NIWA
Taihoro Nukurangi

Roadmap to an updated ecosystem typology for the marine and estuarine domain

Prepared for Ministry for the Environment

September 2024

Climate, Freshwater & Ocean Science

Prepared by:
Carolyn Lundquist
Tom Brough
Terry Hume
Ashley Rowden
Wendy Nelson

For any information regarding this report please contact:

Carolyn Lundquist
Marine Ecologist

+64 7 859 1866
Carolyn.Lundquist@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 11115
Hamilton 3251

Phone +64 7 856 7026

NIWA CLIENT REPORT No: 2024230HN
Report date: September 2024
NIWA Project: LCR24202

Revision	Description	Date
Version 1.0	First draft sent to client	17/7/2024
Version 2.0	Second draft sent to client incorporating amendments as requested	13/9/2024
Version 3.0	Final version sent to client incorporating amendments from advisory and steering groups	27/09/2024

Quality Assurance Statement		
	Reviewed by:	Matt Bennion
	Formatting checked by:	Jo Downey
	Approved for release by:	Michael Bruce

Contents

Tables

Figures

Executive summary

Which domain does this report cover?

This report covers the marine and estuarine domain, which includes marine ecosystem functional groups within the Coastal Marine Area/Territorial Sea and the Exclusive Economic Zone (EEZ), as well as transitional/cross-realm ecosystem functional groups including estuarine and coastal inlets (Freshwater-Marine), brackish water ecosystems (Marine-Freshwater-Terrestrial), shoreline ecosystems (Marine-Terrestrial), and subterranean caves and pools (Subterranean-Marine).

What typologies already exist?

The scope of this project includes the assessment of the Coastal Marine Ecosystem Classification Standard (CMECS) for its suitability to fulfil the Principles for a standardised ecosystem typology and its alignment with the International Union for Conservation of Nature (IUCN) Global Ecosystem Typology (GET) for New Zealand. Prior to this project, marine and estuarine stakeholders had identified CMECS as a preferred framework to adapt to a New Zealand context, building on prior typologies including statistical classifications (i.e., New Zealand Seafloor Community Classification, New Zealand Marine Environments Classification) and abiotic classifications (i.e., New Zealand Coastal Classification and Mapping Scheme, New Zealand Coastal Hydrosystem Typology). The long-term aspiration for the wider MfE project is for a unifying marine and estuarine classification that integrates across coasts, estuaries and deepwater, pelagic and benthic, and vegetated and unvegetated habitats, that considers overlaps with terrestrial and wetland typologies, and that is aligned with a national ecosystem typology for all ecosystem domains.

Do CMECS and existing typologies adhere with the Principles for a standardised ecosystem typology?

CMECS and existing typologies generally align well with the Principles and improve on New Zealand specific typologies which are often limited in extent or ecosystems covered, and often have less flexibility to adjust to novel ecosystem types or reflect temporal change. CMECS is particularly adaptable due to its hierarchical nature, allowing for aggregation and disaggregation across levels to allow it to be fit for purpose based on management needs. The use of modifiers in CMECS allows inclusion of habitat condition or historical extent, temporal change, novel ecosystems, ecotones, and recognition of both benthic and pelagic components. In contrast, the IUCN GET for marine and marine transitional habitats is challenged by the lack of consistent drivers for Level 3 Ecosystem Functional Groups, and ambiguity as to which driver (or transitional biome class) to prioritise in classifying ecosystems to this global typology.

Do CMECS and existing typologies align with IUCN GET?

The overall fits of CMECS and existing typologies were moderate. Of the 34 marine-associated ecosystem functional groups (EFGs) in the New Zealand Exclusive Economic Zone, 20 are exclusively marine, and 14 are cross-realm/transitional functional groups; these transitional ecosystem types are often absent or poorly described in New Zealand domain-specific typologies.

IUCN GET Level 2 biomes are generally good fits to high levels in CMECS, based on depth or pelagic/benthic differentiation. However, Level 3 EFGs do not conform to any consistent hierarchy, with a mix of drivers including substrate, topography, hydrography and biotic elements. In contrast, CMECS (and other existing New Zealand marine and estuarine typologies) have a consistent hierarchy, typically with abiotic and bioregional elements at highest levels, and biotic elements at lower hierarchical levels. Cross-walking was thus not straightforward and typically resulted in one-to-many joins due to ambiguous membership of different levels of CMECS and other typologies to EFGs (e.g., kelp forests could be classified as M1.2 (kelp forests), subtidal rocky reefs (M1.6), or upwelling zones (M1.9) depending on whether a biotic, a substrate or a hydrographic driver is dominant. Ambiguous membership also occurred between transitional biomes and for benthic and pelagic ecosystem components, for example, with one-to-many joins occurring for many transitional EFGs. For example, permanently open riverine estuarine and bays (FM1.2) would likely include coastal salt marshes and reed beds (MFT1.3) as well as rocky shorelines (MT1.1).

What are the next steps for national ecosystem typologies in this domain?

A roadmap outlining the next steps for development of national ecosystem typologies for marine and estuarine ecosystems is provided. One step in the road map was to (re)confirm the stakeholder steering group to progress the typology. Other key steps include defining CMECS levels specific to New Zealand's marine and estuarine ecosystems, including identification of a suitable bioregionalisation and integration with other domain typologies. The high number of ecotones or marine transitional habitats make alignment of cross-domain habitats particularly important; as many of these habitats are limited in extent, and may be classified as rare or uncommon ecosystems, ensuring which domain they are included in is imperative to the development of a comprehensive national ecosystem typology. Case studies should be identified and parameterised to ensure the typology is fit for purpose and used to inform further differentiation of the hierarchical settings within CMECS. Data requirements should be identified and sourced to develop an initial national scale version of New Zealand CMECS. As data availability may improve, and novel ecosystems may emerge, identification of a process for updating the typology is imperative to ensure it remains flexible to accommodate any changing needs of end users.

1 Introduction

1.1 Background

This report sets out a roadmap towards the development of a national marine/estuary ecosystem typology that will fit within a 'global' typology across all ecosystems in New Zealand. In developing this roadmap, consideration has been given to fulfilling the Principles developed through previous engagement with stakeholders (Collins 2024) and defined in Sprague & Wiser (2024). Additionally, attention has been given to the potential purposes and application of marine/estuary ecosystem typologies for marine/estuary management and biodiversity conservation in New Zealand, and the practicalities of both developing and implementing a credible, relevant, justifiable and updatable typology. Roadmaps towards the development of national ecosystem typologies for terrestrial, marine and estuarine, lakes, wetlands, and groundwater ecosystems were developed as part of the same project but are reported separately.

At present, there are multiple marine and estuarine classifications that have been developed in New Zealand (reviewed in Rowden et al. (2018)); some coastal and estuarine ecosystems are also included in wetland and terrestrial classifications. Most classifications are focussed on seafloor/benthic habitat components, with limited consideration of pelagic components. These typologies include biome specific (i.e., estuaries, seamounts, rocky reefs), abiotic (i.e., typologies based on depth, exposure and substrate) and statistical (i.e., based on environmental correlations) typologies.

The Coastal Marine Ecosystem Classification Standard (CMECS) classification, a thematic habitat classification system developed and utilised in the United States of America (USA) (see section 1.3), has been previously identified as a preferred typology to adapt to New Zealand's marine and estuarine ecosystems (Collins 2024), with the intention to retain relevant information included in the existing marine and estuary classifications. Thus, this project specified that CMECS be assessed in terms of its alignment with principles for a new national typology and its alignment with the IUCN Global Ecosystem Typology (IUCN GET). The IUCN GET has been adopted by the United Nations and will be used for monitoring and reporting against the post-2020 Global Biodiversity Framework. Thus, the IUCN GET is being explored for its applicability across six national ecosystem domains for New Zealand (Sprague & Wiser 2024). The long-term aspiration is for a unifying marine and estuarine classification that integrates across coasts, estuaries, and deepwater, pelagic and benthic, and vegetated and unvegetated habitats, including consideration of overlaps with terrestrial and wetland typologies, and is aligned with a national ecosystem typology for all ecosystem domains.

1.2 Existing marine and estuarine ecosystem classifications in NZ

Rowden et al. (2018) reviewed New Zealand ecosystem classifications, with recommendations for updating the existing statistical classification and development of a comprehensive thematic classification. The report also reviewed the suitability of several international classifications for adaptation to New Zealand marine ecosystems. Existing marine-specific classifications at that time included statistical classifications based primarily on broad-scale environmental variables (e.g., the Marine Environments Classification, and the Benthic-Optimised Marine Environments Classification) (Snelder et al. 2004; Bowden et al. 2011); hierarchical classifications such as the New Zealand Coastal Classification and Mapping Scheme provided in the Marine Protected Areas Policy (Ministry of Fisheries and Department of Conservation 2008) which includes primarily abiotic categories of depth, sediment type and exposure; the New Zealand Coastal Hydrosystem Typology (Hume et al. 2016), an updated estuarine classification developed complementarily with wetland experts; and numerous biome-specific habitat classification exercises, e.g., rocky reefs (Shears and Babcock 2004), seamounts (Rowden et al. 2005).

Responding to recommendations in the Rowden et al. (2018) review, a revised statistical classification was developed, the New Zealand Seafloor Community Classification (NZSCC), replacing the Marine Environments Classification (Snelder et al. 2004) and Benthic-Optimised Marine Environments Classification (BOMEC) (Bowden et al. 2011). The NZSCC included 75 statistical classes with differentiation driven by both environmental and biological data across four primarily benthic groups – demersal fish, reef fish, seafloor invertebrates, and reef macroalgae (Stephenson et al. 2022). Descriptions are available of environmental characteristics as well as key fauna and flora associated with each class (Petersen et al. 2020). A nested bioregional version of the NZSCC has also been developed (Stephenson et al. 2023); in this bioregional version, the 75 classes are nested with nine bioregional classes. Within the 75 classes, there is strong overlap of areas with limited records/low environmental coverage with deepwater habitats, but some low environmental coverage is also found in shallow habitats, e.g., estuaries (Lundquist et al. 2021). Differentiation in shallow coastal habitats does not always match expert expectations (see e.g., evaluations in Southland (McCartain et al. 2020)), thus the classification is deemed to be primarily suitable for deeper habitats. Challenges have also been noted in public understanding and accessibility of concepts represented by individual NZSCC classes (Collins 2024).

To progress a thematic classification, workshops were held with respect to the development of a domain-specific thematic classification (Brough et al. 2020). Further discussions with key stakeholders about thematic classifications (Collins 2024) confirm general agreement to support the further development and adaptation of the CMECS classification to New Zealand marine and estuarine ecosystems. An exemplar cross-walking exercise has been performed on existing regional habitat mapping classes using CMECS (Haggitt 2021). Regional councils have also investigated mapping regional marine habitat classes to CMECS (Collins 2024).

1.3 Coastal Marine Ecosystem Classification Standard (CMECS)

There is a broad consensus that an approach such as CMECS could be applied in New Zealand (Collins 2024). CMECS is a thematic habitat classification system developed and utilised in the United States of America (USA). CMECS is a hierarchical classification, allowing for aggregation/disaggregation as need for international reporting and for regional management processes. Hierarchy in CMECS is based on broad-scale descriptors (Biogeographic setting, Aquatic setting), following by three levels of abiotic qualifiers (Water column, Geoform, Substrate), and then introducing biotic components (i.e., biological assemblages, dominant and subdominant species) (Figure 1-1). The biogeographic settings separate units into hierarchical components using well known, published classifications (e.g., Marine Ecosystems of the World (MEOW); Spalding et al. 2007). The aquatic setting separates into marine, estuarine or lacustrine components where additional layers define subsystems (e.g., nearshore, offshore, oceanic). See Federal Geographic Data Committee (2012) for a detailed review of the structure of CMECS.

CMECS also includes the concept of a 'modifier' to account for habitat extent and quality, and to include multiple habitats that co-occur, such as benthic and pelagic components. Modifiers can also be defined as a spatial representation of ecological variability pertaining to the environment itself (e.g., biodiversity, condition) or the way in which it has been characterised (e.g., uncertainty, temporal persistence). In CMECS, a standard list of modifiers has been developed with consistent characteristics and definitions, including common requirements of habitat classifications such as naturalness and uncertainty. These modifiers describe the variability within the ecological units of each component, and CMECS supports the inclusion of further modifiers to assist local or regional level characterisations.

A previous review of New Zealand habitat classifications (Rowden et al. 2018) and subsequent workshops on thematic classifications (Brough et al. 2020) suggested CMECS is a promising candidate for adoption in New Zealand. CMECS has built in requirements for review and updating, and is flexible in the configuration of key tools. These benefits may require further consultation with the administrators of CMECS to adapt them to a New Zealand context. The potential reliance on third parties is a cost associated with adopting CMECS, which may result in reduced control and flexibility of the system in New Zealand.

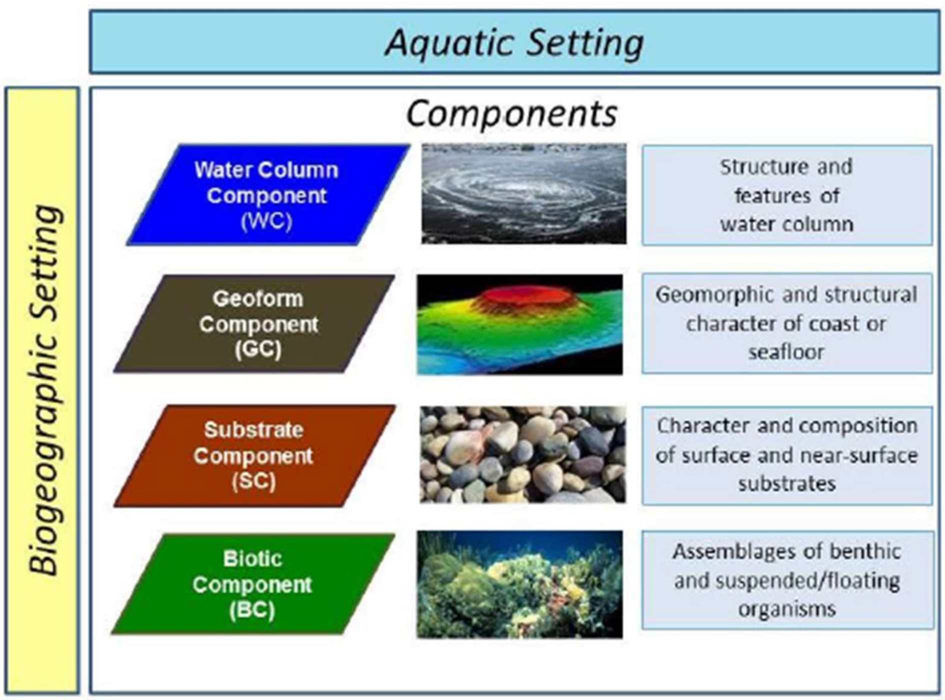

Figure 1-1: An overview of the structure of the Coastal and Marine Ecological Classification Standard. Biogeographic setting, Aquatic setting, Water Column component, Geoform component, Substrate component, and Biotic component. Note Biotypes, and Spatial and temporal modifiers can also be included within the typology.

1.4 Scope of this report

Based on consensus of regional and central government stakeholders on the preference for selecting CMECS as a framework upon which to adapt a national estuarine and marine ecosystems typology (Collins 2024), the scope of the marine and estuarine assessment included primarily assessing CMECS in terms of its alignment both with the IUCN GET and with existing New Zealand marine and estuarine typologies. As part of this assessment, any challenges identified with adopting and implementing a national unifying ecosystem typology in New Zealand were to be identified, and options for mitigation and management to be discussed. The scope of the report included:

- Assessment of how well CMECS (the recommended national ecosystem typology for the Marine and Estuarine domain) meets the Principles.
- Assessment of how well CMECS (the recommended national ecosystem typology for the Marine and Estuarine domain) aligns with IUCN GET.
- Assessment of how well CMECS represents New Zealand's diverse and extensive marine environments, including in the EEZ, particularly at the Biotic Group level.
- Assessment of how well CMECS aligns with other existing marine and estuarine typologies used in New Zealand, including discussion on overlaps between CMECS and terrestrial and wetland typologies, and how these can be integrated.
- A roadmap outlining pathways and steps toward a final marine typology, including a process for defining the biotic community components of CMECS.
- Inclusion of a step to develop a maintenance framework detailing how the typology will be updated, how quality assurance will be maintained, and how information could be stored and made accessible.

2 Methods

2.1 Assessment of how well CMECS and existing typologies meet the Principles

In a series of workshops in 2023, representatives from DOC, regional councils, MPI and MfE identified nine national Principles and five additional requirements for a standardised typology. The initial Principles and requirements are listed in Collins (2024). These Principles and requirements were clarified by the broader project team in consultation with the project Steering Group. The original nine national principles and five requirements were grouped into seven overarching Principles, with sub-principles to inform assessment by the six domains within the broader project (Sprague & Wiser 2024) (Table 2-1).

Table 2-1: Principles and requirements for ecosystem typologies.

Revised from Collins (2024) after consultation with MfE during the course of this project.

Principle	Definition
Hierarchical Structure	Standardised typologies have a structure with levels, with lower levels nested within higher ones. Higher levels of the hierarchy usually encompass more variation than do lower levels, and usually, but not always, correspond with a greater spatial extent. Thus, higher levels are more generic (e.g., forest (terrestrial); warm-wet climate (rivers)) and lower levels are more specific (red-silver beech forest (terrestrial); warm-wet lowland (rivers)).
Spatially explicit	Distributions of typological units should be mappable through any practical combination of ground observation, remote sensing and spatial modelling.

Principle	Definition
Accommodates increased knowledge and change over time	
Updateable	This principle pertains to the products derived from typologies (e.g., maps). Typology-derived products should be able to be changed or updated. This could include the following types of changes: changes to spatial boundaries of ecosystem types based on both improvements in underlying data and real change over time (these two types of change should be able to be distinguished); and temporal changes to attributes (e.g., condition) of the defined ecosystem types.
Flexibility/adaptability	This principle pertains to the typology itself. The typology should be able to be modified, with clear and transparent version history. Changes to a typology could include the following: i) new ecosystem types can be added to the typology as more data becomes available; ii) ecosystem types can be split or combined when justified by new data - these may be ecosystem types that were present, but not defined in the typology or ecosystems that did not exist previously; and iii) methodological changes to the typology to define the ecosystem types more clearly – particularly applies to domains where ecosystem types are defined by environment.
Temporally explicit	This principle pertains to both the typology itself and the derived products. Both the typology and the derived products should be explicit about when the typology was created, when the underlying data were collected, and the time period to which derived products apply and when they have been updated.
Compatibility across domains and typologies	
Compatible	Ecosystem types in a typology are required to have clear relationships with the ecosystem types of other typologies for the same domain that are in use or were widely used in the recent past. This facilitates the transfer information from one typology to another and enables comparisons across typologies.
Consistent use of species concepts	The typology can accommodate that species names or the taxonomic concepts they represent can change through time.
Nesting under IUCN GET	The typology should be able to cross-walk to the IUCN GET, particularly to Level 3 Ecosystem Functional Groups.
Robust	
Parsimony and utility	The typology should be no more complex than required to achieve its specified purposes and should use simple, accessible and clearly defined terminology (Keith et al. 2022 – Appendix 1).
Transparent and reproducible	How the typology itself was created is transparent and is either sufficiently well described that it could be repeated by a different person and achieve the same result, or it is defensible. It should be clear whether the typology is derived from data by quantitative analysis, informed by data, or expert-derived.
Comprehensive	
Coverage for ecotones	The typology should allow areas of transition between ecosystems to be depicted, both by their relationship to the classification units and in mapping.
Accommodates transformed ecosystems	The typology should include ecosystem types that encompass, as much as possible, the full range of ecosystem variation within their spatial, temporal and ecological extents. Transformed ecosystems include the following: human engineered ecosystems; those created by passing an ecological tipping point; successional; and novel ecosystems.
New Zealand-specific principles	

Principle	Definition
Reflects NZ's ecological diversity and processes	NZ's biodiversity and ecosystems should be represented and well described in the typology.
Understood by New Zealanders	The terminology and concepts used in the typology are familiar to NZ ecologists and conservation practitioners.
Takes account of te ao Māori	The typology can accommodate te ao Māori at a local and regional level.

CMECS and a selection of existing marine and estuarine typologies were systematically assessed against each of the MfE principles and requirements for a unifying national ecosystem typology. Results were populated in an accompanying spreadsheet (Appendix A) and are summarised qualitatively below.

Additionally, two virtual stakeholder meetings were held on 10th and 11th June 2024 with the project team and representatives from MfE (Pierre Tellier, Hannah Jones) and Department of Conservation (DOC) (Greig Funnell) to discuss the approach and potential challenges for a unifying national ecosystem typology with respect to marine and estuarine ecosystems. A regional council representative of CSIG (Megan Oliver, Greater Wellington Regional Council) was unable to participate in the stakeholder meetings but provided feedback on the report. All stakeholders were also invited to provide feedback on the draft report for the marine and estuarine domain, and two additional stakeholder representatives were also invited to provide feedback (Shane Geange (DOC); Karen Tunley (Fisheries New Zealand).

2.2 Assessment of how CMECS and existing typologies aligns with the IUCN GET

Within the Marine and Marine transitional realms, all but four Ecosystem Functional Groups (EFGs) within the IUCN GET are present in New Zealand (M1.3 photic coral reefs, M2.5 sea ice, M3.9 chemosynthetic-based ecosystems, MFT1.1 coastal river deltas; EFG occurrence based on the IUCN GET website, noting that M3.9 is likely to exist based on known presence of hydrothermal vents and cold seeps in New Zealand (Lundquist et al. 2020), but data on location of these ecosystems may not have been available to IUCN GET). Of the 34 marine-associated EFGs in the New Zealand Exclusive Economic Zone, 20 are exclusively marine, and 14 are cross-realm/transitional functional groups (Table 2-2), showcasing the broad diversity of ecosystems found within marine and marine transitional ecosystems.

We qualitatively assessed the degree to which CMECS groups could be cross-walked to IUCN GET EFGs. Cross-walking involves groups from one typology being associated with groups from another typology. We considered whether cross-walked relationships would manifest as one-to-one, one-to-many, or many-to-many joins (for further explanation, see Sprague & Wiser 2024).

Table 2-2: Summary of marine and marine transitional IUCN GET Level 3 ecosystem functional groups. Summarised based on Keith et al. (2022). Note four ecosystem functional groups (M1.3 photic coral reefs, M2.5 sea ice, M3.9 chemosynthetic-based ecosystems, MFT1.1 coastal river deltas) that were assessed by IUCN as not occurring in New Zealand are not included here.

Level 1 Realm	Biome ID	Level 2 Biome	ID	Level 3 Ecosystem Functional Group
Freshwater-Marine	FM1	Semi-confined transitional waters biome	FM1.1	Deepwater coastal inlets
Freshwater-Marine	FM1	Semi-confined transitional waters biome	FM1.2	Permanently open riverine estuaries and bays
Freshwater-Marine	FM1	Semi-confined transitional waters biome	FM1.3	Intermittently closed and open lakes and lagoons
Marine	M1	Marine shelf biome	M1.1	Seagrass meadows
Marine	M1	Marine shelf biome	M1.2	Kelp forests
Marine	M1	Marine shelf biome	M1.4	Shellfish beds and reefs
Marine	M1	Marine shelf biome	M1.5	Photo-limited marine animal forests
Marine	M1	Marine shelf biome	M1.6	Subtidal rocky reefs
Marine	M1	Marine shelf biome	M1.7	Subtidal sand beds
Marine	M1	Marine shelf biome	M1.8	Subtidal mud plains
Marine	M1	Marine shelf biome	M1.9	Upwelling zones
Marine	M2	Pelagic ocean waters biome	M2.1	Epipelagic ocean waters
Marine	M2	Pelagic ocean waters biome	M2.2	Mesopelagic ocean water
Marine	M2	Pelagic ocean waters biome	M2.3	Bathypelagic ocean waters
Marine	M2	Pelagic ocean waters biome	M2.4	Abyssopelagic ocean waters
Marine	M3	Deep sea floors biome	M3.1	Continental and island slopes
Marine	M3	Deep sea floors biome	M3.2	Submarine canyons
Marine	M3	Deep sea floors biome	M3.3	Abyssal plains
Marine	M3	Deep sea floors biome	M3.4	Seamounts, ridges and plateaus
Marine	M3	Deep sea floors biome	M3.5	Deepwater biogenic beds
Marine	M3	Deep sea floors biome	M3.6	Hadal trenches and troughs
Marine	M4	Anthropogenic marine biome	M4.1	Submerged artificial structures
Marine	M4	Anthropogenic marine biome	M4.2	Marine aquafarms
Marine-Freshwater-Terrestrial	MFT1	Brackish tidal biome	MFT1.2	Intertidal forests and shrublands
Marine-Freshwater-Terrestrial	MFT1	Brackish tidal biome	MFT1.3	Coastal saltmarshes and reedbeds
Marine-Terrestrial	MT1	Shorelines biome	MT1.1	Rocky Shorelines
Marine-Terrestrial	MT1	Shorelines biome	MT1.2	Muddy Shorelines
Marine-Terrestrial	MT1	Shorelines biome	MT1.3	Sandy Shorelines
Marine-Terrestrial	MT1	Shorelines biome	MT1.4	Boulder and cobble shores
Marine-Terrestrial	MT2	Supralittoral coastal biome	MT2.1	Coastal shrublands and grasslands
Marine-Terrestrial	MT3	Anthropogenic shorelines biome	MT3.1	Artificial shorelines
Subterranean-Marine	SM1	Subterranean tidal biome	SM1.1	Anchialine caves

Level 1 Realm	Biome ID	Level 2 Biome	ID	Level 3 Ecosystem Functional Group
Subterranean-Marine	SM1	Subterranean tidal biome	SM1.2	Anchialine pools
Subterranean-Marine	SM1	Subterranean tidal biome	SM1.3	Sea caves

2.3 Assessment of how well CMECS represents New Zealand's diverse and extensive marine environments

We briefly review CMECS, commenting on its ability to represent New Zealand's diverse and extensive marine environments, including in the EEZ, particularly at the Biotic Group level. We further discuss how well CMECS aligns with other existing marine and estuarine typologies used in New Zealand, including discussion on overlaps between CMECS and terrestrial and wetland typologies, and how these can be integrated.

2.4 Roadmap of steps toward a final marine and estuarine typology

In developing the roadmap for a national marine and estuarine ecosystem typology, we considered:

- The potential purpose(s) and uses for a New Zealand marine and estuarine ecosystem typology.
- The alignment of the CMECS typologies with the principles.
- Pre-requisites for operationalising CMECS in New Zealand.
- The ease of cross-walking the CMECS to the IUCN GET.
- Cross-domain considerations with respect to marine transitional ecosystems.
- A process for defining the biotic community components of CMECS.

As part of the roadmap, we include discussion of a need for a maintenance framework detailing how the typology will be updated, how quality assurance will be maintained, and how information could be stored and made accessible.

3 Results

3.1 Assessment of how well CMECS and existing typologies meet the Principles

CMECS aligns well with most of the Principles, whereas the IUCN GET typology for Level 3 EFGs in marine and marine transitional habitats was assessed as being poorly aligned for several Principles (see Appendix A for details). In comparison to existing national ecosystem typologies, CMECS adheres better to the Principles for the following reasons:

- Flexibility/adaptability because hierarchical structure allows for aggregation/disaggregation, and inclusion of modifiers to represent habitat condition without fundamentally altering the structure of the typology.

- Updateability because new maps of classes could be generated if input data changes or novel ecosystems are discovered, without fundamentally altering the structure of the typology.
- Compatibility because hierarchical structure is based on distinct abiotic and biotic components.
- Transparency and reproducibility because the definitions of classes are reasonably well described.
- Parsimonious due to hierarchical structure with few classes at higher levels of the classification with complexity being added at lower levels, although the large number of classes at Level 6, particularly if modifiers are included, could be unwieldy.
- Ecotones, novel ecosystems, and distinctions with respect to habitat quality and extent allowed via habitat modifier.
- Easily understood with meaningful classes based on clear abiotic and biotic drivers.

In contrast, the IUCN GET at least with respect to marine and marine transitional EFGs, was assessed as being poorly aligned with many of the principles (see Appendix A for details). Much of the poor alignment was with respect to the Level 3 EFGs, which have a mix of non-exclusive drivers (substrate, hydrology, biotic components) within Level 3, whereas other classifications typically have these different drivers distinct within individual typology levels. That said, the IUCN GET did have meaningful classes at Level 3 that were easily understandable, so that classes from other typologies could be easily mapped.

3.2 Assessment of how CMECS and existing typologies aligns with the IUCN GET

The latitudinal range of the New Zealand emergent land masses and islands, variable wave climate driven from the Tasman Sea, Pacific Ocean and Southern Ocean, the extent of the EEZ and Extended Continental Shelf, and the long-standing isolation of the region, have led to a very distinct marine biota. Several species/genera are endemic to the region or to parts of the region. From the reef-forming corals and macroalgae found at Rangitāhua to the biotas of New Zealand's Subantarctic Islands, New Zealand reflects a high degree of bioregionalisation.

The overall fits of the IUCN GET to CMECS and to the marine and estuarine ecosystem typologies (Hume et al. 2016, Ministry of Fisheries & Department of Conservation 2008) were moderate (Table 3-1). The IUCN GET Level 2 biomes were generally good fits to CMECS, with both based on depth or pelagic/benthic differentiation at this higher level. However, Level 3 EFGs did not conform to any consistent hierarchy, with a mix of drivers including substrate, topography, hydrography and biotic elements. In contrast, most other accepted marine and estuarine typologies have a consistent hierarchy, with abiotic and bioregional elements at highest levels, and biotic elements at lower hierarchical levels. The IUCN GET EFGs are also uneven in terms of typical physical extent and size. For example, the M1 'Marine Shelf Biome' (Table 3-1) varies from shallow water vegetation-driven habitats (kelp forests, seagrass meadows) to biogenic habitats (shellfish beds and reefs, photo-limited marine animal forests) to substrate driven biomes (subtidal rocky reefs, sand beds, mud plains) to oceanographic features (upwelling zones) that may be both temporally and spatially dynamic. In contrast, the M2 'Pelagic Ocean Waters Biome' is based primarily on depth, and the M3

‘Deep Sea Floors Biome’ is primarily based on topographic features, though M3 does also include M3.5 ‘Deepwater Biogenic Beds’ that may overlap with topographic features (Table 3-1). There is also strong overlap of class distinctions between the transitional biomes, and lack of consistent drivers within these transitional biomes (Table 3-1). Marine-Terrestrial MT1 and MT3 are indicative of shoreline ecosystems which are substrate based, whereas EFGs within MT2 and Marine-Freshwater-Terrestrial MFT1 are vegetation based. FM1 ‘Transitional Waters’ is defined based on hydrography, and SM13 ‘Subterranean-marine’ is defined based on topographic features to include different types of marine caves and pools.

While these overlaps between EFGs within the IUCN GET framework do not prevent cross-walking or reporting to the IUCN GET, it could result in ambiguities and uncertainty, as well as over-reporting due to overlap of EFGs. For example, coastal kelp forests could be classified as M1.2 (kelp forests), subtidal rocky reefs (M1.6) or upwelling zones (M1.9) depending on whether a biotic, a substrate or a hydrographic driver is dominant. Similarly, while the New Zealand coastal hydrosystem typology (i.e., estuaries and wetlands) generally cross-walks to the IUCN GET, there is also potential confusion between Freshwater-Marine (primarily based on hydrography), Marine-Terrestrial (primarily based on substrate), and Marine-Freshwater-Terrestrial (primarily based on biotic) EFGs. For example, permanently open riverine estuarine and bays (FM1.2) would likely include intertidal forest and shrublands (MFT1.2) and coastal saltmarshes and reed beds (MFT1.3) as well as rocky shorelines (MT1.1). The IUCN GET was also noted as having meaningful classes at higher Level 3, despite them being non-exclusive, such that the IUCN GET could be used to fulfil international reporting requirements.

In summary, the IUCN GET marine and marine transitional habitats suffer from a lack of consistent drivers, with key challenges being the potential multitude of overlapping relevant classes for a particular area. Significant ambiguities are reflected in multiple relevant classes for intertidal and subtidal vegetated ecosystems (e.g., salt marsh, intertidal forests and shrublands, mangroves, kelp and other macro-algal dominated habitats) which could potentially be allocated to a vegetation-based class, a substrate-based class, or a hydrography/topography-based class. While one marine biome (M2) includes pelagic EFGs, pelagic components of other habitats are not included, or are only included implicitly, in other marine biomes. Resolution of ecosystems identified within EFGs is not equal, with higher resolution given to charismatic features (e.g., seagrass, kelp forest) than to common habitats (e.g., soft sediment habitats), biasing the consideration of the diversity within these common habitats that dominate global ecosystem classes. While IUCN GET was notable in its inclusion of some marine transformed ecosystems, it is less flexible in terms of being able to accommodate changes in temporal condition or extent, or habitat degradation.

3.2.1 Alignment of New Zealand primary producers with the IUCN GET

We explored alignment of marine and estuarine ecosystems dominated by primary producers to the IUCN GET EFGs to illustrate inconsistencies with respect to biotic and abiotic hierarchical drivers, size and extent, and species categories. This exercise also identified several marine primary producer-dominated ecosystems found in New Zealand that were missing from the IUCN GET marine domain. In general, primary producers (particularly marine macroalgae) in IUCN GET show inconsistencies in terms of their contribution to nearshore productivity and/or ecosystem functions, and inconsistent use of species concepts, with specific examples provided below.

Seagrass (M1.1)

Seagrass meadows are limited in their extent and contribution to nearshore productivity within the New Zealand region, but are specifically identified as an EFG. In contrast, the diversity of macroalgal assemblages are poorly distinguished in the IUCN GET Level 3 EFGs.

Kelp forests (M1.2)

Kelp forests are present in New Zealand, but their composition, distribution relative to abiotic factors, and associated biota differ substantially between dominant species, suggesting multiple EFGs would be appropriate. Internationally the concept of kelp forest is defined by members of the brown algal order Laminariales, comprised of genera such as *Alaria*, *Laminaria*, and *Saccharina*. These forests of large brown algae are key features of northern hemisphere temperate shores. In the southern hemisphere, and particularly in New Zealand, large brown algae that form kelp forests can be either members of the Laminariales or the brown algal order Fucales, with particularly diverse forests dominated by Fucales. The orders Laminariales and Fucales have entirely different life histories, and it is known that the different life stages respond to biotic and abiotic factors in different ways.

- The following types of 'kelp' forests are found in New Zealand:
  - *Durvillaea* beds – largely restricted to the low intertidal/upper subtidal margins and only found on rocky reefs in exceptionally wave exposed areas. There are multiple species of *Durvillaea* (Fucales), and these have differing physiology and ecology (e.g., susceptibility to rising sea temperatures).
  - Mixed Fucales forests – consisting of species from multiple genera (including *Carpophyllum, Cystophora*, *Sargassum*, *Landsburgia*, *Xiphophora*, *Marginariella*). These are the most commonly found large brown algal assemblages in New Zealand coastal waters.
  - *Ecklonia radiata* forests – frequently this species (a member of the Laminariales) occurs with or adjacent to mixed Fucales assemblages. It is geographically widespread, occupies a wide range of habitats, and is the main species in northern kelp forests. It can be found across a wide range of depths from upper subtidal through to ca. 80 m depending on water clarity.
  - *Lessonia* forests – there are several distinct species of *Lessonia* in New Zealand coastal waters, with some species endemic to particular parts of the archipelago (e.g., *L. tholiformis* restricted to the Chatham Islands; *L. adamsiae* to the Snares). Species of *Lessonia* are restricted to subtidal reefs with strong wave exposure.
  - *Macrocystis pyrifera* forests – restricted to Cook Strait south, these forests have a requirement for a particular combination of hydrodynamic conditions.

In recent years both the extent and health of kelp beds around New Zealand have been recorded as deteriorating, particularly those of *Durvillaea* spp. and *Macrocystis*, leading to these being commented on in the report on the conservation status of New Zealand macroalgae (Nelson et al. 2019). In order to report on changes in the status and condition of these forests types, there should be sufficient granularity in the typology employed to distinguish between different kelp forest types.

Shellfish beds and reefs (M1.4)

While these beds may be defined by the shellfish present, often macroalgae (particularly calcified species/coralline algae) provide critical ecosystem roles in terms of consolidating the bed structure, and providing key settlement triggers and surfaces for larvae. There is evidence that suggests that the impacts of global climate change (including ocean acidifcation), and human induced habitat degradation affect species differently, and the impacts on calcified macroalgae may undermine the overall health of the associated shellfish.

Photo-limited marine animal forests (M1.5)

Often referred to as mesophotic habitats, these macroalgal ecosystems are typically found at depths between 30-150 m. In New Zealand mesophotic macroalgal assemblages have been discovered to be much more common than previously understood, with macroalgae even extending beyond 150 m depths in some places, at the limits of the euphotic zone. It is recognised that the extent of these mesophotic habitats is poorly documented, and their productivity has been underestimated.

Subtidal rocky reefs (M1.6) and Subtidal sand beds (M1.7)

Both EFGs refer to habitats that are defined by abiotic components (i.e., substrata and depth), but vary in species assemblages including in some cases the presence of macroalgae. There will be ambiguity and overall lack of clarity between these abiotic habitats and habitats defined by biotic components.

Macroalgal Groups missing from the IUCN GET classification

None of the marine shelf biomes currently make reference to other macroalgal-defined habitats of significance in the coastal marine euphotic zone. These include:

- **Red algal meadows** - these have been reported as a key biogenic habitat in New Zealand, supporting a range of associated biota, and subject to a range of stressors and threats (Anderson et al. 2019). Recent research on Mediterranean red algal meadows has revealed high associated biodiversity of invertebrates with Rossbach et al. (2021) recommending that these habitats “should be included in conservation strategies”. Schmidt et al. (2021) note the need to further investigate how red algal mats may be moderating local environmental conditions, and to evaluate the potential of red algal mats to serve as refuge habitat for organisms “which may suffer habitat loss from anthropogenic pressure and climate change”.

- **Rhodolith beds** – these are not referred to in the IUCN GET Level 3 categories. Rhodolith beds have ecological importance on a global scale, provide a wealth of ecosystem functions and services, including biodiversity provision and potential climate change mitigation, but remain disproportionately understudied, compared to other coastal ecosystems (tropical coral reefs, kelp forests, mangroves, seagrasses). Although rhodolith beds have gained some recognition as important and sensitive habitats at national/regional levels during the last decade, there is still a notable lack of information and, consequently, a lack of specific conservation efforts. Tuya et al. (2023) note that the lack of information about these habitats, and the significant ecosystem services they provide, is hindering the development of effective conservation measures and limiting wider marine conservation success. This is becoming a pressing issue, considering the multiple severe pressures and threats these habitats are exposed to (e.g., pollution, fishing activities, climate change), which may lead to an erosion of their ecological function and ecosystem services. MacDiarmid et al. (2013) identified rhodolith beds as being sensitive biogenic marine habitats in New Zealand, and Lundquist et al. (2017) reviewed the contributions made by small natural features (SNFs) – ecosystems that 'support a diverse fauna and flora and provide ecosystem services disproportionate to their size' – a category which applies to rhodolith beds. However, the location and extent of rhodolith beds in New Zealand remains poorly documented. Rhodoliths have been shown to be vulnerable to the impacts of a range of human activities, including physical disruption from trawling, dredging, and anchoring, as well as from deterioration in water quality, alterations to water movement through marine engineering, and aquaculture installations such as shellfish rafts and lines and fish. Rhodoliths are considered to be particularly vulnerable given their fragility and slow growth rates. Along with other calcified macroalgae, rhodoliths will experience impacts from ocean acidification resulting from global climate change (Law et al. 2017, Nelson et al. 2019).

- **Macroalgae in soft sediment ecosystems** – these habitats have received little attention in New Zealand, although based on the research in New Zealand harbours that has been conducted, it is likely that soft sediment macroalgal biodiversity has been significantly under-reported and is poorly documented (e.g., Neill et al. 2012, Neill & Nelson 2016).

3.2.2 Cross-walk of CMECS classes to IUCN GET EFGs

CMECS classes were cross-walked to IUCN GET EFGs, using the New Zealand Coastal Hydrosystems Typology as an example (Table 3-1).

The cross-walking process was not straightforward for two main reasons:

1. Ambiguity due to lack of consistency of drivers within Level 3 EFGs.
2. Ambiguity within ecotones/marine transitional habitats where transitional biome allocation is unclear.

Table 3-1: Cross-walking between IUCN GET Level 3 ecosystem functional group and New Zealand coastal hydrosystem typology (NZCHT). Square brackets indicate possible many-to-one join from GETS to CMECS.

IUCN GET v2.1 ecosystem functional group	NZCHT level	CMEC setting/component
	Level 1: Global realm	Biogeographic setting
[Coastal wetlands included across Marine-Freshwater, Marine-Terrestrial, and Marine-Terrestrial-Freshwater transitional biomes; categories are not clearly exclusive]	Level 2: Hydrosystem (palustrine, lacustrine, riverine, estuarine, marine)	Aquatic setting

IUCN GET v2.1 ecosystem functional group	NZCHT level	CMEC setting/component
[Freshwater-Marine biome typically differentiated by geomorphic class] [Marine-Freshwater-Terrestrial differentiated by geomorphic, biotic and tidal components]	Level 3: Geomorphic class (11 classes with 21 subclasses)	Geoform component
[Marine-Freshwater-Terrestrial differentiated by geomorphic, biotic and tidal components]	Level 4: Tidal regime (Subtidal, intertidal, supratidal)	Water column component
[Marine-Terrestrial biome differentiated by both substrate and biotic components, but not geomorphic components] [Marine-Freshwater-Terrestrial differentiated by geomorphic, biotic and tidal components]	Level 5: Structural class (Vegetation, substrate, water structure)	Biotic component, substrate component
[Marine-Terrestrial biome differentiated by both substrate and biotic components, but not geomorphic components] [Marine-Freshwater-Terrestrial differentiated by geomorphic, biotic and tidal components]	Level 6: Composition (Dominant biota, substrate and water types)	Biotic component, substrate component

3.3 Assessment of how well CMECS represents New Zealand's diverse and extensive marine environments

While not unexpected due to the existing consensus of New Zealand users on the usefulness of the CMECS classification, it clearly performs well as a typology. Key features are:

- Classification based on hierarchical and categorical components (Figure 1-1) into meaningful, easily interpretable classes.
- Well tested in the United States of America (USA) where it was developed and has been adopted as a US federal standard for marine, and easily applied to marine ecosystems in New Zealand.
- Highly flexible including habitat modifier that allows for further differentiation with respect to inclusion of multiple ecosystem components (i.e., benthic and pelagic ecosystems), or for consideration of habitat quality or extent. In contrast, the IUCN GET lacks this ability to consider habitat quality or degradation; rather ecosystems would be required to be listed as a separate 'transformed' ecosystem biome.
- Likely suitable for integrating estuaries and coastal wetlands, noting that further development is likely required for these transitional habitats, as well as ecotones across other transitional boundaries such as freshwater, terrestrial and subterranean. An ongoing challenge for all marine classifications is the poor delineation of coastal

marine area based on mean high-water springs (MWHS) which creates disjuncts between coastal wetlands, saltmarsh, dune habitats and other marine habitats that are mapped across this MWHS boundary.

- Inclusion of bioregional component, which is the Marine Ecosystems of the World (MEOW) high level global marine regionalisation (Spalding et al. 2007). MEOW bioregions are somewhat complementary to prior New Zealand marine classifications, with 3 northern New Zealand bioregions (Kermadec Islands, Northeast, Three Kings to North Cape), 4 southern New Zealand bioregions (Chatham, Central, South, Snares), and 3 Subantarctic bioregions (Bounty/Antipodes, Campbell, Auckland Isles). While these MEOW bioregions don't necessarily overlap with existing regional management boundaries (i.e., regional council Coastal Management Areas or CMAs) or Territorial Seas/EEZ boundaries, this aspect could also be further explored in developing a CMECS classification to ensure bioregional boundaries are fit for purpose in a New Zealand context.

3.4 Roadmap of steps toward a final marine and estuarine typology

A previous stakeholder workshop identified the following key themes as priorities to develop a strategic workplan for incorporating New Zealand's marine and estuarine ecosystems into CMECS (Collins 2024). These themes include:

- Ensuring ability of CMECS to incorporate information and classes derived within existing marine and estuarine classifications, with preference for integrating estuaries into a marine ecosystem typology.
- Relevance and adaptability of CMECS across all biomes, in particular its coverage of sandy and rocky shores.
- Processes for classifying transitional areas/ecotones where different ecosystems intersect, including interface with terrestrial zones.
- Extending Scope of CMECS to cover the Exclusive Economic Zone.
- Refining the biotic component of CMECS and listing habitat types is a priority.
- Confirming funding and collaboration opportunities to progress a New Zealand CMECS marine and estuarine typology, and allocation of various agencies to lead different aspects of the refinement process.

We used these themes and further feedback from stakeholders to develop a draft roadmap for the development of a strategic workplan for incorporating New Zealand's marine and estuarine ecosystems into CMECS.

3.4.1 Roadmap steps

Critical steps in developing a national marine and estuarine ecosystem typology include (Figure 3-1):

1. Establish/reconfirm membership of a marine and estuarine ecosystem typology working group.
2. Comprehensively map alignment of CMECS settings and components to IUCN GET Biomes.

3. Evaluate bioregional setting of CMECS and assess appropriateness of MEOW.
4. Confirm approach for combining benthic and pelagic components of ecosystems.
5. Define consistent approach for use of CMECS modifiers (temporal and spatial).
6. Comprehensively delineate and adapt CMECS levels, including biotic components, to New Zealand marine and estuarine ecosystems.
7. Identify how the New Zealand CMECS can be used alongside the NZSCC.
8. Explore integration of the marine and estuarine ecosystem typology across other domains (e.g., terrestrial, wetland).
9. Perform end user case studies for a marine and estuarine ecosystem typology to ensure it is fit for purpose.
10. Determine data requirements and availability to parameterise CMECS across settings and components.
11. Source required data and map to CMECS classes.
12. Identify process for updating and maintaining New Zealand CMECS.

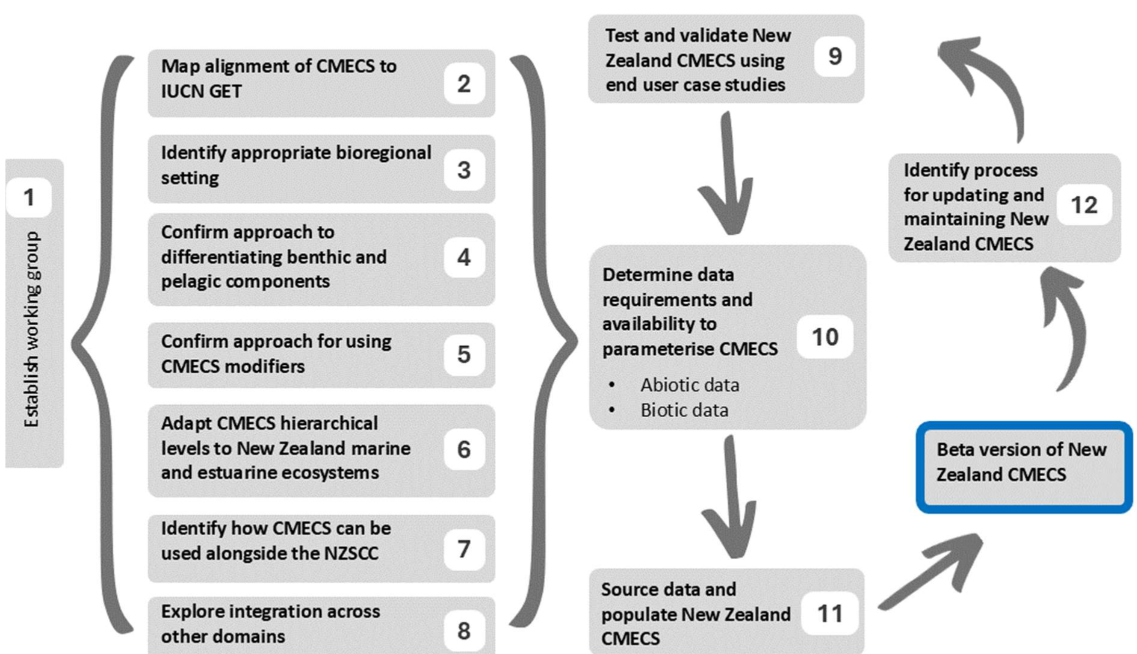

Figure 3-1: Steps in draft road map to develop a marine and estuarine ecosystem typology for New Zealand.

3.4.2 Step 1: Establish/reconfirm membership of a marine and estuarine ecosystem typology working group.

One step in the road map was to clarify the purposes of typologies across various stakeholders/partners, and (re)confirm the stakeholder steering group to progress the typology.

What is the purpose of this step?

- Confirm membership of a marine and estuarine ecosystem typology working group.
- Clarify the purposes of typologies across various stakeholders/partners.
- Confirm the steps in developing a national marine and estuarine ecosystem typology.

Why do we need this step?

- Uptake of the typology will require buy-in from potential users.
- Co-design will increase relevance and legitimacy of the typology.
- Co-design will allow for confirming funding and collaboration opportunities, and allocation of various agencies to lead different aspects of the refinement process.

Things we need to consider:

- Greater relevance and legitimacy will increase the likelihood of the typology being adopted by users.
- Confirmation of typologies being fit for purpose should come from users.

Proposed actions:

- Establish a marine and estuarine ecosystem typology working group including representatives from:
  - Ministry for the Environment.
  - Department of Conservation.
  - Fisheries New Zealand.
  - Regional councils.
  - Research community (CRIs, Universities, Museums, etc.).
- Establish a lead agency for this working group to manage communications and coordination across agencies to progress the roadmap.
- Run an in-person workshop with the marine and estuarine ecosystem typology working group to:
  - Co-develop a list of key requirements for the typology to fulfil the user needs to ensure CMECS is compatible with these requirements.
  - Identify potential end user case studies (see Step 9).
  - Discuss how the road map will be resourced.

- Confirm and prioritise other steps in the process.

3.4.3 Step 2: Comprehensively map alignment of CMECS settings and components to IUCN GET Biomes

CMECS levels specific to New Zealand's marine and estuarine ecosystems should be broadly aligned with IUCN GET and/or other unifying national typologies, as the IUCN GET has been adopted by the United Nations and will be used for monitoring and reporting against the post-2020 Global Biodiversity Framework. The high number of ecotones or marine transitional ecosystems make alignment of cross-domain habitats particularly important.

What is the purpose of this step?

- To map alignment of CMECS settings and components to IUCN GET Biomes and Ecosystem Functional Groups.
- To ensure levels of aggregation are compatible with reporting requirements at national and international scales.

Why do we need this step?

- Substantial research has gone into existing classifications, particularly those for different biomes such as coastal hydrosystems, seamounts and rocky reefs, as well as more broadly applicable classifications. A clear pathway to cross-walking these ecosystems into a national typology will ensure known and important ecosystems are not excluded.
- International reporting will likely require any national typology to be able to be mapped against the IUCN GET typology.
- Only a limited subset of CMECS classes were cross-walked with IUCN GET.
- Many transitional ecosystems or ecotones are limited in extent, and may be classified as rare or uncommon ecosystems. Their placement within a comprehensive national ecosystem typology should be consistently defined to ensure they are not excluded from national and international reporting.

Things we need to consider:

- Ensure existing regional classifications are accounted for.
- Ensure marine transitional/cross-boundary habitats are included.
- Ensure compatibility to aggregate/disaggregate for various purposes, for example international reporting to IUCN GET.

Proposed actions:

- Identify existing regional classifications and classify to IUCN GET/CMECS to ensure all relevant habitats are accounted for.
- Confirm alignment of cross biome habitats and ensure consistent defining attributes, inclusion and boundaries.

3.4.4 Step 3: Evaluate bioregional setting of CMECS and assess appropriateness of MEOW.

CMECS includes a high-level biogeographic setting as one component of the typology. CMECS is based on the Marine Ecosystems of the World (MEOW) bioregionalisation (Spalding et al. 2007), which includes 11 classes within New Zealand's EEZ which may or may not be fit for purpose for New Zealand.

What is the purpose of this step?

- Confirm the selection of a bioregionalization for use as a classifier in the ecosystem typology.
- Map management boundaries against the selected bioregionalization.

Why do we need this step?

- If bioregions are used as a classifier, they should be fit for purpose in a New Zealand context.
- The New Zealand context makes the selection of bioregionalisation an important consideration to ensure these are fit for purpose and the most appropriate typology is employed.

Things we need to consider:

- Bioregions may not be required depending on objectives of the typology.
- Management boundaries may poorly overlap with MEOW boundaries, but may be required to integrate into the typology to ensure it is fit for purpose.
- Other ecological bioregionalisations may be more appropriate than MEOW for a New Zealand typology.
- The usefulness of management vs. ecological boundaries should be clarified.

Proposed actions:

- Assess appropriateness of MEOW (Spalding et al. 2007) bioregions for New Zealand.
- Assess other bioregionalisations to determine most appropriate to inform a New Zealand typology.
- Once a bioregionalization is selected, determine overlay with current management boundaries.

3.4.5 Step 4: Confirm approach for combining benthic and pelagic components of ecosystems.

Marine ecosystems include both pelagic and benthic components, though each component may be composed of different species assemblages and be driven by environmental factors that vary at different temporal and spatial scales.

What is the purpose of this step?

- Define a process for representing both pelagic and benthic components in the ecosystem typology.

Why do we need this step?

- An ecosystem typology should include both benthic and pelagic components, when relevant.
- A clear process for mapping and including both seafloor (benthic) and water column (pelagic) must be defined for a marine and estuarine typology.

Things we need to consider:

- It may be appropriate to separate benthic and pelagic components in some ecosystems (e.g., deepwater) but not in others (e.g., shallow estuaries and harbours).
- Processes in pelagic and benthic ecosystems may occur at different scales, meaning lack of paired alignment of pelagic and benthic ecosystems.
- CMECS allows for a modifier to include multiple habitat components.

Proposed actions:

- Confirm suitable approach for inclusion of both benthic and pelagic ecosystem components.
- Confirm whether this approach should vary between depth (e.g., shallow vs. deepwater biomes).
- Confirm best process for inclusion of multiple ecosystem components in CMECS, i.e., through using modifiers.

3.4.6 Step 5: Define consistent approach for use of CMECS modifiers (temporal and spatial).

Modifiers are a useful tool in CMECS that allow for the indication of habitat condition, quality or extent, to indicate habitat degradation.

What is the purpose of this step?

- Define a consistent approach for how modifiers can be used to indicate habitat condition, quality or co-occurring ecosystem components.

Why do we need this step?

- Modifiers can have many purposes, including indications of multiple co-occurring ecosystem components such as benthic and pelagic ecosystem components.
- A consistent use of modifiers can ensure consistency across the typology.

Things we need to consider:

- How modifiers are used to indicate habitat condition, quality, or previous extent.
- How modifiers are used to indicate co-occurring ecosystem components.

- Other uses of modifiers that should be accommodated in the typology.

Proposed actions:

- Examine existing guidance for using modifying in CMECS.
- Define consistent approach for modifiers (temporal and spatial) for New Zealand CMECS to indicate condition/quality/extent.

3.4.7 Step 6: Comprehensively delineate and adapt CMECS levels, including biotic components, to New Zealand marine and estuarine ecosystems.

Key steps include defining CMECS levels specific to New Zealand's marine and estuarine ecosystems, including identification of biotic components. The high number of ecotones or marine transitional ecosystems make alignment of cross-domain habitats particularly important. As many of these transitional ecosystems are limited in extent, and may be classified as rare or uncommon ecosystems, ensuring which domain they are included in is imperative to the development of a comprehensive national ecosystem typology.

What is the purpose of this step?

- Map CMECS levels to New Zealand marine and estuarine ecosystems.
- Adapt CMECS hierarchical levels as required to ensure they are applicable to the diversity of New Zealand marine and estuarine ecosystems, and are suitable for hierarchical aggregation befitting international and national reporting standards.

Why do we need this step?

- Substantial research has gone into existing classifications, particularly those for different biomes such as coastal hydrosystems, seamounts and rocky reefs, as well as more broadly applicable classifications. A clear pathway to cross-walking these ecosystems into a national typology will ensure known and important ecosystems are not excluded.
- Validation of the CMECS approach through ensuring it accommodates relevant marine and estuarine ecosystem components is required to ensure it is fit for purpose.

Things we need to consider:

- Ensure existing regional classifications are accounted for.
- Ensure marine transitional/cross-boundary habitats are included.
- Ensure compatibility to aggregate/disaggregate for various purposes.

Proposed actions:

- Identify existing regional classifications and ensure all relevant habitats are accounted for. Consider performing cross-walks for existing classifications to facilitate transitioning to a novel classification.

- Confirm appropriateness of levels (settings and components) in CMECS to a New Zealand context, and identify gaps in levels required to accommodate relevant New Zealand marine and estuarine ecosystem components.
- Confirm hierarchical structure (physical then biotic) approach to CMECS is appropriate in a New Zealand context.
- Identify approach to delineate biotic components, including dominant and sub-dominant species, taxonomic protocols, and other required information to maintain consistency at this classification level.
- Confirm alignment of cross biome habitats and ensure consistent defining attributes, inclusion, and boundaries.
- Validate approach using case studies across estuaries, coastal and deepwater ecosystems.

3.4.8 Step 7: Identify how the New Zealand CMECS can be used alongside the NZSCC.

The NZSCC is a statistical classification that was developed to facilitate differentiation of marine ecosystems, due to the paucity of data in many areas of New Zealand's EEZ. The NZSCC is informed by both environmental and biotic components, and it is likely to provide additional hierarchical structure for a marine and estuarine ecosystem typology, particularly in deepwater areas dominated by soft-sediment ecosystems.

What is the purpose of this step?

- Determine how best to incorporate information from NZSCC into New Zealand CMECS.

Why do we need this step?

- NZSCC provides additional statistically-derived information that can inform a marine and estuarine ecosystem typology, and its hierarchical structure.

Things we need to consider:

- NZSCC is a statistical classification; both environmental and biotic drivers were incorporated in its development.
- Many NZSCC classes are associated with low environmental coverage, i.e., limited data available to define that class.
- NZSCC lacks the ability to define small scale features such as coastal vegetation or reef habitats that may be important for finer scale ecosystem classification.

Proposed actions:

- Identify how the NZSCC classes cross-walk to New Zealand CMECS.
- Determine if NZSCC classes would best be used as a CMECS modifier, or as additional hierarchical elements within New Zealand CMECS.

3.4.9 Step 8: Explore integration of the marine and estuarine ecosystem typology across other domains (e.g., terrestrial, wetland).

A large portion of marine and estuarine EFGs in IUCN GET are ecotones or cross-boundary ecosystems, and there is lack of clarity on where to place these cross-boundary ecosystems within a national ecosystem typology.

What is the purpose of this step?

- Clarify placement of cross-boundary ecosystem functional groups with marine elements.
- Ensure all cross-boundary ecosystems are included within a national ecosystem typology.

Why do we need this step?

- Coastal marine and estuarine ecosystems are at the boundary of other domains, and artificial boundary lines such as the Coastal Marine Area may create artificial separation of habitats that cross these boundaries (such as supratidal regions in estuaries, dunes, and coastal margins).
- Clarification is required to ensure these cross-boundary ecosystems are included within the national typology, and identify which domain they should be allocated to.

Things we need to consider:

- A significant proportion of 'marine' ecosystem functional groups are identified as cross-realm or transitional ecosystems in the IUCN GET.
- Domain-specific typologies may vary in hierarchical drivers (e.g., biotic or abiotic components).
- As many transitional ecosystems are limited in extent, and may be classified as rare or uncommon ecosystems, a national ecosystem typology should have a consistent approach to their inclusion to ensure they are not excluded.

Proposed actions:

- Determine which marine and estuarine ecosystems are categorised within cross-realm/transitional ecosystem categories.
- Coordinate with other domains to explore cross-domain integration and ensure all cross-realm/transitional ecosystems are represented within the national ecosystem typology.

3.4.10 Step 9: Perform end user case studies for a marine and estuarine ecosystem typology to ensure it is fit for purpose.

The primary goal of a typology is to group entities with common characteristics in a way that minimises within group variation and maximises between group differentiation and allows for use in policy, management, planning and reporting. Different users may require different applications of the typology, and the ability to aggregate and disaggregate is a useful way to allow for higher to lower resolution of the typology to be fit for purpose for national to regional and local scale processes. Collins (2024) listed several potential applications of a marine and estuarine ecosystem typology, including conservation planning, protected area design, State of the Environment Reporting, and Red Listing of ecosystems. Performing case studies of the application of the ecosystem typology can determine if it is fit for purpose for different management and policy needs and explore what levels of hierarchical aggregation suit different applications.

What is the purpose of this step?

- Perform case studies of the application of the ecosystem typology.
- Determine if the ecosystem typology is suitable across a range of management and policy needs.
- Explore what levels or hierarchical aggregation are required to suit a diversity of management and policy needs.

Why do we need this step?

- If the typology is not applicable to the needs of New Zealand stakeholders, it will not be used.
- How the marine and estuarine ecosystem typology will be used may influence the detail of differentiation within levels/components.

Things we need to consider:

- Appropriate levels of aggregation may differ between management, policy and reporting applications, and between different stakeholder interests.
- Greater applicability will increase the likelihood of the typology being adopted by users.

Proposed actions:

- Perform case studies to test suitability of the typology for a range of end user needs.
  - Identify a diversity of applications that the typology could inform.
  - Identify potential case studies to test relevant applications of the case study.
  - Prioritise and perform case studies based on data availability and resourcing.

3.4.11 Step 10: Determine data requirements and availability to parameterise CMECS across settings and components.

A large number of environmental and biotic datasets are required to parameterise CMECS across its hierarchical elements. Many of these datasets have already been compiled, where others may require new data to be collected or collated. All datasets should be assessed for their applicability to the current state of marine and estuarine ecosystems, as some older datasets may no longer represent the current ecosystems in a location.

What is the purpose of this step?

- Determine the suit of datasets required to populate the hierarchical framework of New Zealand CMECS.
- Assess existing datasets for suitability and applicability.
- Identify minimum data collection standards to inform each level of CMECS.
- Determine priorities for collecting new or updating existing datasets required to populate New Zealand CMECS.

Why do we need this step?

- Developing, validating, and delivering a marine and estuarine ecosystem typology requires data to parameterise the settings and components of CMECS.

Things we need to consider:

- Data requirements will be influenced by requirements to make the typology fit for purpose for different end-users, which may drive the level of differentiation within the classification at a national scale.
- National scale datasets have been compiled, but show consistent spatial biases and gaps based on survey effort, often with respect to commercial uses or consent conditions.
- Types of data vary between point records of occurrence and abundance, polygons of mapped habitats, and predictive models of habitat suitability and abundance.

Proposed actions:

- Determine what data are required to develop, validate, and deliver the marine and estuarine ecosystem typology.
- Identify minimum data collection standards to inform each level of CMECS.
- Establish whether the required data are available and accessible.
- Determine data gaps and a process to fill them.

3.4.12 Step 11: Source required data and map to CMECS classes.

Following road map step 10, address priorities in data collection to populate New Zealand CMECS.

What is the purpose of this step?

- Source marine and estuarine datasets in a structured and prioritised way to populate the hierarchical structure of CMECS.

Why do we need this step?

- Developing, validating, and delivering a marine and estuarine ecosystem typology requires data to parameterise the settings and components of CMECS.

Things we need to consider:

- Quality of different datasets may vary.

- How to specify the quality/degree of accuracy of the data.
- Types of data varies between point records of occurrence and abundance, polygons of mapped habitats, and predictive models of habitat suitability and abundance.
- Existing datasets are often not quality controlled.
- Datasets are regularly updated through provision of additional survey data, or through new or revised modelling efforts.

Proposed actions:

- Source data, including agreements for data accessibility. Ideally all national scale datasets should be available within creative commons licensing procedures.
- Collate data in a form suitable for typology development, validation, and delivery.
- Determine process for filling data gaps.

3.4.13 Step 12: Identify process for updating and maintaining New Zealand CMECS.

Identification of a process for updating the typology based on new data, or to include novel ecosystem classes is also a required next step.

What is the purpose of this step?

- Ensure that new datasets are able to be included in New Zealand CMECS.
- Ensure that New Zealand CMECS can be adapted to include novel ecosystem classes.

Why do we need this step?

- The typology should be made available to end users.
- The typology needs to be flexible to be able to be updated within new information.
- Ongoing hosting and maintenance of New Zealand CMECS will need to be resourced.

Things we need to consider:

- The effectiveness of the typology and its use will depend strongly on the commitment to invest in and develop the steps identified in this roadmap. Datasets accumulate gradually, such that an appropriate timeframe for substantial improvements in the typology should be identified.
- A maintenance procedure for the NZSCC has been developed, and could be emulated as a framework for updating a national marine and estuarine ecosystem typology (Stephenson 2023).
- Novel ecosystems could occur for many reasons, for example, due to changes in taxonomy, dominance by invasive species, changes in reporting of gradients in habitat degradation, or substantial anthropogenic modification of existing systems. The typology should be flexible to allow for inclusion of new components across different levels.

Proposed actions:

- Determine process for updating typology with a maintenance framework.
- Recalculate using updated environmental data, and quality assurance of datasets used to parameterise the typology.
- Confirm process for storing and making the typology accessible, including datasets used to parameterise the typology.
- Determine whether definitions of existing classes/levels require modification based on new data or novel ecosystems.
- Introduce new and/or replace existing classes/levels.

4 Conclusions

Prior stakeholder workshops with respect to marine and estuarine ecosystem typologies have identified CMECS as a suitable approach for a unifying classification within this domain. Assessing CMECS against MFE's typology principles shows broad alignment and flexibility of this hierarchical approach based on abiotic and biotic components. CMECS is more flexible and more consistent in its approach than the marine ecosystem functional groups available in the current iteration of the IUCN GET, however, New Zealand's experience in developing a bespoke CMECS typology could be useful in informing further iteration of the IUCN GET marine and marine transitional biomes. While much progress has already occurred within this domain's development of a unifying typology, a roadmap delineates the large number of steps required to parameterise CMECS for New Zealand marine and estuarine ecosystems.

5 Acknowledgements

We thank our marine and ecosystem typology steering group (Pierre Tellier and Hannah Jones, MfE; Greig Funnell and Shane Geange, DOC; Megan Oliver, C-SIG and Greater Wellington Regional Council; Karen Tunley, FNZ) for participation in an online workshop and/or for feedback on this report. We also thank Rowan Sprague and Susan Wiser for their guidance on this inter-agency project, Graeme Inglis for assistance with the project and feedback on the report, and Nidhi Yogesh for her assistance with preparing graphics.

6 References

Anderson, T.J., Morrison, M., MacDiarmid, A., Clark, M., D'Archino, R., Nelson, W., Tracey, D., Gordon, D., Read, G., Kettles, H., Morrisey, D., Wood, A., Anderson, O., Smith, A.M., Page, M., Paul-Burke, K., Schnabel, K., Wadhwa, S. (2019) Review of New Zealand's Key Biogenic Habitats. *NIWA Client Report* 2018139WN, prepared for the Ministry for the Environment: 190.

Bowden, D.A., Compton, T.J., Snelder, T.H., Hewitt, J.E. (2011) Evaluation of the New Zealand Marine Environment Classifications using Ocean Survey 20/20 data from Chatham Rise and Challenger Plateau. *New Zealand Aquatic Environment and Biodiversity Report* No. 77: 27.

Brough, T., Rowden, A.A., Stephenson, F. (2020) Towards a new thematic marine habitat classification for New Zealand *NIWA Client Report* 2020251HN prepared for the Department of Conservation, Project DOC19208: 33.

Collins, K. (2024) Standardised ecosystem typologies: Recommendations for New Zealand. *Collins Consulting Limited Client Report* 554 prepared for the Ministry for the Environment. 21 p. plus App.

Department of Conservation, Ministry of Fisheries (2011) Broad scale gap analysis of coastal marine habitats and marine protected areas in the New Zealand Territorial Sea. Department of Conservation, Wellington, New Zealand: 50 plus App.

Federal Geographic Data Committee (FGDC) 2012 Coastal and Marine Ecological Classification Standard (FGDC-STD-018-2012) Federal Geographic Data Committee, USA: 342.

Haggitt, T. (2021). CMECS crosswalking habitat classification evaluation – Ulva Island/Te Wharawhara Marine Reserve and Kapiti Island Marine Reserve. eCoast Client Report prepared for Department of Conservation: 35.

Hume, T., Gerbeaux, P., Hart, D., Kettles, H., Neale, D. (2016) A classification of New Zealand's coastal hydrosystems. *NIWA Client Report* HAM2016-062, Project MFE15204, prepared for the Ministry for the Environment: 120.

Jackson, S., Lundquist, C.J. (2016) Limitations of biophysical habitats as biodiversity surrogates in the Hauraki Gulf Marine Park. *Pacific Conservation Biology*, 22: 159-172.

Law, C.S., Bell, J., Bostock, H., Cornwall, C., Cummings, V., Currie, K., Davy, S., Gammon, M., Hepburn, C., Lamare, M., Mikaloff-Fletcher, S., Nelson, W., Parsons, D., Ragg, N., Sewell, M., Smith, A., Tracey, D. (2017) Ocean acidification in New Zealand waters. New Zealand *Journal of Marine & Freshwater Research*, 52: 155–195.

Lundquist, C., Brough, T., McCartain, L., Stephenson, F., Watson, S. (2021) Guidance for the use of decision-support tools for identifying optimal areas for biodiversity conservation: *NIWA Client Report* 2020347HN, Project #DOC19207, prepared for the Department of Conservation: 124.

Lundquist, C., Bulmer, R.H., Clark, M.R., Hillman, J.R., Nelson, W.A., Norrie, C.R., Rowden, A.A., Tracey, D.M., Hewitt, J.E. (2017) Challenges for the conservation of marine small natural features. *Biological Conservation* 211: 69–79.

Lundquist, C., Stephenson, F., McCartain, L., Watson, S., Brough, T., Nelson, W., Neill, K., Anderson, T., Anderson, O., Bulmer, R., Gee, E., Pinkerton, M., Rowden, A., Thompson, D. (2020) Evaluating Key Ecological Areas datasets for the New Zealand Marine Environment. *NIWA Client report* 2020109HN, Project DOC19206prepared for the Department of Conservation: 120.

MacDiarmid, A., Bowden, D., Cummings, V., Morrison, M., Jones, E., Kelly, M., Neil, H., Nelson, W., Rowden, A. (2013) Sensitive marine benthic habitats defined. NIWA Client Report WLG2013-18, prepared for the Ministry for the Environment: 72.

McCartain, L., Watson, S., Brough, T., Lundquist, C. (2020) Assessment of Southland Marine Significant Ecological Areas*. NIWA Client Report* prepared for Ministry of Business, Innovation and Employment Envirolink Fund to Environment Southland, Project ELF20216: 112.

Ministry of Fisheries, Department of Conservation (2008) Marine protected areas: Classification, protection standard and implementation guidelines. Ministry of Fisheries and Department of Conservation, Wellington, New Zealand: 54.

Nelson, W.A., Neill, K., D’Archino, R., Rolfe, J.R. (2019) Conservation status of New Zealand macroalgae, 2019. *New Zealand Threat Classification Series* 30. Department of Conservation, Wellington: 33.

Nelson, W.A., Twist, B.A., Neill, K.F., Sutherland, J.E. (2019) Coralline algae of New Zealand: a summary of recent research and the current state of knowledge. *New Zealand Aquatic Environment and Biodiversity*, 232: 58.

Neill, K., D’Archino, R., Farr, T., Nelson, W. (2012) Macroalgal diversity associated with soft sediment habitats in New Zealand. *New Zealand Aquatic Environment and Biodiversity Report* 87: 127.

Neill, K.F., Nelson, W.A. (2016) Soft sediment macroalgae in two New Zealand Harbours: seasonal changes in biomass and species. *Aquatic Botany* 129: 9–18.

Petersen, G., Stephenson, F., Rowden, A.A., Brough, T. (2020) Seafloor Community Classification: Group descriptions. *NIWA Client Report* 2020230HN prepared for Department of Conservation, Project DOC19208: 237.

Rossbach, F.I., Casoli, E., Beck, M., Wild, C. (2021) Mediterranean red macro algae mats as habitat for high abundances of serpulid polychaetes. *Diversity*, 13: 265.

Rowden, A.A., Clark, M.R., Wright, I.C. (2005) Physical characterisation and a biologically focused classification of "seamounts" in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research*, 39: 1039-1059.

Rowden, A.A., Lundquist, C.J., Hewitt, J.E., Stephenson, F., Morrison, M. (2018) Review of New Zealand’s coastal and marine habitat and ecosystem classification. *NIWA Client Report* DOC17310 prepared for the Department of Conservation: 89.

Schmidt, N., El-Khaled, Y.C., Rossbach, F.I., Wild, C. (2021) Fleshy red algae mats influence their environment in the Mediterranean Sea. Frontiers in Marine Science, 8: 721626.

Shears, N.T., Babcock, R.C. (2004) Quantitative classification of New Zealand's shallow subtidal reef communities. Science for Conservation Series (New Zealand Department of Conservation: 158.

Snelder, T., Leathwick, J., Image, K., Weatherhead, M., Wild, M. (2004) The New Zealand Marine Environments Classification. *NIWA Client Report* MFE04505 prepared for the Ministry for the Environment: 86.

Spalding, M.D., Fox, H.E., Allen, G.R., Davidson, N., Ferdana, Z.A., Finlayson, M., Halpern, B.S., Jorge, M.A., Lombana, A., Lourie, S.A., Martin, K.D., McManus, E., Molnar, J., Recchia, C.A., Robertson, J. (2007) Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *Bioscience*, 57(7): 573-583.

Sprague, E.I., Wiser, S.K. (2024) Investigating a unifying ecosystem typology for all of New Zealand. *Manaaki Whenua Landcare Research Client Report* No. LC4514 prepared for the Ministry for the Environment. 69 p.

Stephenson, F. (2023) Developing a maintenance framework for the NZSCC. *Ocean Analytics Client Report* prepared for the Department of Conservation: 30.

Stephenson, F., Rowden, A.A., Brough, T., Petersen, G., Bulmer, R.H., Leathwick, J.R., Lohrer, A.M., Ellis, J.I., Bowden, D.A., Geange, S.W., Funnell, G.A., Freeman, D.J., Tunley, K., Tellier, P., Clark, D.E., Lundquist, C.J., Greenfield, B.L., Tuck, I.D., Mouton, T.L., Neill, K.F., Mackay, K.A., Pinkerton, M.H., Anderson, O.F., Gorman, R.M., Mills, S., Watson, S., Nelson, W.A., Hewitt, J.E. (2022) Development of a seafloor community classification for the New Zealand region using a gradient forest approach. *Frontiers in Marine Science*, 8: 792712.

Stephenson, F., Rowden, A.A., Tablada, J., Tunley, K., Brough, T., Lundquist, C.J., Bowden, D.A., Geange, S. (2023) A seafloor bioregionalisation for *New Zealand. Ocean & Coastal Management,* 242: 106688.

Tuya, F., Schubert, N., Aguirre, J., Basso, D., Bastos, E., Berchez, F., Fraga, A., Bosch, N.E., Burdett, H., Espino, F., Fernandez Garcia, C., Francini-Filho, R., Gagnon, P., Hall-Spencer, J., Haroun, R., Hoffman, L., Horta, P.H., Kamenos, N.A., Le Gall, L., Magris, R.A., Martin, S., Nelson, W.A., Neves, P., Olivé, I., Otero-Ferrer, F., Peña, V., Pereira-Filho, G., Ragazzola, F., Rebelo, A.C., Ribeiro, C., Rinde, E., Schoenrock, K., Silva, J., Sissini, M., Tamega, F. (2023) Levelling-up rhodolith-bed science to address global-scale conservation challenges. *Science of the Total Environment* 892:164818.

Appendix A Alignment with Principles and Requirements

Table A-1: Evaluation of marine and estuarine classifications against the Principles.

Principles and Requirements		IUCN (Marine EFGs)	CMECS	NZCHT	CMHEC
1. Hierarchical structure	1.1 Level type	Inconsistent – Environmental/Biotic	Biogeographic/Environmental/Biotic	Environmental/Biotic	Biogeographic/Environmental, limited Biotic elements
	1.2 Nesting type	Imperfectly nested. Appears to be driven by both top down (levels 1-4) and bottom up (levels 5-6). However, nesting in marine and marine transitional EFGs has no consistent hierarchical structuring elements (e.g., sediment, topography, hydrography, biotic drivers), and is often ambiguous.	Perfectly nested from physical (aquatic water column and geoform) structure to biological structure (substrate and biotic components). Generally top-down entry but can be driven by both top down and bottom up. For biogeographic regions, it adopts the approach described by Spalding et al. (2007) in Marine Ecosystems of the World (MEOW). Modifiers are useful to include co-occurring habitats or habitat qualifiers	Perfectly nested from system physical processes level to biotic components. For biogeographic region, it adopts the approach described by Spalding et al. (2007) in Marine Ecosystems of the World (MEOW).	Perfectly nested. For biogeographic region, it uses 14 bioregions based primarily on management boundaries.
2. Spatially explicit	2.1.1 Is typology mapped?	Yes, can be mapped at local and international level, though noting lack of data for much of NZ's EEZ to inform any classification, thus approaches have been such as MEC/NZSCC to inform lack of knowledge of subtidal pelagic and benthic habitats.	Yes, can be mapped at local and international level, though is not yet mapped in New Zealand.	Yes, to class IV (tidal regime) at national scale (Hume et al. 2016)	Yes, at national scales (Department of Conservation and Ministry of Fisheries 2011), and at local scales for various regional processes (e.g., Jackson & Lundquist 2016).
	2.1.2 Indicate extent, resolution, and accuracy.	Global. Some global datasets are likely inaccurate at local scales	Can be mapped to high resolution at lower levels.	Can be mapped to high resolution at lower levels.	Can be mapped to high resolution at lower levels. However, is limited to

Principles and Requirements		IUCN (Marine EFGs)	CMECS	NZCHT	CMHEC
		(e.g., lack of cold seeps, hydrothermal vents; coastal vegetation likely not up to date).			Territorial Sea/CMA and to depths of 200 m.
	2.1.3 Also indicate how the ecosystem occurrence is represented (i.e., points, polygons, etc.)	Polygons	Polygons	Polygons	Polygons
	2.1.4 If not mapped, are there data that could be used to produce maps?	Yes.	Yes.	n/a	n/a
	2.2 Extent (current, historical, potential)	Global datasets informing Level 3 EFGs.	n/a	All NZ estuaries, class IV with recent (last decade) data.	Variable data quality for substrate and biogenic habitat components.
	2.3 Are the methods used to map the typology sufficiently well described that they could be reproduced by a third party?	No. Some lack of clarity about ambiguous/overlapping categories within EFGs.	Yes.	Yes.	Yes.
	2.4 Other comments	Many locations would qualify as multiple EFGs.	n/a	n/a	n/a
3.1. Accommodates	3.1.1 Spatial boundaries on maps	Yes.	Yes.	Yes.	Yes.

Principles and Requirements		IUCN (Marine EFGs)	CMECS	NZCHT	CMHEC
increased knowledge and change over time: Updateable	can change over time?				
	3.1.2 Temporal changes can be made to mapped unit attributes?	No.	Yes. Modifiers can be used to delineate extent or quality.	No.	No.
3.2. Accommodates increased knowledge and change over time: Flexible/adaptable	3.2.1 New ecosystem types can be added	In theory yes, with iterative process with IUCN experts.	Yes.	Yes, but unlikely.	No.
	3.2.2 Ecosystems can be split or combined	In theory yes, with iterative process with IUCN experts.	Yes.	No.	No.
	3.2.3 Methods can be changed to better define ecosystem types	In theory yes, with iterative process with IUCN experts.	Yes, easily modifiable.	No.	No.
3.3. Accommodates increased knowledge and change over time: Temporally explicit	3.3.1 Time span of underlying data and when typology created documented. Changes have been date-stamped	No.	Yes. Modifiers can be used to delineate date-stamp.	No.	No.
	3.3.2 If maps have been created, is the time period of application documented? Have any changes been date-stamped?	No.	Modifiers can be used to delineate date-stamp.	No.	No.

Principles and Requirements		IUCN (Marine EFGs)	CMECS	NZCHT	CMHEC
4.1. Compatibility across domains and typologies: Compatible	4.1.1 Rationale behind typology structure clear?	Yes, at Level 1 and 2. No at Level 3.	Yes.	Yes.	Yes.
	4.1.2 Does it build on/acknowledge other typologies? Are relationships to units in other typologies explained?	No.	No.	No.	No.
	4.1.3 Could the typology be cross-walked to other typologies in the domain	Yes, however ambiguity and overlaps particularly in marine transitional EFGs challenge the cross-walk process.	Yes.	Yes.	Yes.
	4.1.4 Other comments	n/a	n/a	n/a	n/a
4.2. Compatibility across domains and typologies: Consistent use of species concepts	4.2.1 Describe whether and how taxonomic changes can be accommodated	Presumably yes, at Level 6 when biotic component is identified.	Yes.	n/a	n/a
	4.2.2 Biotic names follow a reference taxonomy (e.g., NZOR). Please provide name of reference taxonomy	n/a	Yes, assume would follow WoRMS or national taxonomic standards for biotic components.	n/a	n/a
4.3. Compatibility across domains	Yes, No, Partial	Partial	Partial	Partial	Partial

Principles and Requirements		IUCN (Marine EFGs)	CMECS	NZCHT	CMHEC
and typologies: Nesting under IUCN GET					
5.1. Robust: Parsimony & utility	5.1.1 Detailed descriptions of units exist?	Yes.	Yes.	Yes.	No.
	5.1.2 Clearly applicable diagnostic criteria to allow identification of units	No at EFG level 3.	Yes.	Yes.	Yes.
	5.1.3 Do ecosystem names facilitate identification in the field?	Yes.	Yes.	Yes.	Yes.
	5.1.4 Are the number of units manageable? Please specify the number of units at each level.	Yes. Broad scale for EFGs (34 in New Zealand for marine EFGs)	Yes, hierarchical structure allows aggregation/disaggregation as relevant to suit purposes.	Yes. 11 geomorphic classes at level III. Further detail is typically within estuary variability in abiotic and biotic components.	Yes. Approximately 40-50 classes in typical CMA depending on data resolution for substrates, and availability of biogenic habitat information.
5.2. Robust: Transparent & reproducible	5.2.1 Method to produce typology documented and independently reproducible	Yes. While overlapping classes, all classes are reasonably straightforward to identify.	Yes.	Yes.	Yes.

Principles and Requirements		IUCN (Marine EFGs)	CMECS	NZCHT	CMHEC
	5.2.2 If 5.2.1 is 'No', is the method defensible?	n/a	n/a	n/a	n/a
	5.2.3 Was typology data derived, data underpinned, or expert-derived/qualitative	Expert derived/qualitative.	Informed by data.	Informed by data.	Informed by data.
6. Comprehensive	6.1 Does it accommodate transformed ecosystems including engineered, passed tipping point, successional, novel	Yes. M4 includes transformed ecosystems that could be further iterated. However, no ability to accommodate change in habitat quality. Some classes to delineate artificial shores, canals ditches and drains.	Yes. Inclusion of anthropogenic features within CMECS allows the classification of all environmental components presently found in nature. Modifiers can be used to delineate novel/transformed ecosystems, or Level 6 can be expanded to be indicative of novel ecosystems.	Yes, in Level V (Structural class) and Level VI (Composition).	No.
	6.2 Does it accommodate ecotones?	Yes. 14 marine transitional EFGs.	Yes. Modifiers can be used to further delineate ecotones if specific component is not available in classification.	No.	No.
	6.3 Does it distinguish biotic (e.g., species) assemblages that are uncommon?	No.	Yes. Modifiers can be used to indicate naturally uncommon or rare taxa.	No.	No.
	6.4 Is there any other form of ecosystem variation that is missing from the typology?	n/a	n/a	Estuary focus.	High differentiation of hard/coarse substrate categories, but limited differentiation of soft substrates.

Principles and Requirements		IUCN (Marine EFGs)	CMECS	NZCHT	CMHEC
7. New Zealand-specific	7.1 Reflects NZ ecological diversity and processes (if NO explain why)	Yes. Designed to map at a global scale, but finer detail available.	Yes, within lower levels.	Yes, particularly the diversity of estuary types.	Yes.
	7.2 Does the typology use terminology and concepts familiar to NZ ecologists and conservation practitioners?	Yes.	Yes. Much more detail provided in (sensible and common language) nomenclature and classification categories. CMECS components start with general- or landscape-scale units in the upper levels and narrow to detailed, fine-scale units at the lowest levels. The appropriate hierarchical level of bio-physical description in any component should be determined based on user needs and project objectives.	Yes (though some technical hydrological concepts will be less familiar to non-experts in coastal hydrology).	Yes, though ecosystem/habitat types (e.g. deep mud/low exposure) are difficult to conceptualise without relevant biotic community.
	7.3 Takes account of Te Ao Māori [any comments on how this could be achieved will be useful]	No.	No but could be included as a modifier, or additional ecosystem types added following appropriate input.	No.	No.