional EFGs include M1.9 ‘Upwelling zones’ and MT3.1 ‘Artificial shorelines’. Further analysis and mapping of upwelling would require defining spatial and temporal characteristics that delineate these zones. As discussed previously, data sets to inform MT3.1 are largely incomplete, with more shoreline infrastructure, particularly smaller structure on private land, not being mapped, and larger shoreline infrastructure requiring conversion from point to polygon data sets for ports and marinas.

Four additional marine transitional groups could not be mapped using data from the marine and estuarine biome (SM1.1 ‘Anchialine caves’, SM1.2 ‘Anchialine pools’, SM1.3 ‘Sea caves’, and MT2.1 ‘Coastal shrublands and grasslands’), because no data were available in marine data sets. Here we note the challenges of the high number of marine transitional groups, and the somewhat arbitrary national boundary for marine regions (at the Marine High Water Springs), which excludes many IUCN GET marine transitional EFGs from being included in national and regional marine data sets (e.g. sand dunes, sandy beaches). Many of these marine transitional EFGs include sensitive or vulnerable habitats, and many have been mapped within terrestrial databases (e.g. sandy shorelines, though note the comments in section 3.1.5 on the reliability of these maps, particularly if using a 100 m resolution raster).

The DOC NUE layer includes 13 coastal NUEs (active sand dunes, basic coastal cliffs, calcareous coastal cliffs, coastal cliffs on acidic rocks, coastal cliffs on quartzose rocks, coastal rock stacks, coastal turfs, dune deflation hollows, shell barrier beaches, shingle beaches, stable sand dunes, stony beach ridges, and ultrabasic sea cliffs), four wetland NUEs (dune slacks, lagoons, estuaries, damp sand plains), and three NUEs that are ‘induced by native vertebrates’ (seabird-burrowed soils, seabird guano deposits, and marine mammal haul-outs). It should be noted that seabird colonies can be found tens of kilometres inland from the shore. We also note the current uncertainties with respect to data sharing of these data sets, as discussed elsewhere. Within the data sets mapped here NUEs related to large seabird and marine mammal areas were not included. NUE areas in many cases directly overlap other central and regional government data sets that indicate the locations of these colonies. Estuaries and lagoons were adequately covered within the NZ Coastal Hydrosystems Classification and associated data sets. Coastal rock stacks and other intertidal beach habitats (shingle beaches, shell barrier beaches) are often included in regional council data sets but are not identified in national marine sediment layers.

3.6.6 Recommendations specific to this domain

- Work with New Zealand marine and estuarine domain experts and the IUCN GET Scientific Committee to refine EFGs that do not translate cleanly to New Zealand, and/or facilitate the definition of new EFGs.
- Address the challenge of the IUCN GET approach for marine and marine transitional EFGs that does not include a consistent hierarchy of sedimentary, geomorphic, hydrodynamic or biological features.
- Update exports to IUCN GET for the marine and marine transitional EFGs as the New Zealand specific adaptation of CMECS become available. Consensus of regional and central government stakeholders resulted in the selection of CMECS as a framework upon which to adapt a national estuarine and marine ecosystems typology (Collins 2024).

- Determine the best way to represent long, narrow features that are systematically lost when converted to 100 m resolution raster grids.
- Negotiate access to relevant marine layers within the DOC Naturally Uncommon Ecosystems and include new Naturally Uncommon Marine Ecosystems as they are developed (e.g. current project contracted by DOC to Earth Sciences NZ).
- Prioritise the development and interpretation of nationally consistent substrate layers across intertidal/shoreline, shallow, and deep subtidal areas.
- Prioritise the compilation of nationally consistent layers for marine mammal and seabird colonies, noting that currently compilations include a variety of historical and current data, and both point records and polygons.
- Consult with regional authorities to compile/refine data sets to inform shoreline anthropogenic layers.
- Update data sets that are anticipated to change at shorter temporal scales (e.g. seagrass, kelp forest) or due to changes in licensing/permits for marine activities (e.g. offshore wind).
- Avoid uploading data sets that are incomplete or not robust, given that updates to the IUCN GET from New Zealand are not guaranteed to occur. Consider a regular schedule for reconfirming or updating data layers.
- Create national data sets for sensitive ecosystems (kelp forests, subtidal biogenic habitats). A methodology has been developed for kelp forest mapping using remote sensing that could be applied nationally. A mapping and validation exercise for subtidal biogenic habitats in the Hauraki Gulf (Bennion et al. 2024) could be used as a framework for developing and validating national-scale layers.
- Query with the IUCN GET governance group whether seabird and pinniped colonies appropriately fit the description of an EFG.

3.7 Compilation into a current ecosystem map

3.7.1 Stacked raster methods

Each domain team sent their spatial data on EFGs to the Bioeconomy Science Institute to lead the compilation of all EFG layers across the six domains. The domain data provided varied by spatial data format (i.e. rasters or shape files), by resolution, and by map projection. Therefore, where required, all spatial data for each domain were resampled, rasterised, and reprojected such that all resulting EFGs were raster layers with a consistent resolution, extent, and map projection. The final EFGs have a 100 m resolution and a 3,336 km by 2,116 km extent, and were in the NIWA Albers equal-area map projection.

All EFG layers were uploaded to the LRIS portal[13]. EFGs from the same biome (IUCN GET Level 2) were grouped into sets on LRIS for ease of access.

We did not create a single contiguous map of the EFGs because many of our crosswalks resulted in one-to-many or many-to-many matches (i.e. a New Zealand ecosystem type aligned with multiple IUCN GET EFGs, or several New Zealand ecosystem types aligned with multiple IUCN GET EFGs). However, we did create a map of the dominant biomes within the land area of New Zealand to illustrate the approximate extent of biomes present (Figure 1).

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[13] https://lris.scinfo.org.nz/data/

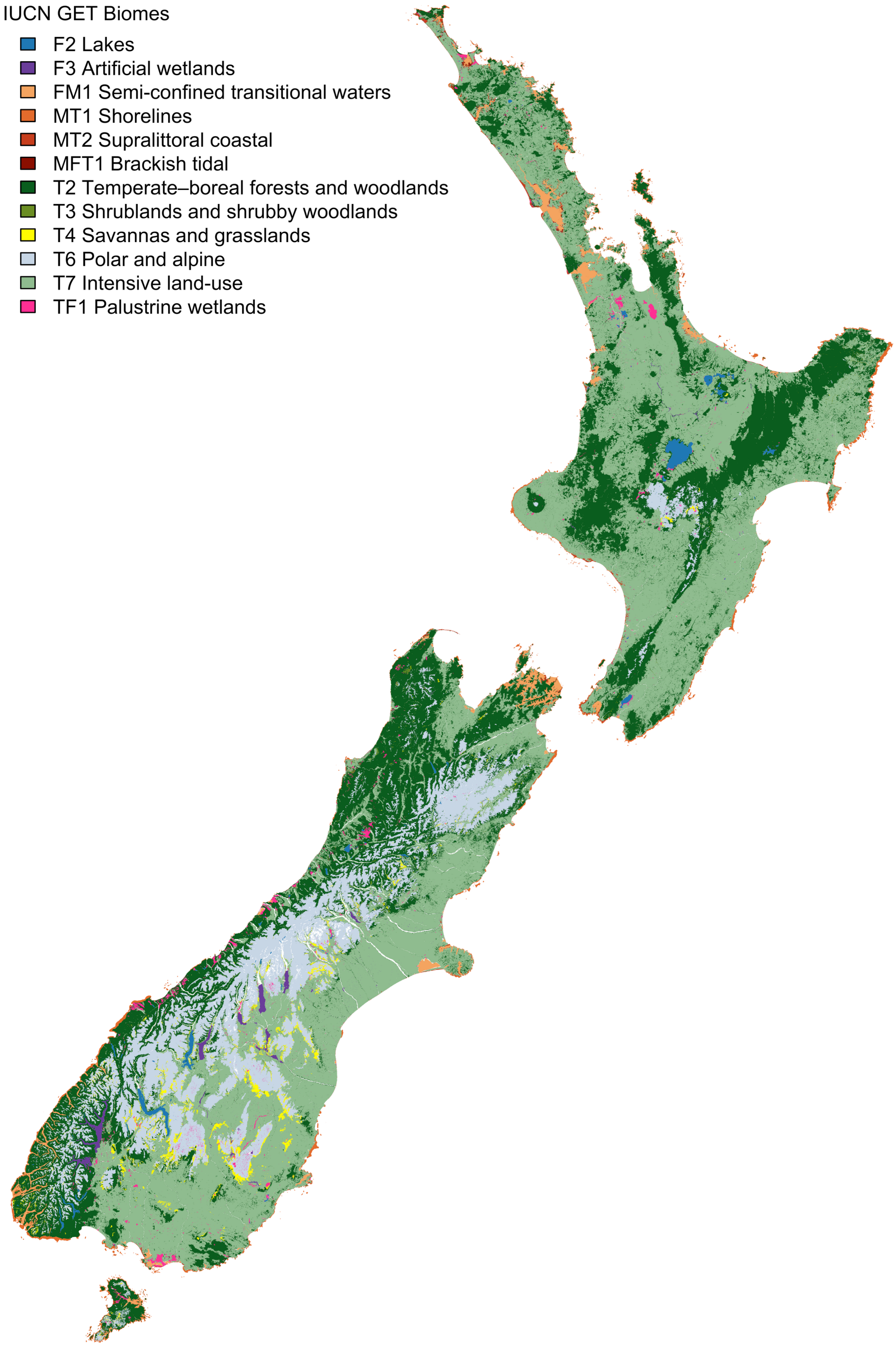

Figure 1. Map of IUCN GET biomes (Level 2) in New Zealand, mapped using existing data sources. The codes in the legend correspond to an IUCN GET biome.

Notes: Even though they are present in New Zealand, this map excludes the following biomes because they could not be easily visualised on this map: SF1 'Subterranean freshwaters biome', F1 'Rivers and streams biome', and the biomes in the marine domain. Note that F3 'Artificial wetlands biome' is composed of water bodies such as large reservoirs, constructed lakes, canals, and drains.

3.7.2 Additional metadata

We recorded the metadata for all the data sources we used (in an accompanying spreadsheet). We also noted the EFGs that are present in New Zealand and mapped, probably present but not mapped due to lack of available data, and EFGs that are not present in New Zealand (Appendix 4).

4 Conclusions

The current ecosystem map was completed at a national scale, using the IUCN GET EFGs as the defined ecosystem types. These EFGs are global in nature, so their spatial distribution as represented by the current ecosystem map is coarse at a national scale.

This project was a first step in harmonising the conceptual and spatial boundaries between domains at a national scale for the EFGs. Producing these mapped layers of EFGs present in New Zealand exposed challenges with existing data, current New Zealand typologies, and the EFG descriptions. Nonetheless, the current ecosystem map provides a starting point for future national-scale ecosystem mapping in New Zealand.

The current ecosystem map can be used as the baseline against which future changes to ecosystem extent and presence can be compared. A past ecosystem map of the pre-human spatial distribution of terrestrial forested ecosystems is currently in development, led by the Bioeconomy Science Institute. The past ecosystem map will be a companion map to the current ecosystem map and will show change in approximate ecosystem extents since human arrival in New Zealand.

4.1 Limitations and challenges

This is the first version of the current ecosystem map and it has multiple limitations. These can be grouped into three main categories: existing typologies, conceptual alignment of our New Zealand ecosystem types to the EFGs, and existing data and mapping.

Previous work investigating the IUCN GET for New Zealand found that New Zealand domain typologies generally fit well under the IUCN GET framework (Franklin & Booker 2024; Houghton et al. 2024; Lundquist et al. 2024; McCarthy & Wiser 2024; Wood & Schallenberg 2024; Burge 2025), although the lakes domain typology was found to be a poor fit. When we began work on crosswalking to the EFGs we found that because our existing typologies are currently being revised for some domains and the typologies are not mapped, we instead had to crosswalk existing spatial data sets to the EFGs.

This project allowed us to test the ability to crosswalk existing spatial data sources to the EFGs. We found that the IUCN GET descriptions of EFGs were qualitative for some domains (e.g. rivers) and did not clarify how to determine the dominant ecosystem type where there were two or more EFGs present. For example, for the lakes domain, some lakes in New Zealand mapped to both F2.1 ‘Large permanent freshwater lakes’ and F3.1 ‘Large reservoirs’, and there was no guidance about how to determine which EFG is dominant. Finally, we found that while most New Zealand ecosystem types and data could fit within the IUCN GET framework, there were a few New Zealand ecosystems that are not well represented in the IUCN GET, particularly in the terrestrial and marine domains. These conceptual challenges meant that our crosswalks were more subjective than we would have liked, because we had to rely on our own interpretations of the EFG descriptions to allocate our New Zealand ecosystems and data to the IUCN GET.

Another limitation of the current ecosystem map is that there are gaps between and overlaps among domains in the mapped layers. Although we are confident that we mapped most EFGs that are present in New Zealand's land and water, there were a few we identified as probably being present but we did not have the spatial data to map them (see Appendix 4). There were some EFGs that we did map for which our data sets are incomplete, so for those EFGs the gaps in the data resulted in gaps in the current ecosystem map. A few instances of boundary issues between domains were discovered, where there was a gap in existing data between domains and therefore a gap in the current ecosystem map. We also struggled with how to visualise extent when multiple EFGs are present in the same location.

There were three types of overlap in EFGs:

- several EFGs present three-dimensionally at the same location (e.g. groundwater aquifers underneath a wetland, or marine seafloor, benthic, and pelagic layers stacked in three-dimensional space)
- several EFGs present conceptually due to our crosswalks of New Zealand ecosystem data to the EFGs (e.g. a New Zealand ecosystem type was allocated to multiple EFGs)
- thematic overlap occurs across domains, where the same EFG is represented in more than one domain.

In these cases, polygons representing the same EFG may be derived from different source data sets that were originally developed for different purposes and at different thematic and spatial scales, and so may have different ecological meanings or interpretations. For example, FM1.3 ‘Intermittently closed and open lakes and lagoons’ was mapped in both the Lakes and Marine and estuarine domains. We were unable to visualise these types of overlap well. Appendix 5 shows the land areas of New Zealand there are multiple EFGs present.

Also, this map does not accurately represent both the extent (area) and presence (occurrence) of all EFGs in New Zealand. This is because for several EFGs present in New Zealand, individual occurrences are too small in area to be captured by the 100 × 100 m pixel size we have used; as a consequence we have excluded these EFGs. Also, the rivers domain mapped rivers as lines due to the dynamic nature of river flow widths, which means the EFG maps for rivers are not representative of the rivers ecosystems' extent.

5 Recommendations

This is the first version of the current ecosystem map, so we recommend the following cross-domain activities to improve this map in the future.

1. Continue revising the current New Zealand domain typologies at IUCN GET Level 6.
2. Provide feedback to the IUCN GET Scientific Committee about which EFG descriptions need more quantitative information, and which New Zealand ecosystem types are not defined well by the existing EFGs.
3. Fill gaps in data to map EFGs that occur in New Zealand but are not yet mapped, as well as gaps and overlaps in the current ecosystem map between domains.
4. Extend coverage of the current ecosystem map to offshore islands and the rest of New Zealand's Exclusive Economic Zone.
5. Resolve boundary overlap in the current ecosystem map between domains.

5.1 Creating finer conceptual resolution ecosystem maps

The current ecosystem map represents global ecosystem groups that occur in New Zealand, which means the conceptual (i.e. thematic) resolution of the map is broad. As New Zealand's domain typologies are developed and revised, ecosystem maps produced at a finer conceptual resolution (e.g. IUCN GET Level 6) will be more applicable to national- and regional-scale biodiversity planning and resource management. We recommend creating these finer-resolution maps from the bottom up rather than using the current ecosystem map to dictate where ecosystems are located. Then when the current ecosystem map is updated, the IUCN GET Level 6 ecosystem maps can be aggregated to create a current ecosystem map for IUCN GET Level 3 EFGs.

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Appendix 1 – Terrestrial domain mapping rules

Table A1.1. Rules for mapping Terrestrial EFGs

LCDB class	Ancillary variable(s)	EFG	Rationale
Alpine Grass/Herbfield	–	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Broadleaved Indigenous Hardwoods	Warm temperate forest = 0	T2.3 ‘Oceanic cool temperate rainforests’	Outside areas mapped as warm temperate.
Broadleaved Indigenous Hardwoods	Warm temperate forest = 1	T2.4 ‘Warm temperate laurophyll forests’	Areas mapped as warm temperate.
Built-up Area (settlement)	–	T7.4 ‘Urban and industrial ecosystems’	–
Deciduous Hardwoods[a]	Warm temperate forest = 0	T2.3 ‘Oceanic cool temperate rainforests’	Outside areas mapped as warm temperate.
Deciduous Hardwoods[a]	Warm temperate forest = 1	T2.4 ‘Warm temperate laurophyll forests’	Areas mapped as warm temperate.
Depleted Grassland[b]	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence including salt influx, strong winds and sunshine, and periodic disturbances.
Depleted Grassland[b]	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Depleted Grassland[b]	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T7.5 ‘Derived semi-natural pastures and old fields’	–
Estuarine Open Water	–	–	Outside Terrestrial domain
Exotic Forest	–	T7.3 ‘Plantations’	This LCDB class can also include wilding pines, which technically do not belong in T7.3, but we do not have the ability to map these areas separately.
Fernland[b]	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence including salt influx, strong winds and sunshine, and periodic disturbances.
Fernland[b]	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Fernland[b]	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T7.5 ‘Derived semi-natural pastures and old fields’	Almost all of these areas would have been forested prior to anthropogenic disturbance.

LCDB class	Ancillary variable(s)	EFG	Rationale
Flaxland[b]	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence, including salt influx, strong winds and sunshine, and periodic disturbances.
Flaxland[b]	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Flaxland[b]	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T7.5 ‘Derived semi-natural pastures and old fields’	Almost all of these areas would have been forested prior to anthropogenic disturbance.
Forest - Harvested	–	T7.3 ‘Plantations’	T7.3 technically excludes harvested plantations, but it is not clear where these would otherwise fit, and in many cases they are quickly replanted.
Gorse and/or Broom[b]	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence, including salt influx, strong winds and sunshine, and periodic disturbances.
Gorse and/or Broom[b]	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Gorse and/or Broom[b]	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T7.5 ‘Derived semi-natural pastures and old fields’	Almost all of these areas would have been forested prior to anthropogenic disturbance.
Gravel and Rock	Alluvial substrate = 1	–	Outside Terrestrial domain (river banks, etc.)
Gravel and Rock	Alluvial substrate = 0 Above treeline = 0	T3.4 ‘Young rocky pavements, lava flows and screes’	–
Gravel and Rock	Alluvial substrate = 0 Above treeline = 1	T6.2 ‘Polar/alpine cliffs, screes, outcrops and lava flows’	–
Herbaceous Freshwater Vegetation	–	–	Outside Terrestrial domain
Herbaceous Saline Vegetation	–	–	Outside Terrestrial domain
High Producing Exotic Grassland	LUM high producing = 0 Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
High Producing Exotic Grassland	LUM high producing = 1	T7.2 ‘Sown livestock pastures’	We only allocated this class to T7.2 when the LUM also categorised the area as having high-producing grasses (this LCDB class also included non-intensively managed grasslands with high vigour)
High Producing Exotic Grassland	LUM high producing = 0 Above treeline = 0	T7.5 ‘Derived semi-natural pastures and old fields’	See row above.

LCDB class	Ancillary variable(s)	EFG	Rationale
Indigenous Forest	Warm temperate forest = 0	T2.3 ‘Oceanic cool temperate rainforests’	Outside areas mapped as warm temperate.
Indigenous Forest	Warm temperate forest = 1	T2.4 ‘Warm temperate laurophyll forests’	Areas mapped as warm temperate.
Lake or Pond	–	–	Outside Terrestrial domain
Landslide	Above treeline = 0	T3.4 ‘Young rocky pavements, lava flows and screes’	–
Landslide	Above treeline = 1	T6.2 ‘Polar/alpine cliffs, screes, outcrops and lava flows’	–
Low Producing Grassland[b]	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence including salt influx, strong winds and sunshine, and periodic disturbances.
Low Producing Grassland[b]	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Low Producing Grassland[b]	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T7.5 ‘Derived semi-natural pastures and old fields’	–
Mangrove	–	–	Outside Terrestrial domain
Manuka and/or Kanuka[a]	Warm temperate forest = 0	T2.3 ‘Oceanic cool temperate rainforests’	Outside areas mapped as warm temperate.
Manuka and/or Kanuka[a]	Warm temperate forest = 1	T2.4 ‘Warm temperate laurophyll forests’	Areas mapped as warm temperate.
Matagouri or Grey Scrub[b]	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence, including salt influx, strong winds and sunshine, and periodic disturbances.
Matagouri or Grey Scrub[b]	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Matagouri or Grey Scrub[b]	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T7.5 ‘Derived semi-natural pastures and old fields’	Almost all of these areas would have been forested prior to anthropogenic disturbance.
Mixed Exotic Shrubland[b]	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence, including salt influx, strong winds and sunshine, and periodic disturbances.
Mixed Exotic Shrubland[b]	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Mixed Exotic Shrubland[b]	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T7.5 ‘Derived semi-natural pastures and old fields’	Almost all of these areas would have been forested prior to anthropogenic disturbance.
Orchard, Vineyard or Other Perennial Crop	–	T7.3 ‘Plantations’	–
Permanent Snow and Ice	–	T6.1 ‘Ice sheets, glaciers and perennial snowfields’	–

LCDB class	Ancillary variable(s)	EFG	Rationale
River	–	–	Outside Terrestrial domain
Sand and Gravel	Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Non-shoreline sands most closely match this EFG.
Sand and Gravel	Inland = 1 Above treeline = 0	T3.4 ‘Young rocky pavements, lava flows and screes’	–
Sand and Gravel	Above treeline = 1	T6.2 ‘Polar/alpine cliffs, screes, outcrops and lava flows’	–
Short-rotation Cropland	–	T7.1 ‘Annual croplands’	–
Sub Alpine Shrubland	–	T6.4 ‘Temperate alpine grasslands and shrublands’	Most (c. 80%) of this class occurs above treeline. Sub-alpine areas are difficult to otherwise classify due to the lack of an EFG covering many of New Zealand’s shrublands (See section 3.1.4).
Surface Mine or Dump	–	T7.4 ‘Urban and industrial ecosystems’	–
Tall Tussock Grassland	Sand substrate = 1 *or* Salt spray = 1 Inland = 0 Above treeline = 0	MT2.1 ‘Coastal shrublands and grasslands’	Areas with a coastal influence including salt influx, strong winds and sunshine, and periodic disturbances.
Tall Tussock Grassland	Above treeline = 0 Sand substrate = 1 *and* Inland = 1 OR Sand substrate = 0 *and* Salt spray = 0	T4.5 ‘Temperate subhumid grasslands’	–
Tall Tussock Grassland	Above treeline = 1	T6.4 ‘Temperate alpine grasslands and shrublands’	–
Transport Infrastructure	–	T7.4 ‘Urban and industrial ecosystems’	–
Urban Parkland/Open Space	–	T7.4 ‘Urban and industrial ecosystems’	–

[a] While descriptions of these LCDB classes may superficially match other EFGs (i.e. T2.2 ‘Deciduous temperate forests’, T3.3 ‘Cool temperate heathlands’), the ecosystem properties and ecological drivers defined in the IUCN descriptions largely exclude their presence in New Zealand. See section 3.1.4.

[b] These LCDB classes share the same set of rules designed to identify coastal/dune-based systems, semi-natural grasslands/old fields, and alpine grasslands and shrublands.

Appendix 2 – Wetland domain mapping rules

Table A2.1 Rule set to classify likelihood of each wetland class, for any given raster cell (100 × 100 m)

Variable	Description	Swamp	Marsh	Bog	Fen	Seepage	Pākihi	Gumland
pH class	pH < 4.8	0.1	0	1	0.8	1		
	4.8 ≤ pH ≤ 5.4	0.5	0	0.8	1	1		
	5.4 < pH ≤ 5.7	0.8	0.2	0.6	0.8	1		
	5.7 < pH ≤ 6.4	1	0.6	0	0.6	1		
	6.4 < pH ≤ 7.5	0.8	1	0	0	1		
	7.5 < pH ≤ 8.3	0.1	0.6	0	0	0.8		
	pH > 8.3 (unclassified, no data exists)							
Drainage class	Very poor	1	0	1	1	0		
	Poor	1	0.2	1	1	0.2		
	Imperfect	0.8	1	0.6	0.6	0.4		
	Moderately well	0.3	0.9	0	0.5	1		
	Well	0.1	0.9	0	0.1	1		
Peat content	Pure peat		0	1	0.8	0		
	Mineral/peat		0.5	0.8	1	1		
	Pure mineral		1	0	0.1	1		
Red tussock (NZLRI)	No	1	1	1	0.5			
	Yes	0	0	0	1			
Subalpine herbfield (NZLRI)	No	1	1		1			
	Yes	0	0.5		1			
Upland	Elevation < 600 M	1						
	Elevation ≥ 600 M	0.5						
Slope	Slope < 6°	1				0		
	Slope ≥ 6°	0.5				1		
Lake nearby	Yes (lake intersects raster cell)			0.1	0.1			
	No (lake does not intersect raster cell)			1	1			
River nearby	Yes (river intersects raster cell)				0.1			
	No (river does not intersect raster cell)				1			
Subcatchment size (assessed	x < 100 (< 1 km^2)				1	1		
	100 ≤ x ≤ 1000 (1–10 km^2)				1	0		

Variable	Description	Swamp	Marsh	Bog	Fen	Seepage	Pākihi	Gumland
using the number of [uphill] 100 x 100 m cells that are considered to drain into the cell in question)	x > 1,000 (> 10 km^2)				0.1	0		
Fertility	Low fertility	0.2	0.2	1	1			
	Moderate fertility	0.8	0.8	0	0.8			
	High fertility	1	1	0	0.1*			
Pākihi soils	High probability soil series						1	
	Not listed in high probability						0	
Gumland soils	High probability soil series							1
	Low probability soil series							0.2
	Not listed							0

Notes: These rules follow the principles of Ausseil et al. 2008. Where no multiplier is given, the wetland probability is unaffected by that variable. For pākihi and gumland, this means they are entirely driven by the soils that are mapped in that location, and so almost certainly are assigned pākihi or gumland where high probability soils exist.

*This differs from the value in Ausseil et al. 2008 because some cells remained unclassified where red tussock exists and soil fertility was mapped as high (all wetland class probabilities had a value of zero), and this change allowed those cells to retain at least one wetland class membership.

Table A2.2 Further detail on peat soil classification

Peat content class	Description	Rule
Pure peat	Soils dominated by peat with little or no mineral substrate	• Soil code starts with ‘O’ and particle size = Tp (North & South Island FSL* data sets) • Soil code starts with ‘O’ and top rock = Pt (Stewart Island / Rakiura data set)
Peat and mineral substrate	Organic soils with substantial mineral influence or shallow peat over mineral substrate	• Soil code starts with ‘O’ and particle size ∈ {Tc, Tl, Ts} • Third character of NZSC code = ‘O’ (e.g. mineral–organic intergrades) • Stewart Island / Rakiura: NZSCLS contains ‘O’ (any position) but top rock ≠ Pt
Pure mineral	Mineral soils without peat influence	• All remaining soil polygons not classified as organic or peat–mineral

Note: These rules are a revision of Ausseil et al. 2008.

*FSL = Fundamental Soil Layer

Table A2.3 Further detail on soil series that indicate pākihi and gumland (names as per FSL layers under the variable 'SERIES')

Pākihi high probability	Gumland high probability	Gumland low probability
Maimai	Wharekohe	Ruakaka
Rutherglen	Hukerenui	One Tree Point
Hukarere	Kara	Tangitiki
Addison	Te Kopuru	Mahurangi
Charleston	Te Hapua	Oturu
Flagstaff	Parahaki	Hurewai
Waiuta	Kaikino	Puketitoi
Casolis		Pukewaenga
Kotinga		Waikare
Mawhera		Otaika
Okarito		Otongaroa
Kumara		Albany
Kongahu		Waipapa
Onahau		Waipu
Capleston		Wairua
Denniston		Otonga
Omanu		Otakairangi
Lockington		
Bromielaw		
Ballarat		
Tiropahi		

Notes: A separate process later separates pākihi and gumlands that are peat-dominated (which are classified into IUCN GET peat bogs) and those that are more mineral soil (which are classified into the heathland EFG). See Table 1 for more detail on this later step. These soils are a revision of Ausseil et al. 2008.

Appendix 3 – Summary of Marine and Marine transitional EFGs

Table A3.1 Summary of Marine and Marine transitional EFGs and primary data sets available to map Marine and Marine transitional groups in New Zealand

Level 1 realm	Level 2 biome	Level 3 EFG code	Level 3 EFG name	EFG present	Data available to map EFG	Data sources used
Freshwater-Marine	Semi-confined transitional waters biome	FM1.1	'Deepwater coastal inlets'	Yes	Yes	Coastal Hydrosystems Classification (Hume et al. 2016)
		FM1.2	'Permanently open riverine estuaries and bays'	Yes	Yes	Coastal Hydrosystems Classification (Hume et al. 2016)
		FM1.3	'Intermittently closed and open lakes and lagoons'	Yes	Yes	Coastal Hydrosystems Classification (Hume et al. 2016)
Marine	Marine shelf biome	M1.1	'Seagrass meadows'	Yes	Yes	National blue carbon data set (Bulmer et al. 2024).
		M1.2	'Kelp forests'	Yes	Incomplete	No comprehensive national data set. Some regional maps available from satellite remote sensing. High temporal variability in distributions.
		M1.3	'Photic coral reefs'	No	n/a	EFG not present in New Zealand.
		M1.4	'Shellfish beds and reefs'	Yes	Incomplete	No robust/ comprehensive national data set. Some regional models predicting habitat suitability for shellfish, local knowledge of occurrence.
		M1.5	'Photo-limited marine animal forests'	Yes	Incomplete	No robust/ comprehensive national data set. Some regional models predicting habitat suitability of biogenic habitats, local knowledge of occurrence.
		M1.6	'Subtidal rocky reefs'	Yes	Yes	National rocky reef layer based primarily on data from navigational charts (DOC & Ministry of Fisheries 2011). Assumed to be incomplete for deeper reefs.
		M1.7	'Subtidal sand beds'	Yes	Incomplete	National sediment grainsize maps (Bostock et al. 2019a,b). Low-resolution/sampling effort in many areas; grainsize available as % mud, % sand, % gravel and % carbonate sediments.

Level 1 realm	Level 2 biome	Level 3 EFG code	Level 3 EFG name	EFG present	Data available to map EFG	Data sources used
Marine (Cont.)	Marine shelf biome (Cont.)	M1.8	‘Subtidal mud plains’	Yes	Incomplete	National sediment grainsize maps (Bostock et al. 2019a,b). Low-resolution/sampling effort in many areas; grainsize available as % mud, % sand, % gravel and % carbonate sediments.
		M1.9	‘Upwelling zones’	Yes	No	Physical oceanographic data sets available, but no data layer representing upwelling zones. Would require defining spatial and temporal characteristics that delineate an upwelling zone.
		M1.10	‘Rhodolith / Maërl beds’	Yes	Incomplete	No robust/ comprehensive national data set. Some local knowledge of occurrence.
Marine	Pelagic ocean waters biome	M2.1	‘Epipelagic ocean waters’	Yes	Yes	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
		M2.2	‘Mesopelagic ocean water’	Yes	Yes	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
		M2.3	‘Bathypelagic ocean waters’	Yes	Yes	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
		M2.4	‘Abyssopelagic ocean waters’	Yes	Yes	National bathymetry layer used to extract pelagic layers (Mitchell et al. 2012).
		M2.5	‘Sea ice’	No	n/a	EFG not present in New Zealand.
Marine	Deep sea floors biome	M3.1	‘Continental and island slopes’	Yes	Yes	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.2	‘Submarine canyons’	Yes	Yes	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.3	‘Abyssal plains’	Yes	Yes	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).

Level 1 realm	Level 2 biome	Level 3 EFG code	Level 3 EFG name	EFG present	Data available to map EFG	Data sources used
Marine (Cont.)	Deep sea floors biome (Cont.)	M3.4	‘Seamounts, ridges and plateaus’	Yes	Yes	Seamounts – Underwater topographic features (Clark et al. 2022); plateaus – digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.5	‘Deepwater biogenic beds’	Yes	Incomplete	No robust/ comprehensive national data set. Some national models predicting habitat suitability of biogenic habitats, local knowledge of occurrence from ocean seafloor surveys.
		M3.6	‘Hadal trenches and troughs’	Yes	Yes	Digital seafloor geomorphic features map (GSFM) of the global ocean (Harris et al. 2014).
		M3.7	‘Chemosynthetic-based ecosystems’	Yes	Yes	Global hydrothermal vent data set (Ramirez-Llodra & Baker 2006); cold methane seeps (Greinert et al. 2010). Best available but likely incomplete, as seafloor surveys regularly find new chemosynthetic features.
Marine	Anthropogenic marine biome	M4.1	‘Submerged artificial structures’	Yes	Yes	Offshore platforms, submarine cables, submarine pipelines, shipwrecks compiled for Ministry for the Environment Naturalness data set, compiled from various sources (Lundquist et al. 2025).
		M4.2	‘Marine aquafarms’	Yes	Yes	Aquaculture farms (finfish and shellfish), compiled for Ministry for the Environment Naturalness data set, compiled from various sources (Lundquist et al. 2025).
Marine-Freshwater-Terrestrial	Brackish tidal biome	MFT1.1	‘Coastal river deltas’	No	n/a	EFG not present in New Zealand.
		MFT1.2	‘Intertidal forests and shrublands’	Yes	Yes	National blue carbon data set (Bulmer et al. 2024).
		MFT1.3	‘Coastal saltmarshes and reedbeds’	Yes	Yes	National blue carbon data set (Bulmer et al. 2024).

Level 1 realm	Level 2 biome	Level 3 EFG code	Level 3 EFG name	EFG present	Data available to map EFG	Data sources used
Marine-Terrestrial	Shorelines biome	MT1.1	'Rocky shorelines'	Yes	Yes	National rocky reef layer based primarily on data from navigational charts (DOC & Ministry of Fisheries 2011). Assumed to be incomplete for deeper reefs.
		MT1.2	'Muddy shorelines'	Yes	Incomplete	National sediment grainsize maps (Bostock et al. 2019a,b). Low-resolution/sampling effort in many areas; grainsize available as % mud, % sand, % gravel and % carbonate sediments. Resolution at shoreline/intertidal zone is too coarse to represent local variation in sedimentary categories.
		MT1.3	'Sandy shorelines'	Yes	Incomplete	National sediment grainsize maps (Bostock et al. 2019a,b). Low-resolution/sampling effort in many areas; grainsize available as % mud, % sand, % gravel and % carbonate sediments. Resolution at shoreline/intertidal zone is too coarse to represent local variation in sedimentary categories.
		MT1.4	'Boulder and cobble shores'	Yes	Incomplete	National sediment grainsize maps (Bostock et al. 2019a,b). Low-resolution/accuracy in many areas; grainsize available as % mud, % sand, % gravel and % carbonate sediments. Resolution at shoreline/intertidal zone is too coarse to represent local variation in sedimentary categories.
Marine-Terrestrial	Supralittoral coastal biome	MT2.1	'Coastal shrublands and grasslands'	Yes	*	Best addressed by terrestrial biome.
		MT2.2	'Large seabird and pinniped colonies'	Yes	Yes	Data sets on seal and sea-lion breeding colonies and haul-out sites, and roosting and breeding seabird colonies, compiled from central and regional government data sets for key ecological area data sets (Lundquist et al. 2020a).

Level 1 realm	Level 2 biome	Level 3 EFG code	Level 3 EFG name	EFG present	Data available to map EFG	Data sources used
Marine-Terrestrial	Anthropogenic shorelines biome	MT3.1	'Artificial shorelines'	Yes	Incomplete	No comprehensive national map of artificial shoreline structures; some features available for regional authorities, but primarily reflect structures on public land. Available data sets on ports, marinas, boat ramps, roads compiled for Ministry for the Environment Naturalness project (Lundquist et al. 2025).
Subterranean-Marine	Subterranean tidal biome	SM1.1	'Anchialine caves'	Yes	*	Best addressed by subterranean biome.
		SM1.2	'Anchialine pools'	Yes	*	Best addressed by subterranean biome.
		SM1.3	'Sea caves'	Yes	*	Best addressed by subterranean biome.

Appendix 4 – Status of EFGs in New Zealand

Table A4.1 Full list of IUCN GET Ecosystem Functional Groups (EFGs), and their status in New Zealand

EFG code	EFG name	Status	Notes
T1.1	'Tropical/Subtropical lowland rainforests'	Not present in NZ	
T1.2	'Tropical/Subtropical dry forests and thickets'	Not present in NZ	
T1.3	'Tropical/Subtropical montane rainforests'	Not present in NZ	
T1.4	'Tropical heath forests'	Not present in NZ	
T2.1	'Boreal and temperate high montane forests and woodlands'	Not present in NZ	
T2.2	'Deciduous temperate forests'	Not present in NZ	
T2.3	'Oceanic cool temperate rainforests'	Present and mapped	
T2.4	'Warm temperate laurophyll forests'	Present and mapped	
T2.5	'Temperate pyric humid forests'	Not present in NZ	
T2.6	'Temperate pyric sclerophyll forests and woodlands'	Not present in NZ	
T3.1	'Seasonally dry tropical shrublands'	Not present in NZ	
T3.2	'Seasonally dry temperate heath and shrublands'	Unknown if present in NZ	
T3.3	'Cool temperate heathlands'	Present and mapped	
T3.4	'Young rocky pavements, lava flows and screes'	Present and mapped	
T4.1	'Trophic savannas'	Not present in NZ	
T4.2	'Pyric tussock savannas'	Not present in NZ	
T4.3	'Hummock savannas'	Not present in NZ	
T4.4	'Temperate woodlands'	Present but not enough data	
T4.5	'Temperate subhumid grasslands'	Present and mapped	
T5.1	'Semi-desert steppe'	Not present in NZ	
T5.2	'Succulent or Thorny deserts and semi-deserts'	Not present in NZ	
T5.3	'Sclerophyll hot deserts and semi-deserts'	Not present in NZ	
T5.4	'Cool deserts and semi-deserts'	Not present in NZ	
T5.5	'Hyper-arid deserts'	Not present in NZ	
T6.1	'Ice sheets, glaciers and perennial snowfields'	Present and mapped	
T6.2	'Polar/alpine cliffs, screes, outcrops and lava flows'	Present and mapped	
T6.3	'Polar tundra and deserts'	Present but not enough data	Present on the subantarctic islands
T6.4	'Temperate alpine grasslands and shrublands'	Present and mapped	

EFG code	EFG name	Status	Notes
T6.5	‘Tropical alpine grasslands and herbfields’	Not present in NZ	
T7.1	‘Annual croplands’	Present and mapped	
T7.2	‘Sown pastures and fields’	Present and mapped	
T7.3	‘Plantations’	Present and mapped	
T7.4	‘Urban and industrial ecosystems’	Present and mapped	
T7.5	‘Derived semi-natural pastures and old fields’	Present and mapped	
S1.1	‘Aerobic caves’	Present but not enough data	
S1.2	‘Endolithic systems’	Present but not enough data	
S2.1	‘Anthropogenic subterranean voids’	Present but not enough data	
SF1.1	‘Underground streams and pools’	Present but not enough data	
SF1.2	‘Groundwater ecosystems’	Present but not enough data	Requires further work to link to functional characteristics
SF2.1	‘Water pipes and subterranean canals’	Present but not enough data	
SF2.2	‘Flooded mines and other voids’	Present but not enough data	
SM1.1	‘Anchialine caves’	Possibly present but not enough data	
SM1.2	‘Anchialine pools’	Unknown if present in NZ	
SM1.3	‘Sea caves’	Unknown if present in NZ	
TF1.1	‘Tropical flooded forests and peat forests’	Not present in NZ	
TF1.2	‘Subtropical/temperate forested wetlands’	Present and mapped	
TF1.3	‘Permanent marshes’	Present and mapped	
TF1.4	‘Seasonal floodplain marshes’	Present and mapped	
TF1.5	‘Episodic arid floodplains’	Not present in NZ	
TF1.6	‘Boreal, temperate and montane peat bogs’	Present and mapped	
TF1.7	‘Boreal and temperate fens’	Not present in NZ	
F1.1	‘Permanent upland streams’	Present and mapped	
F1.2	‘Permanent lowland rivers’	Present and mapped	
F1.3	‘Freeze-thaw rivers and streams’	Unknown if present in NZ	We don't have the data to identify or map these ecosystems if they are present.
F1.4	‘Seasonal upland streams’	Not present in NZ	Unclear from IUCN GET description if this group includes naturally intermittent/ ephemeral reaches. We don't have the data to identify or map these ecosystems if they are present.

EFG code	EFG name	Status	Notes
F1.5	‘Seasonal lowland rivers’	Not present in NZ	Unclear from IUCN GET description if this group includes naturally intermittent/ ephemeral reaches. We don't have the data to identify or map these ecosystems if they are present.
F1.6	‘Episodic arid rivers’	Not present in NZ	
F1.7	‘Large lowland rivers’	Not present in NZ	
F2.1	‘Large permanent freshwater lakes’	Present and mapped	
F2.2	‘Small permanent freshwater lakes’	Present and mapped	
F2.3	‘Seasonal freshwater lakes’	Present but not enough data	Very limited data available
F2.4	‘Freeze-thaw freshwater lakes’	Present and mapped	Limited data available
F2.5	‘Ephemeral freshwater lakes’	Present and mapped	Limited data available
F2.6	‘Permanent salt and soda lakes’	Not present in NZ	
F2.7	‘Ephemeral salt lakes’	Present and mapped	Limited data available.
F2.8	‘Artesian springs and oases’	Present but not enough data	
F2.9	‘Geothermal pools and wetlands’	Present but not enough data	No comprehensive national map available but some regional maps exist.
F2.10	‘Subglacial lakes’	Not present in NZ	
F3.1	‘Large reservoirs’	Present and mapped	
F3.2	‘Constructed lacustrine wetlands’	Present and mapped	
F3.3	‘Rice paddies’	Not present in NZ	
F3.4	‘Freshwater aquafarms’	Present but not enough data	
F3.5	‘Canals, ditches and drains’	Present but not enough data	
FM1.1	‘Deepwater coastal inlets’	Present and mapped	
FM1.2	‘Permanently open riverine estuaries and bays’	Present and mapped	
FM1.3	‘Intermittently closed and open lakes and lagoons’	Present and mapped	
M1.1	‘Seagrass meadows’	Present and mapped	
M1.2	‘Kelp forests’	Present but not enough data	No comprehensive national map available but some regional maps exist.
M1.3	‘Photic coral reefs’	Not present in NZ	
M1.4	‘Shellfish beds and reefs’	Present but not enough data	
M1.5	‘Photo-limited marine animal forests’	Present but not enough data	
M1.6	‘Subtidal rocky reefs’	Present and mapped	
M1.7	‘Subtidal sand beds’	Present but not enough data	
M1.8	‘Subtidal mud plains’	Present but not enough data	
M1.9	‘Upwelling zones’	Present but not enough data	

EFG code	EFG name	Status	Notes
M1.10	‘Rhodolith/Maërl beds’	Present but not enough data	
M2.1	‘Epipelagic ocean waters’	Present and mapped	
M2.2	‘Mesopelagic ocean water’	Present and mapped	
M2.3	‘Bathypelagic ocean waters’	Present and mapped	
M2.4	‘Abyssopelagic ocean waters’	Present and mapped	
M2.5	‘Sea ice’	Not present in NZ	
M3.1	‘Continental and island slopes’	Present and mapped	
M3.2	‘Submarine canyons’	Present and mapped	
M3.3	‘Abyssal plains’	Present and mapped	
M3.4	‘Seamounts, ridges and plateaus’	Present and mapped	
M3.5	‘Deepwater biogenic beds’	Present but not enough data	
M3.6	‘Hadal trenches and troughs’	Present and mapped	
M3.7	‘Chemosynthetic-based-ecosystems’ (CBE)	Present and mapped	
M4.1	‘Submerged artificial structures’	Present and mapped	
M4.2	‘Marine aquafarms’	Present and mapped	
MT1.1	‘Rocky shorelines’	Present and mapped	
MT1.2	‘Muddy shorelines’	Present but not enough data	
MT1.3	‘Sandy shorelines’	Present but not enough data	
MT1.4	‘Boulder and cobble shores’	Present but not enough data	
MT2.1	‘Coastal shrublands and grasslands’	Present and mapped	
MT2.2	‘Large seabird and pinniped colonies’	Present and mapped	
MT3.1	‘Artificial shorelines’	Present but not enough data	
MFT1.1	‘Coastal river deltas’	Not present in NZ	
MFT1.2	‘Intertidal forests and shrublands’	Present and mapped	
MFT1.3	‘Coastal saltmarshes and reedbeds’	Present and mapped	

Appendix 5 – Overlaps of mapped EFGs (marine biomes excluded)

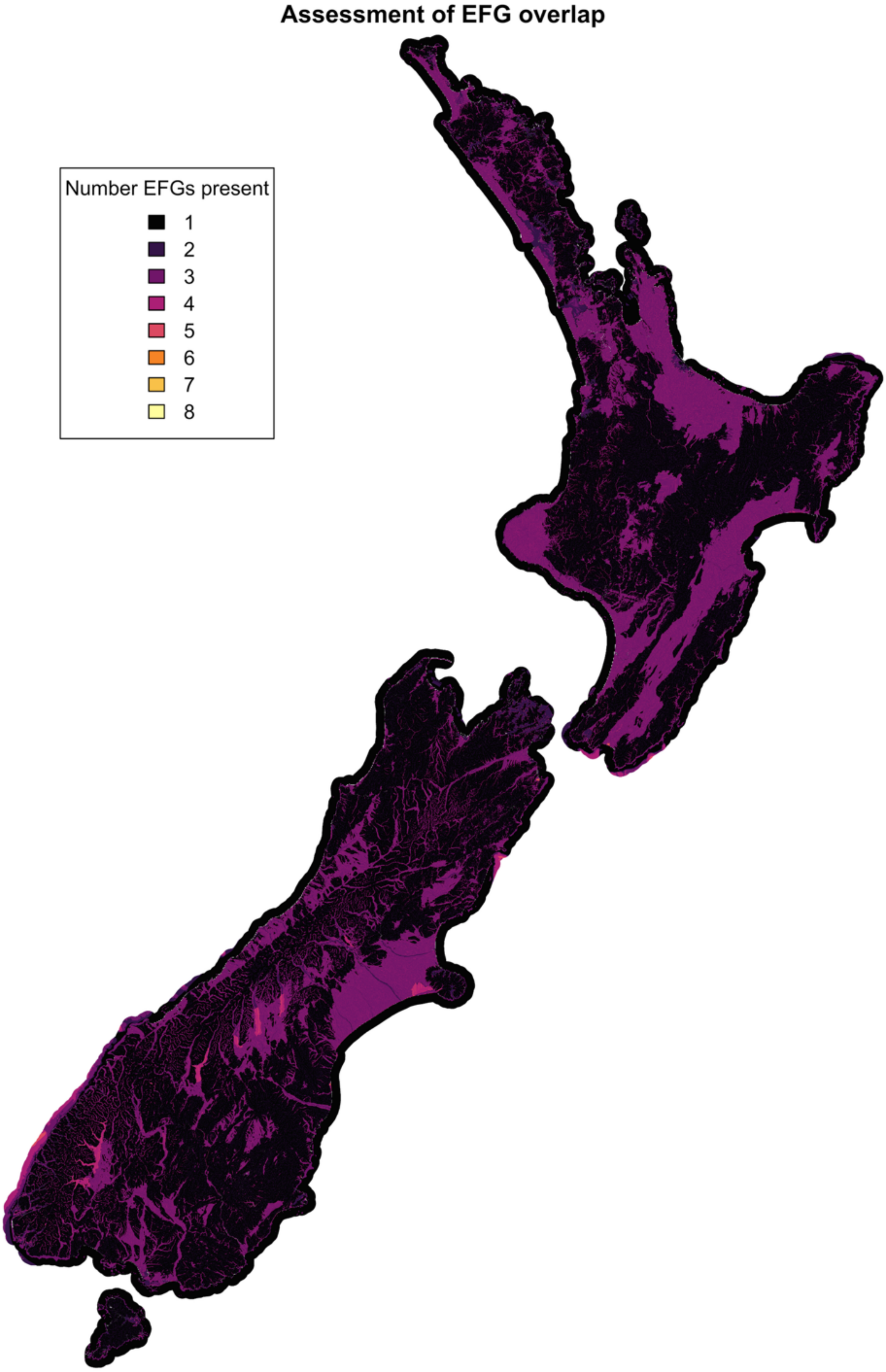

Figure A5.1 Number of IUCN GET Ecosystem Functional Groups (EFGs) present in each location across New Zealand.