# Combined Biotope Classification Scheme (CBiCS)

*A New Marine Ecological Classification Scheme to Meet New Challenges*

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Australian Marine Ecology
Fathom Pacific
Victoria State Government
Environment, Land, Water and Planning

## *Unified Marine Ecological Classification*

A new scheme for marine ecological classification, the Combined Biotope Classification Scheme (CBiCS), was developed to meet the requirements of modern environmental management.

CBiCS provides a system to standardise classification of new and legacy data from the littoral zone to the deep-sea. CBiCS is implemented via controlled databases, catalogues and web-based services. CBiCS has detailed classification components and hierarchies, tested with real data from multiple ecosystems. It is supported by a comprehensive implementation framework and provides managers with unprecedented ability to house and analyse marine data.

# Needs and Objectives

Marine ecological classification (MEC) provides a means of describing, mapping and monitoring biological communities, abiotic structural habitat components and ecosystem types (Fig. 1). MEC can be applied at a range of spatial scales, aligned with the natural hierarchy of scales covered by the methods or sensors being deployed. For example, benthic environments may be surveyed using satellite imagery, swath acoustics or airborne LiDAR at large scales, imaging transects at intermediate scales, and image frames, quadrats or grab samples at small spatial scales.

MEC is a central component of marine spatial planning and the results of classification are typically communicated by maps, referred to as ‘habitat maps’. Seagrass beds, canopy-forming kelp, mangroves and saltmarshes and ‘reefs’ and other benthic habitat types are among the coastal ecosystem components that have been classified, modelled or mapped in Victoria in the past. However, interpretations of these data have been limited by the use of un-standardised classifications or classes that do not sufficiently resolve to the level of species, community or ecological function. The implementation of previous classifications has also been hindered by the lack of hierarchical structures and catalogues.

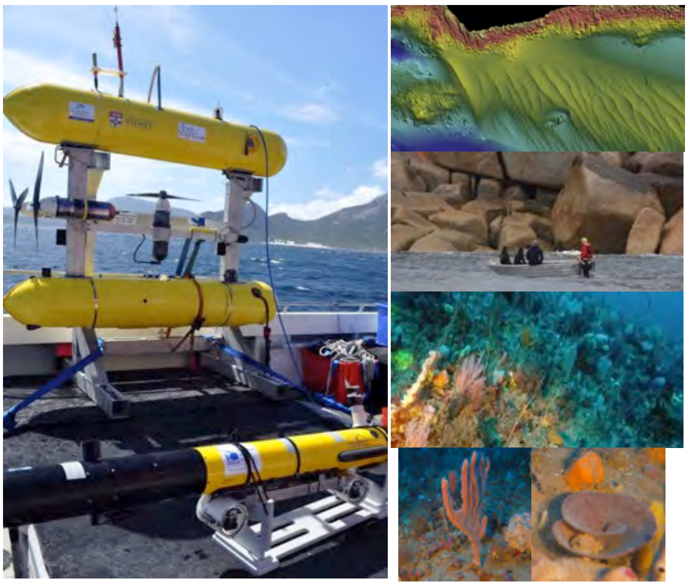


**Figure 1: Some elements of a marine ecological classification and mapping study. A comprehensive classification scheme is required to standardise and unify data.**

CBiCS was developed to meet the objectives listed in Table 1.

**Table 1: CBiCS development objectives**

| Objective | Target |
|---|---|
| Mapping and monitoring | Classes suitable for mapping and mapping biotic components |
| High resolution and sensitivity | Resolves biodiversity to community or near-species level<br>Top-down and bottom-up operability<br>Minimises subjectivity to avoid 'inferred' or 'expert' opinions |
| Hierarchical with ecological alignment | True hierarchical levels that reflect ecologically coherent groupings and movement through hierarchy align with scales of sensor acuity, user skills and information needs |
| Comparability | External - comparable to allow integration of legacy data and inclusion of data from other schema (e.g., littoral vegetation, coral reefs)<br>Internal - hierarchies aligned across biotic and abiotic components such that classifications provide like-for-like mapping strata |
| Parsimonious | Classes simplify ecological representation without significant information loss<br>Classes and structure represent known ecological groupings and thus have an implicit qualitative model |
| Flexible and updatable | Editable classes, but with immutable UUIDs<br>Links with morphospecies classification and tools to automate updates (e.g., taxonomic name changes via freely accessible web APIs) |
| Controlled | Centralised database records<br>Web-reviewable<br>Guidance, training and quality control requirements<br>Defined rule set for describing, applying or modifying classes |
| Catalogues and Support | Online database and query implementation<br>Comprehensive cataloguing and description of classes<br>Georeferenced imagery in catalogue |

# Review, Design and Testing

## Review Phase

The first step to developing CBiCS was a comprehensive review of existing classification schema. The review acknowledged a range of schema that have been deployed in Australia in terrestrial and marine environments.  The review identified that several schema in use in Australia were developed to achieve classification within a particular agency's monitoring program in a particular subset of environments.  Initial findings of the review converged on four central themes that limited the success, uptake or scalability of existing Australian and other schema:

1. The existing schema represent 'flat' classification structures with classes representing a matrix of end-node choices;
2. Use of pseudo-hierarchies: the levels of the hierarchy were arbitrary and not calibrated to a level of ecological coherence or information content;
3. Subjectivity and observer error in classification with limited documentation or support with respect to training and quality checking mechanisms; and
4. The systems were 'closed' and not supported by a tools that could be used to deploy across wider range of environments by a wider range of workers.

Another early finding of the review was that the field of terrestrial vegetation deployed more mature classification schema that were standardised across the field.  With respect to management use and implementation success, Ecological Vegetation Classes (EVCs), in use since 1994, provided a useful model for how a classification scheme marine realm could 'look' in practice: standardised terminologies, training and accreditation programs, online resources, national uptake, etc.

Consideration of existing national and international schema were constrained to those that:

- Were comprehensive and spanned multiple ecosystems;
- Were supported by documentation;

- Had provenance, testing and successful uptake; and
- Were adaptable to Australia and scalable.

With these criteria, the schema that were identified to show the most promise were:

- The Joint Nature Conservancy Committee–European Nature Information System biotope classification scheme (referred to as the 'JNCC scheme') (Connor et al. 2004):
    - Comprehensive hierarchical biotic classification scheme;
    - Provenance, testing and successful uptake;
    - Well documented and supported within a legislative framework;
    - Derived from biological communities with similarities to Australian temperate systems;
    - Scalable to other Australian environments;
    - Does not include classification of abiotic components.
- The Coastal and Marine Ecosystem Classification Standard (referred to as the 'CMECS scheme') (FGDC 2012):
    - Multiple abiotic and biotic components;
    - Comprehensive abiotic classification hierarchies;
    - Provenance, testing and successful uptake in multiple US jurisdictions;
    - US environments cover coral reefs to ice habitats so adaptable to Australia;
    - Well documented.

These two classification systems are principally 'top-down' systems. That is, a biotic class is derived through a process of working down hierarchies from low 'resolution' at the top through to increasingly detailed levels. Our review and experience with monitoring data identified that a mechanism for so called 'bottom-up' classification was also required. That is, providing the capacity for imagery or other data products from the field to be 'scored' in such a way as to derive a biotope classification from species assemblages with 'samples'. Therefore, the review determined that an additional element to the classification system would be required, that being a new CBiCS-designed morphospecies classification scheme. This new morphospecies classification scheme is described in detail herein.

Our review found that there were issues with existing morphospecies classification schema that prohibited their direct adoption within a framework of biotope classification:

- The components did not align well with habitat and biotope classification;
- They did not classify organisms to a level that reflected species-level biodiversity, which is important for monitoring;
- They were not amenable for image processing and machine learning, which are important for the large image data sets that charactersise modern methods.

## Design Phase

The core components of CBiCS combine the abiotic components of CMECS, with the biotic component of the JNCC scheme. These components are labelled similarly to CMECS: Biogeographic Setting; Aquatic setting; Substrate component; Geoform component; Hydroform component; and Biotic component.

We added two more components: Morphospecies component and Categories component. The Categories component includes categories from CMECS and JNCC, such as temperature, salinity and substrate origin classes.

The classes within each of these components was seeded with classes from CMECS and EUNIS, and then added and extended with classes and descriptions from various Australian sources.

## Testing and Application Phase

CBiCS was tested and extended through practical application in Victoria. Large mapping and monitoring data sets were reclassified into CBiCS classes. These encompassed all marine habitats from saltmarsh and mangroves, sediment and seagrass beds, kelp beds and deep sponge gardens. The system was applied to various data types, including long term intertidal and subtidal reef monitoring data and reclassification of imagery from towed video, drop camera, ROV and AUV platforms.

Existing habitat maps and ground-truthing data for Victorian embayments (Port Phillip Bay, Western Port and Gippsland Lakes) were reclassified using CBiCS progressively through its application. The biggest test of the system was the application to circalittoral reef environments of the Victorian open coast. There was relatively poor existing knowledge of circalittoral reef biotopes along the Victorian open coast and the ability for CBiCS to effectively classify these high complexity biotopes was confirmed.

The system was adapted throughout the testing and application phase, while simultaneously describing new and unmapped biotopes throughout Victoria. There was concurrent testing and application using data multiple international projects, from coral reefs to abyssal basins.

Importantly, the CBiCS testing phase included testing of the system's practical utility in four emerging areas:

1. Ecosystem accounting – testing was achieved via a concurrent DELWP program.
2. Automation of geoform classifications – testing was achieved through a process of classifying areas of Port Phillip Bay that had detailed multibeam bathymetry, coastal LiDAR, aerial imagery and ground-truthing data. Supervised machine learning algorithms linked to the classification hierarchies were successfully used to automate the identification of seabed textures, relief, shading and other metrics to assign classes (Fig. 2).
3. Automated image scoring of morphospecies and development of morphospecies training sets for machine learning. Tested and applied to ROV imagery in the Entrance Canyon, Victoria.
4. Collation and unification of historical databases into a single, centralised resourceusing standardised classes and labels. Evidenced by collation into the Victorian CoastKit database and atlas.

Several information sharing workshops were held throughout the development and testing phase, including those related to the implementation of a national classification standard.

CBiCS was developed through a consultative process over some three years and the key milestones are shown in Fig. 3. The progressive developments illustrated in Fig.3 iteratively fed back into the core design elements to improve the system. CBiCS is now available online as a comprehensive repository of classified data and a documented and supported biotope classification scheme.

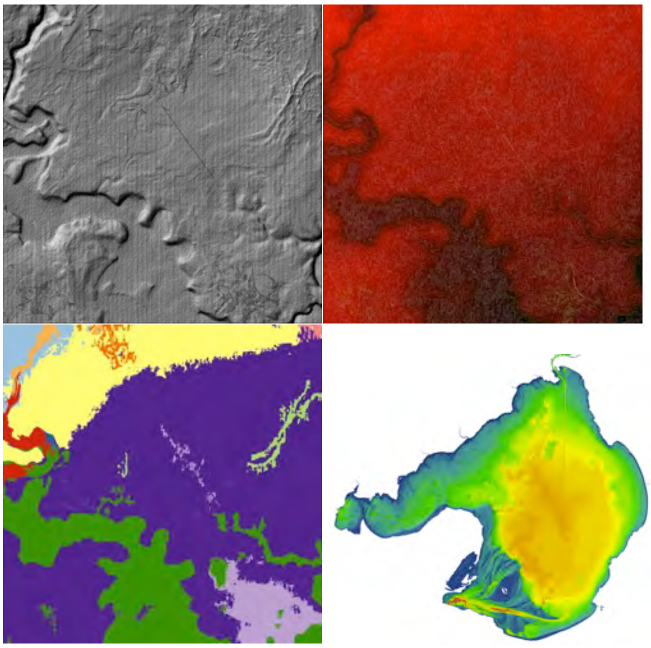


**Figure 2: Segmentation of remote-sensing products, linked with a supervised biotope training-and-classification workflow was applied in Port Phillip Bay**

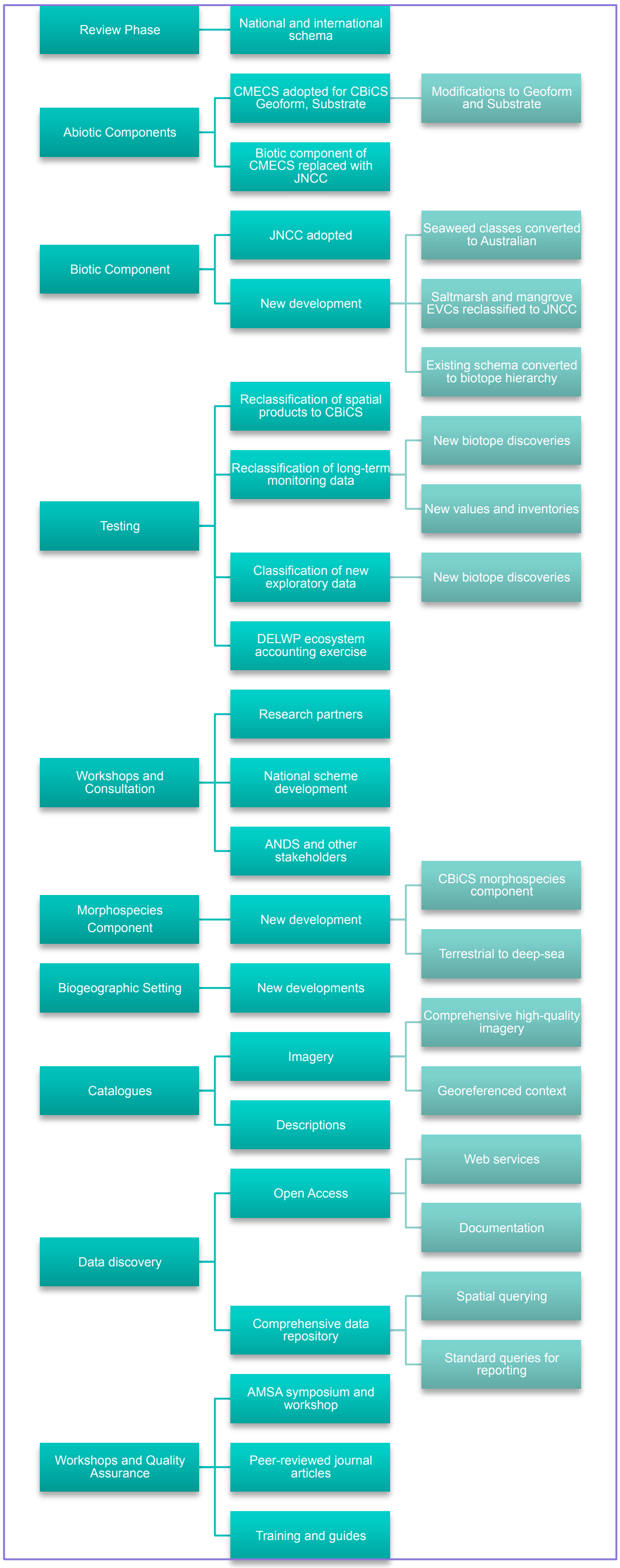



**Figure 3: Summary of the CBiCS development process**

# What is a Biotope?

At the core of CBiCS is the concept of the *biotope*. The term describes a:

*Community of species in a defined abiotic habitat.*

Central to the derivation of a biotope class is the concept that biological communities are controlled by the physicochemical components of their habitat, such as the geomorphic structure and substrate composition of the seabed. As such, a biotope class has a fundamentally different descriptive structure to classes historically used (Table 2.)

There are conventions applied to biotope naming. The class title aspires to include key ecological information content and is referenced by a coding system and various abbreviated labels to facilitate mapping.

CBiCS has eight classification components, each with a hierarchical structure. Hierarchical levels are calibrated across components so that a classification made a certain level achieves ecological coherence. While each component is meaningful as a stand-alone hierarchy (e.g. a researcher can classify coastal geoforms in isolation from the biotic components), the power of the system is fully realised when the components are used together to derive a biotope classification (Fig. 4).

Biotopes are not simply a choice list of possible biological classes. Rather, a biotope is the fifth level of a carefully calibrated classification hierarchy in the biotic component of the CBiCS. The levels group biotopes into sets that have known ecological coherence. As described further below, a CBiCS biotic class provides:

- An ecologically coherent grouping;
- A spatially consistent grouping;
- A level of predictability that is testable;
- An association with known or hypothesised ecosystem properties (and services);
- A core unit of management.

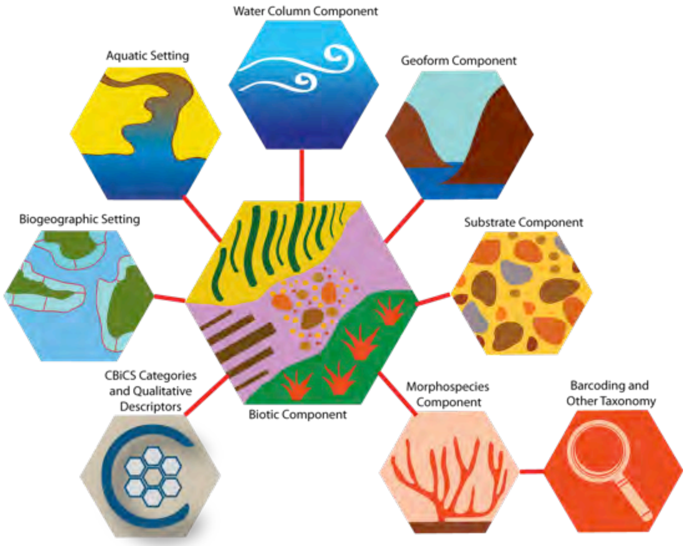



**Figure 4: CBiCS hierarchical components used to formulate a biotope classification**

Biotic classification can be challenging, particularly when exploring new environments or where ground-truthing is complicated by poor image quality. While the biotic component can be used to classify biotic communities at higher levels of the hierarchy, it is stressed that the level of the biotope (level 5) should be targeted to provide the information requirements of effective research and natural resource management.

Therefore, CBiCS also provides a tool for setting objectives for new studies. With a comprehensive and standardised classification system in place, the methodological, technological or training solutions to achieve the required biotope level of classification can be clearly identified. For example, citizen science programs can be targeted at higher level than the resolutions required by researchers and natural resource managers.

**Table 2: Examples of CBiCS biotopes**

| Example historical class | Example CBiCS Biotope |
|---|---|
| Seagrass | ba5 Sublittoral sediment<br>ba5.8 Sublittoral seagrass beds<br>ba.83 *Zostera–Ruppia* beds<br>*ba5.831 Zostera nigricaulis* |
| Canopy-forming algae | ba3 Infralittoral rock and other hard substrata<br>ba3.1 High energy infralittoral rock<br>ba3.14 High energy *Ecklonia* communities<br>ba3.141 *Ecklonia radiata* forest with cushion fauna on very exposed subtidal rock |
| *Caulerpa* Dominant Macroalgae | ba3 Infralittoral rock and other hard substrata<br>ba3.3 Low energy infralittoral rock and other hard substrata<br>ba3.36 *Caulerpa* assemblages on low energy rock<br>ba3.362 *Caulerpa remotifolia* on low energy rock |
| Mixed invertebrates | ba4 Circalittoral rock and other hard substrata<br>ba4.1 High energy open-coast circalittoral rock<br>ba4.1d Moderate to high complexity circalittoral rock with prominent sea plumes, sea tulips and hydroid fans<br>ba4.1d4 Diverse sponge assemblage including lamellate covering and mounded sponges and with *Pyura spinifera* and *Pteronisis* (Cape Otway C) |
| Unvegetated sediment | ba5 Sublittoral sediment<br>ba5.3 Sublittoral mud<br>ba5.32 Sublittoral mud in variable salinity (estuaries)<br>ba5.322 Estuarine mud with large funnel burrows |

The use of the term *biotope* is standard in other jurisdictions but has not commonly been applied to marine classification in Australia until now. The adoption of this terminology brings several benefits to the functionality of marine ecological classification. Biotope classification brings a focus onto ecologically relevant classes, enshrining the concept of biological communities interacting with physical habitats that is important for natural resource management and conservation. Biotopes are not only useful mapping units but also have application for monitoring and describing community succession over time.

These benefits also come with some new challenges to the fields of marine habitat mapping and monitoring. To classify a biotope, achieving the types of classifications listed in Table 2, there needs to be an understanding of four aspects of the system in question (Fig. 5).

International experience shows that uptake of the terminology is easily achievable. Furthermore, this representation of marine environments brings alignment with the concepts routinely used in terrestrial mapping, and facilitates effective communication across multiple stakeholders.

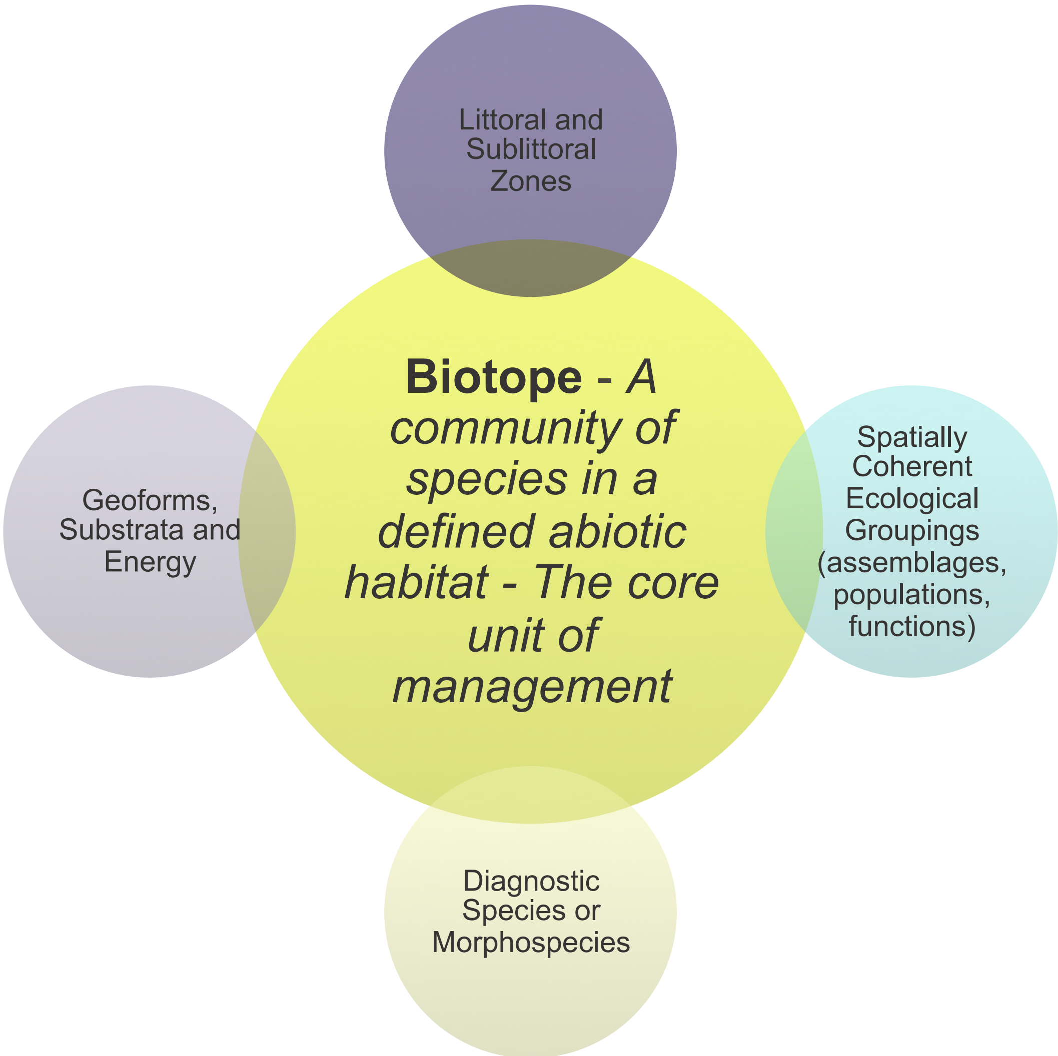



**Figure 5: Elements of a biotope introduced by adoption of CBiCS**

# CBiCS Components

## Biotic Component

The biotic component is the central classification component of CBiCS, comprising six hierarchical levels (Fig. 6). The design of this hierarchy and its core elements are adopted directly from the JNCC scheme that is a proven system for classification. Indeed, with some simple translation, many of the actual classes from the JNCC scheme that are mapped in Europe (e.g., seaweed biotopes, mussel, worm and other biogenic reefs) could be imported directly into the Australian context.

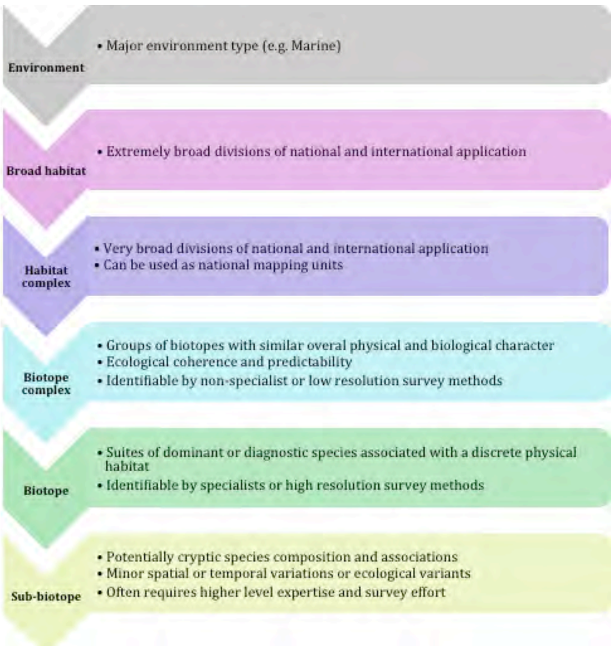



**Figure 6: CBiCS Biotic Component hierarchy**

### Level 1 – Environment

The top level follows the EUNIS separation of major environments such as marine (including estuarine), coastal, inland surface waters, constructed environments and can be expanded to include other classes.

### Level 2 – Broad Habitat

In the marine environment, broad habitats are segregated at this level by habitat zones and substratum type (sediment, coral reef, ice, or rock and other hard substrata). Zones are defined following standard zonation of coastal and marine environments that is known to form high level ecological groupings: littoral, infralittoral, circalittoral, deep-sea bed, and pelagic water column (Fig. 7).

The littoral zone is defined as not being permanently inundated. The supralittoral zone is handled within the coastal environment at Level 1. The infralittoral zone is characterised as being dominated by macroalgae for temperate waters (i.e. the euphotic zone) and temperate circalittoral zone reefs are characterised by sessile invertebrates. The deep-sea bed is defined as being beyond the continental shelf.

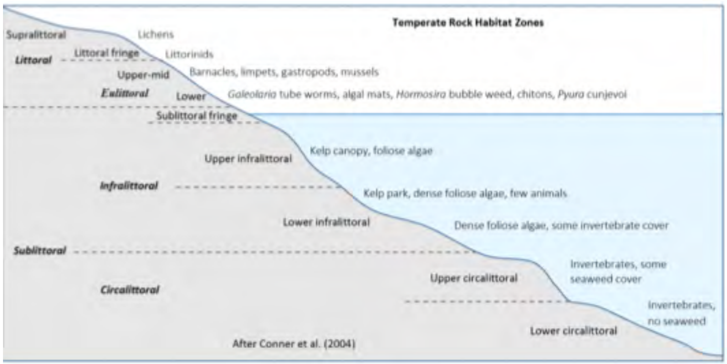



**Figure 7: Broad habitat divisions of the biotic component**

### Level 3 – Habitat Complex

At this level, rock and other hard substrata are segregated on the basis of energy levels and sediments are segregated on the basis of grain size (which is a function of energy).

Rock and other hard substrate is divided into three energy levels: high, moderate and low. These energy levels are demonstrated to have a strong influence on littoral and sublittoral biotopes. For example, distributions of bull kelp (*Durvillea potatorum*) in the lower eulittoral zone and growth forms of common kelp (*Ecklonia radiata*) in sheltered versus exposed reefs (Fig. 8) are dictated by an interaction between energy, substrate type and co-occurring species.

Just as energy regimes dictate biotopes at level 3, biotopes can be informative of energy regimes where they are not known *a-priori*. Classification work in Victoria uncovered nuances between tidal energy and swell or wave energy. For example, at Entrance Canyon, Port Phillip Bay and in some locations in Western Port, strong tidal currents and water mass interactions can create high-energy conditions with biotope characteristic of higher energy systems in areas relatively sheltered from swell waves.

At level 3 of the hierarchy, some regional-scale patterns may emerge that interact with geoforms. For example, intertidal communities associated with high-energy granite in eastern Victoria are fundamentally different to those on high-energy basaltic platforms in central Victoria.

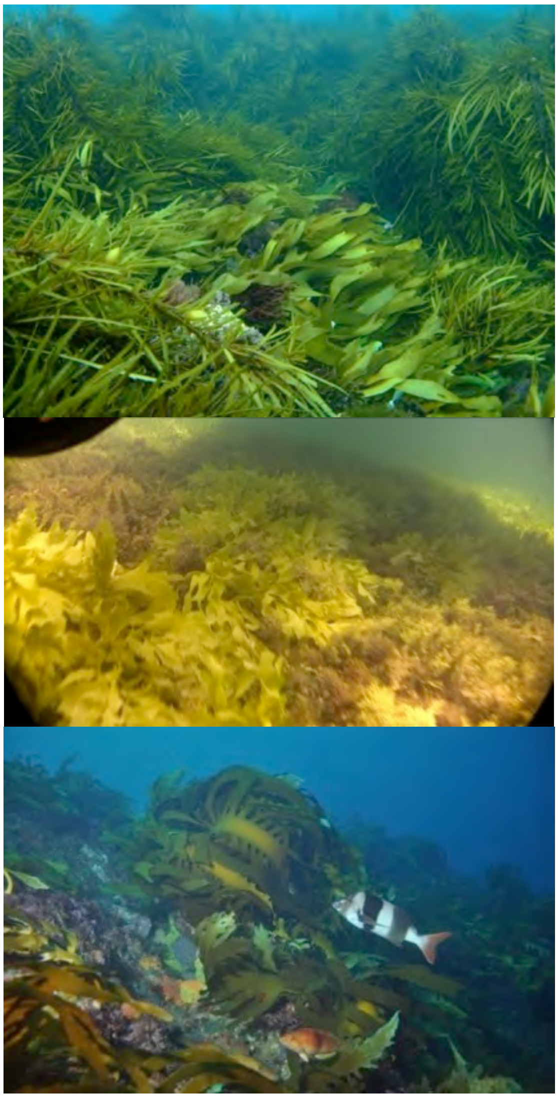


**Figure 8: High energy (top) and low energy (middle) upper infralittoral *Ecklonia* biotopes and high energy lower infralittoral *Ecklonia* biotope (bottom).**

### Level 4 – Biotope Complex

At this level of the hierarchy, biotopes are grouped into sets with similar physical and biological characteristics. This grouping usually has inherent spatial consistency that, along with the preceding levels, can be mapped using modern remote sensing products. This is possible because at the biotope complex level, there is considerable predictability in biological assemblages and abiotic parameters. For example, the biotope complex classes:

- High energy mussel, barnacle and limpet communities on mid to upper eulittoral slope; and
- High energy seaweed, *Pyura* and chiton communities on lower eulittoral slope

These are two fundamentally distinct classes, mappable on the basis of terrain data, with a biological predictability supported by decades of intertidal zonation study. In the JNCC scheme, a biotope complex is defined as being relatively easy to identify by either a non-specialist or by coarser survey methods. CBiCS follows this, but places an emphasis on visible biological characteristics in defining biotope complexes.

### Level 5 – Biotope

Biotopes are segregated on the basis of community composition and/or diagnostic species. Diagnostic species could be those that are dominant or those that are in low abundance but frequently occurring and thus are 'indicative' of a specific biotope (Fig. 9).


**Figure 9: Diagnostic species that are indicative of biotopes. Top - purple pyramid sponge (conical morph of *Spheciospongia purpurea*) indicative of a western Victorian circalittoral reef biotope. Bottom – seaweed *Perithalia caudata* (at bottom centre and upper left) in a diverse algal assemblage is indicative of particular biotopes.**

Detailed observations or quantitative sampling by workers trained in marine species identification is often required to identify biotopes.  For example, the *Phyllospora comosa* seaweed biotope complex (level 4) is segregated into some biotopes on the basis of understorey composition (Fig. 10).  The understorey composition may not be immediately visible from high-altitude imagery, for example, but is intrinsic to community composition and ecosystem function.

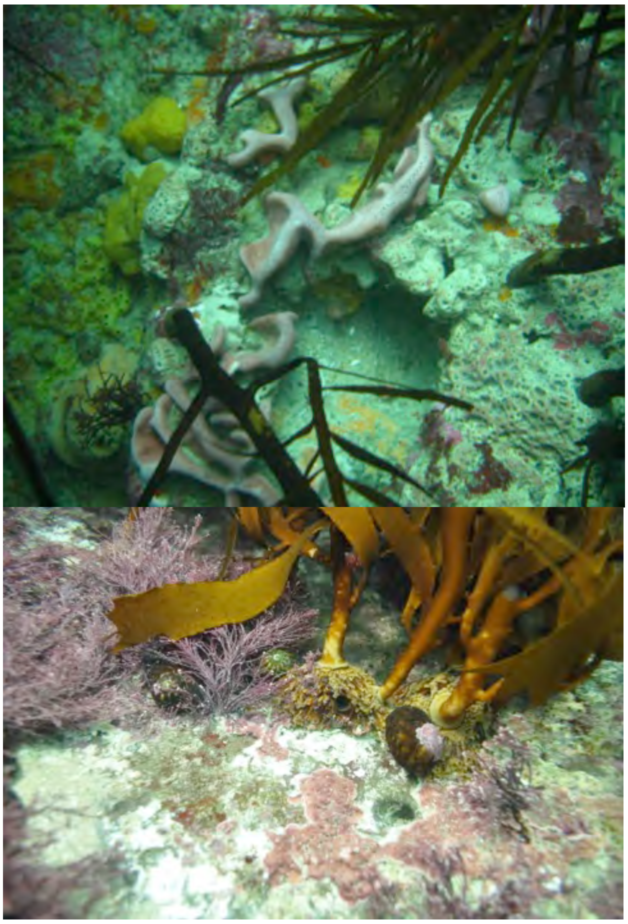


**Figure 10: *Phyllospora* biotopes differentiated on the basis of understory communities comprising: cushion fauna (top) and coralline algae erect and crustal forms (bottom).**

The biological communities of most significance in sediment beds are infaunal (living within the sediment interstices).  Biotope classes can be derived from knowledge of infaunal communities and data from comprehensive historical sampling in Port Phillip Bay, for example, have been used to digitise sediment biotopes.  In the absence of sampling data, there are useful proxies available that are discernable from high resolution acoustics or imagery.  The morphology of burrows, bioturbation and broad scale seabed textures (e.g. sand waves, ripples, hummocks) are indicative of infaunal communities, energy regimes and processes.

At finer resolutions, surficial filaments, mats and films are indicative of microphytobenthos, bacterial activity, tube-dwelling fauna, etc. (Fig. 11).

A range of estuarine and marine sediment beds in estuarine and marine environments have been classified using this method, significantly expanding the ecological information content for this expansive habitat.  CBiCS provides a standard nomenclature for these assignments through the cataloguing system and classification of bioturbation via the morphospecies component.

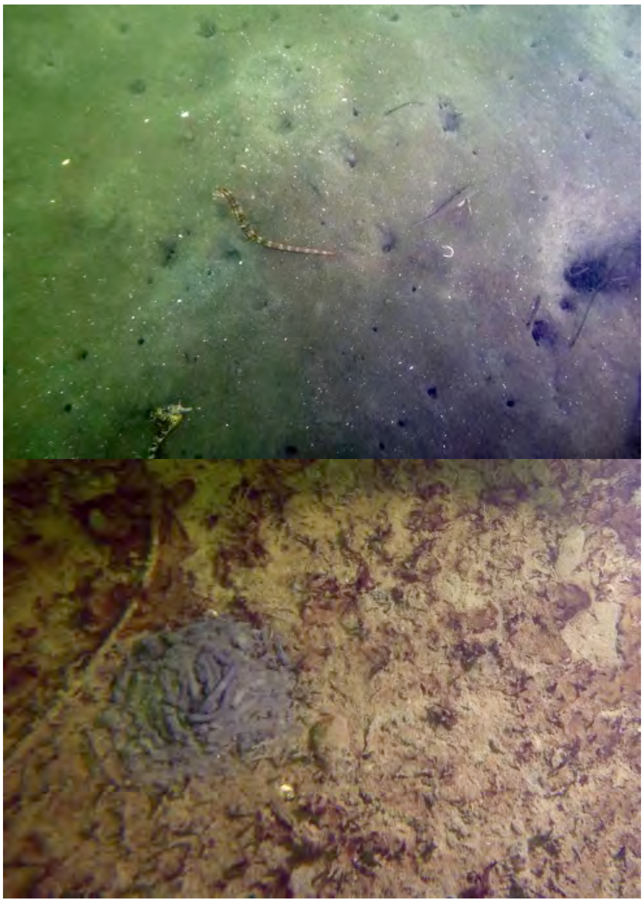


**Figure 11: Sediment biotopes.  Top - funnel burrows (apparently associated with the bridled goby, *Arenigobius bifrenatus,* seen at centre right of image, and co-occurrence of big-belly seahorse *Hippocampus abdominalis*). Bottom – bacterial mats, waste cast and egg mass of infaunal mollusc, seen at top right of image.**

### Level 6 – Sub-biotope

Sub-biotopes are defined by subtle differences in species assemblage structure and geographical, temporal or environmental variants.  Identifying sub-biotopes often requires greater expertise and/or survey effort and may only be apparent after longer-term monitoring, to provide context of observations.

A challenge of biotope and sub-biotope classification, and indeed biotic classification in general, is the need to understand whether the spatial unit in question represents a coherent class or a transitional state between two classes. Again, the ability to ascribe a class may only be possible after detailed study to fully catalogue variants and neighbouring areas.

Some Victorian sub-biotopes are able to be confidently defined on the basis of existing knowledge, and others are assumed pending further analysis (Fig. 12).

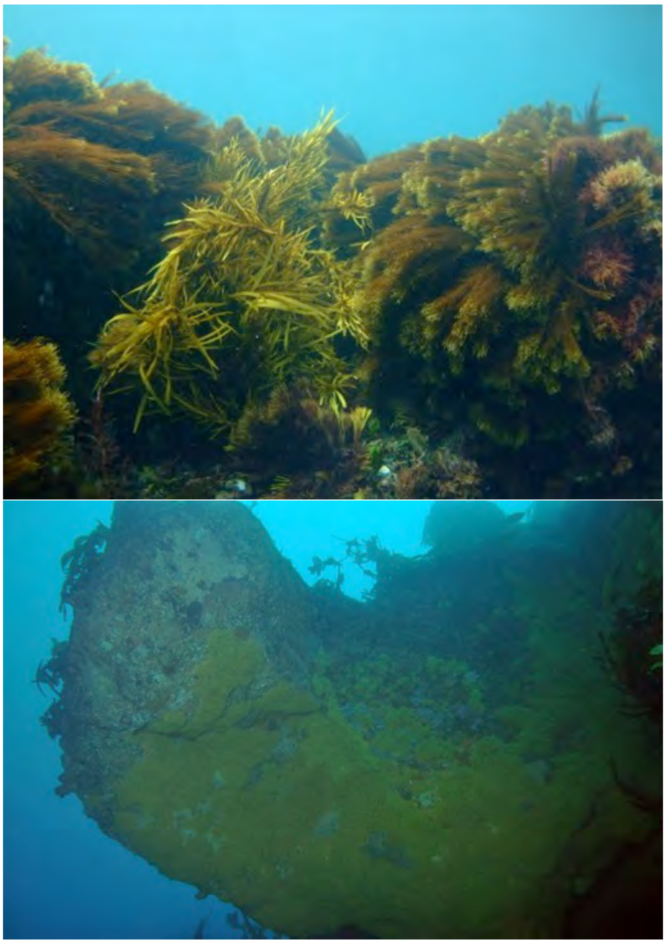


**Figure 12: Sub-biotopes. Top – The occurrence of *Perithalia* as a dominant component of the sub-canopy within a *Phyllospora* biotope is a distinguishing feature of this sub-biotope. Bottom – Yellow zooanthid community on the underside of a ledge, typical of distinct communities that can occur associated with ledge-edge and other fine-scale geoforms, may represent valid sub-biotopes.**

### Key Lessons from Biotope Classification

Over 450 marine biotopes have been described and catalogued in Victorian waters to date through a process of data-driven and qualitative assessments.

A challenge of biotope classification, and indeed all classification efforts, is the need to understand the full range that exists before ascribing classes and gauging the significance of variants (Fig.13). This is particularly true when embarking on studies in new environments.

The implementation of biotope classification in Victoria and elsewhere has highlighted the importance of having ecologists with taxonomic expertise actively engaged in classification and mapping.

A perennial challenge of ground-truthing is dealing with transitional zones. Modern remote-sensing tools that provide base maps to inform the design of ground-truthing surveys will assist by providing *a-priori* and iterative segmentation. Ground-truthing surveys can then target elucidation of within-segment biotopes with some information about likely transition zones.

**Figure 13: Seagrasses with hard corals and sponges on a tropical coral reef. Classification of this biotope as a spatially and ecologically coherent unit was only possible with knowledge of surrounding biotopes and transitions**

Another perennial challenge to classification is that of converging on a well calibrated and consistently applied level of 'splitting' and 'lumping' of the types observed. Testing in Victoria has confirmed that the structure of the CBiCS biotic component is calibrated to ecologically functional types – evidenced by successful application across disparate data sources. Importantly, the classifications are auditable and well documented to foster a process of quality assurance and the system is structured so as to allow for corrections with improved knowledge.

The Victorian biotope classification process has found that a lack of detailed knowledge about ecosystem functioning of biotopes does not hinder the assignment of discernable types into separate biotopes or sub-biotopes, in accordance with the rules of classification associated with those levels and the resolution of the data available.  Biotope classes are devised on the basis of visually or acoustically distinct features, with due consideration to the appropriate ecological knowledge about the *likely* functional characteristics of a biotope (e.g. understorey fauna likely being significant differentiating factor seaweed community types) in preference to over-simplifying the classification for convenience.

Testing in the Victorian context has shown that these types of visually apparent structural differences often represent ecologically significant biotope and sub-biotope ‘splits’ when compared with available quantitative data.

Testing has also confirmed that descriptors of biotope splits should not rely on subjective ‘line calls’.  Such classifications can adversely affect training data sets being used for biotope mapping and prediction. Advancements in computer vision and machine learning aid in the quantification of potentially subtle distinctions, bringing the resolution of the biotic classes in-line with the high resolution of spatial positioning and abiotic data acquisition.

The CBiCS Categories component was also developed to provide a standardised set of labels and descriptors for annotating biotopes and morphospecies, as well as descriptors contextualising data sets.

The CBiCS guidance documentation (see Further Reading below) offers additional tips for biotope classification based on the lessons of the Victorian classification process.

## Biogeographic Setting Component

Application of CBiCS required reorganisation of existing Australian bioregional divisions that were not nested consistently within international schema. CBiCS directly adopted the three levels of the Marine Ecoregions of the World (MEOW) for coastal and shelf areas (Spalding et al. 2007) as the upper three levels of the biogeographic setting hierarchy (Fig. 14).

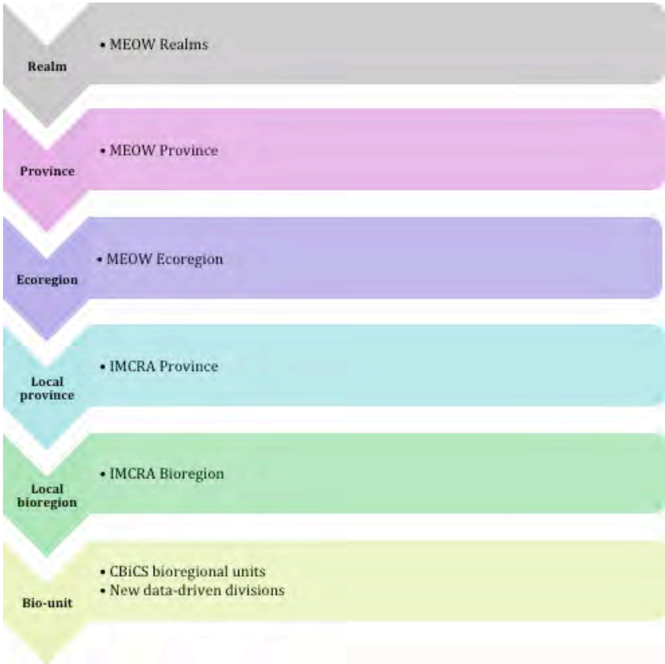



**Figure 14: CBiCS Biogeographic Setting hierarchy.**

The Australian Integrated Marine and Coastal Regionalisation of Australia (IMCRA) has two levels: IMCRA Provinces and IMCRA Meso-scale Bioregions. IMCRA provinces are at a similar scale to MEOW ecoregions, but the former does not nest within or align with the latter. IMCRA bioregions similarly do not conveniently nest within IMCRA provinces or MEOW regions at any level.

In lieu of a complete reanalysis of the Australian bioregionalisation, the CBiCS Biogeographic Setting component placed the two IMCRA categories below the MEOW divisions. While the spatial alignments are not optimal, this organisation allows the global and Australian context to be captured in the one hierarchy.

CBiCS introduces a new bioregional division at Level 6 of the hierarchy, termed 'bio-unit'. CBiCS bio-units delineate areas within bioregions that have distinctive ecophysical properties. Natural resource agencies or state departments often compartmentalise areas that represent socio-ecological units at the scale of 1–10s of kilometres (e.g. Port Phillip Bay, Western Port, Gippsland Lakes, Nooramunga in Victoria). These management areas are linked with new data-driven regionalisations erected by CBiCS on the basis of biotope analysis.

Figure 15 shows an example of new bio-units established for Victoria nested within higher levels.

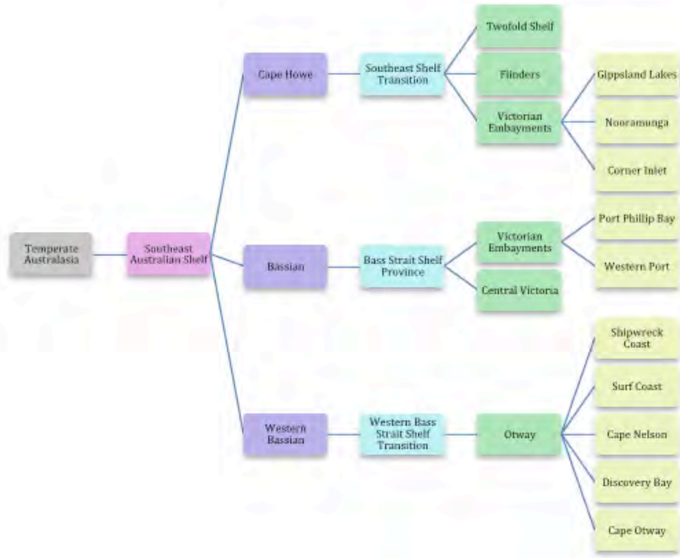



**Figure 15: Example of Bioregional Setting classification and CBiCS bio-unit classes (Level 6).**

## Aquatic Setting Component

Aquatic Setting provides a high level context of the aquatic environment, freshwater influence and depth band of the habitats and biotopes of interest. CBiCS directly adopts the Aquatic Setting component of the CMECS scheme which has three levels (Fig. 16).

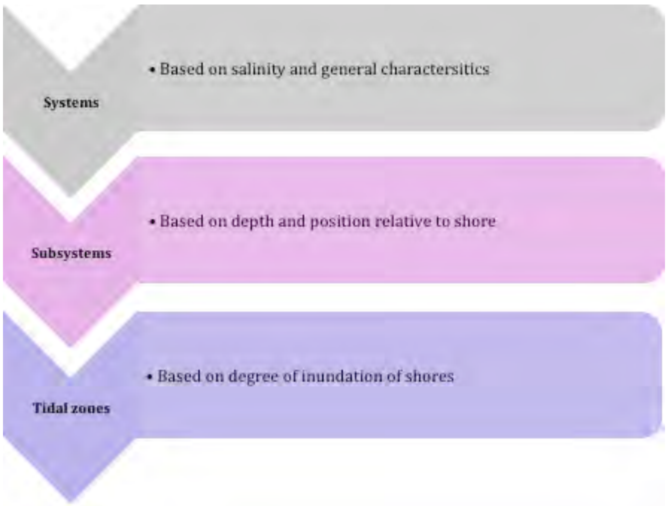



**Figure 16: CBiCS Aquatic Setting hierarchy (following CMECS).**

The significance of Aquatic Settings in driving spatial patterns of biological communities is well established. The primary purposes of Aquatic Setting is to provide a context or grouping of studies or data into high level groups.

CMECS defines estuaries as "waters with an open surface connection to the sea". For CBiCS, the term estuary was modified to include coastal lagoons that can be closed from the sea for periods of time. This aligns CBiCS with estuarine environments found in temperate Australia and also aligns more closely to existing estuary mapping and classification (e.g. Heap et al. 2001).

CMECS distinguishes between open water and coastal estuarine as a water depth greater than 4 m. For CBiCS, this limit was modified to 6 m depth to align with the international Ramsar wetland boundaries that are a common mapping requirement.

For CBiCS, the 30 m depth contour is used to distinguish the nearshore marine subsystem from the offshore subsystem, following CMECS. This somewhat arbitrary division practically convenient for providing large-scale habitat contexts. It is recognised that this depth contour can occur close to shore in some areas, and in these circumstances can conveniently represent the energy regimes in the littoral, supralittoral and sublittoral zones. For example, where a 30 m contour occurs in close proximity to shore, the shoreline environment will likely be exposed to high energy regimes and the neighbouring intertidal and terrestrial environment is likely to consist of cliff, bluff, boulder, platform type geoforms.

The Aquatic Setting hierarchy encompasses the littoral and sublittoral zonation terminology (Fig. 17).

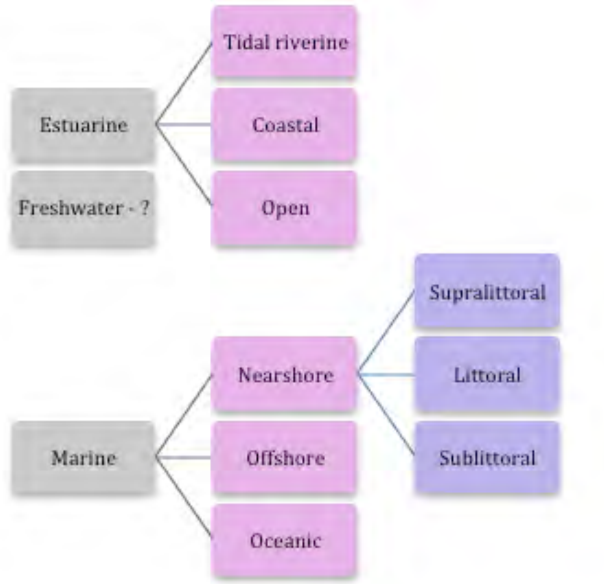



**Figure 17: Aquatic Setting classification**

It should be noted that a depth contour alone does not directly relate to the differentiation of the infralittoral zone from the circalittoral zone in the biotic component. For the biotic component, CBiCS conforms to the EUNIS/JNCC categorisation of infralittoral and circalittoral zones which is based on the depth of the euphotic zone and thus community types. The depth of the boundary between infralittoral and circalittoral zones varies considerably between locations and is can be shallower or deeper than 30 m. Therefore, while a depth of 30 m does approximate the coastal euphotic zone in temperate Australia, demarcating real biotic zones, for example from seaweed infralittoral to invertebrate circalittoral biotopes, requires biological data.

## Water Column Component

The water column component provides a classification of water column physicochemical properties, layers and structural forms, termed hydroforms (Fig. 18). The water column component follows the CMECS descriptors with some additions to provide compatibility with the water column classes of the JNCC scheme, adding a placeholder for light climate classes.

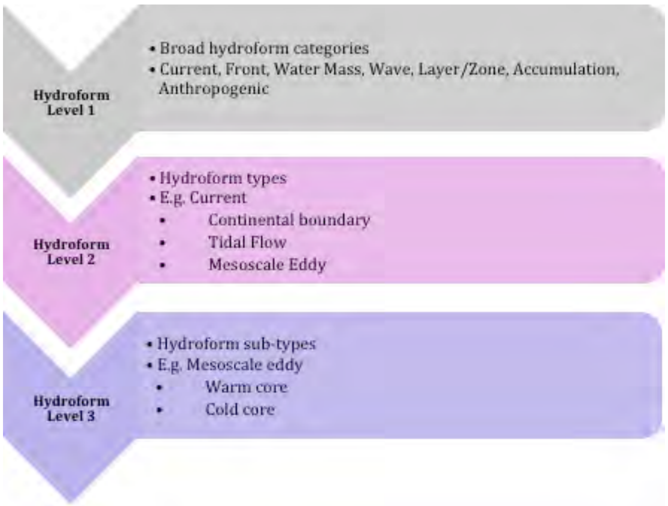



**Figure 18: CBiCS Water Column Component hierarchy.**

Classification of the water column features within CBiCS follows the following principles:

1. Water column components link with biotic component classes in ecologically meaningful ways (e.g. energy levels for defining different infralittoral rock biotopes);
2. Hydroform classes are hierarchically nested according to the type and scale of the hydroform structure; and
3. Classes are relevant to describing biotopes by using both physicochemical properties and environmental processes that are known to drive biological assemblage distributions.

The water column is also classified using the following parameters additional to the hydroform, including:

- Water column layer (Fig. 19);
- Depth band;
- Current regime;
- Wave and tidal energy level;
- Temperature regime;
- Salinity regime;
- Light climate;
- Other biogeochemical features (where known).

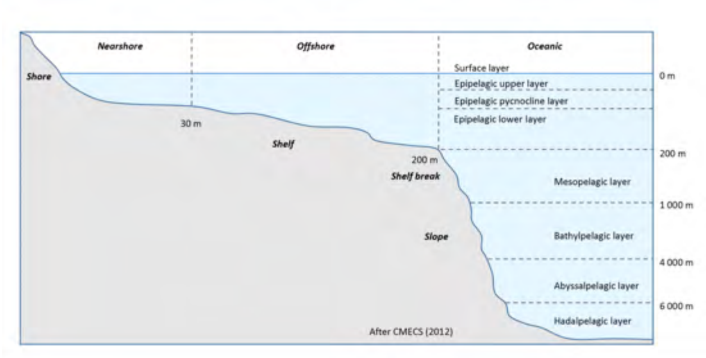



**Figure 19: Divisions of the water column used in CBiCS, adopted from CMECS.**

The hydroform classes are arranged in a hierarchical structure with respect to spatial and temporal scales of formation, as per CMECS. However, there is further work required to develop a standardised description of hydroforms and the biogeochemical habitat features of the water column as they related to biological communities. For example, neither CMECS nor JNCC directly classifies the light climate, which is particularly relevant to biotopes. The light climate is influenced by several factors, including local resuspension of sediments, terrestrial inputs of turbid water, plankton blooms and shading by shoreline topography and structures.

## Geoform Component

The Geoform Component provides a hierarchical multi-scale classification of seabed and coastal morphology (Fig. 20).

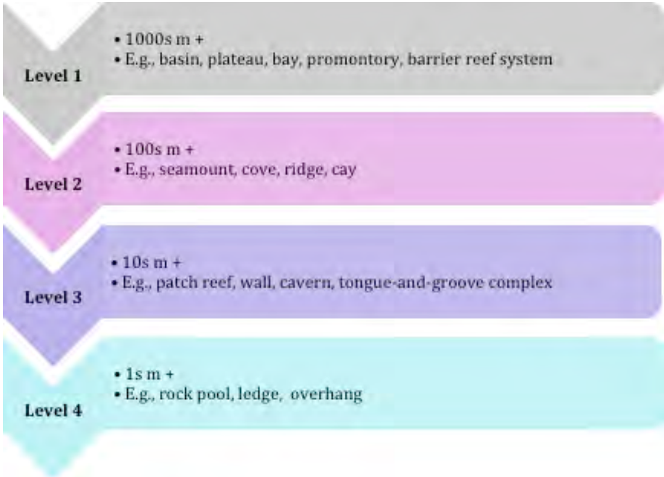



**Figure 20: CBiCS Geoform component hierarchy.**

The CBiCS Geoform component is based on a merger of CMECS and JNCC parameters, with adaptations to maintain the linkage between geoforms and predictability of biotopes. CBiCS extends the physiographic setting of CMECS to include common seascape and landscape classes and complexes of geoforms that do not fit within the geoform hierarchy and are well above the spatial scale of biotopes, such as atolls, deltas, canyons, continental shelfs, seamounts and other large scale features.

Benthic biotopes are highly influenced by geoforms. Geoforms vary in nature according to the composition of geoform structural elements, such as ridges, hollows, slopes, scarps, outcrops etc. Each geoform element influences biota according to the nature of vertical and horizontal faces for attachment, influences on water movements and turbulence and the provision of interstitial spaces, such as crevices or boulder junctions (Fig. 21).

CMECS provides a systematic classification of geoforms that is based on two relative size scales. It also provides classes for tectonic setting, physiographic setting and geoform origin. The JNCC scheme also incorporates geoform classes in the upper levels of the biotic hierarchy. For example, 'rock cliffs, ledges and shores' are separated from unconsolidated coastal geoforms at a high level. The CBiCS Geoform component draws these two approaches together. The CMECS parameters are represented directly within CBiCS, with the exception that larger scale geoforms described in CMECS were moved out of the geoform hierarchy. The upper levels of the CBiCS geoform hierarchy replicate that of the upper levels of the biotic component (and the JNCC scheme). Classes within the lower levels of the geoform hierarchy were defined and calibrated in accordance with equivalent levels in the biotic component.

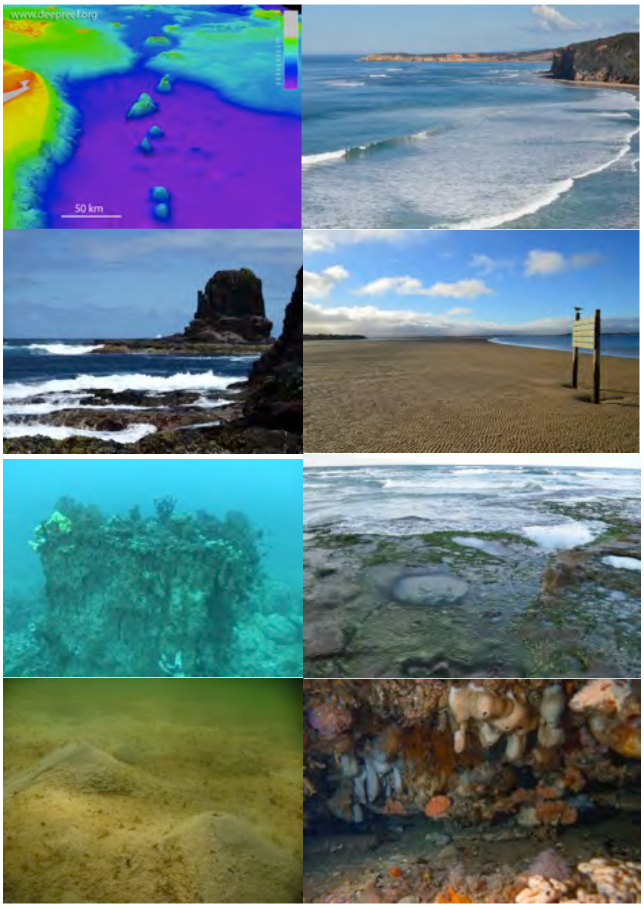



**Figure 21: Examples of the scales at which geoforms are applied in CBiCS at levels 1 to 4 (from top panel to bottom panel).**

The CBiCS Geoform component has incorporated a standardised terminology for coral reef structures. There was no equivalent terminology for temperate reef structures and CBiCS initiated a system for classifying reef geoform classes that relate to biotopes. CBiCS also developed a consistent methodology for describing sediment geoforms using a scalar approach.

Geomorphological descriptors that provide general habitat context, such as origin, physiographic setting and tectonic setting (as per CMECS) are not part of the geoform hierarchy, but are provided in the Category component of CBiCS.

The fundamental concept of the application of the CBiCS Geoform component is summarised as follows:

- Just as a biotope is composed of a particular assemblage of taxa, so a particular geoform at a particular level is composed of an ‘assemblage’ of geoform elements at lower levels.
- Geoform elements at the most resolved levels are comprised of combinations of faces and textures (e.g. horizontal reef tops, vertical faces, ledge undercuts).
- Just like large geoforms at the 1000s m scale, geoform elements at the most resolved level, (i.e. meter scale), can be interpreted or measured using remote sensing (e.g., terrain from UAV imagery on an intertidal reef platform, scanning sonar from an ROV on a reef wall). Similar to the concept applied to biotopes of minimising subjectivity by using information content inherent in imagery, such geoform measures can be quantitatively applied into the future.

The CBiCS Geoform component allows for the adoption of existing classifications of large-scale geoforms. There are circumstances when integrating project- or region-specific names at the lower levels of the hierarchy can be useful. Descriptive names are indeed available for some features of national importance (e.g. seamounts and ‘reefs’ are often named) and this aids in communication (Fig. 22).

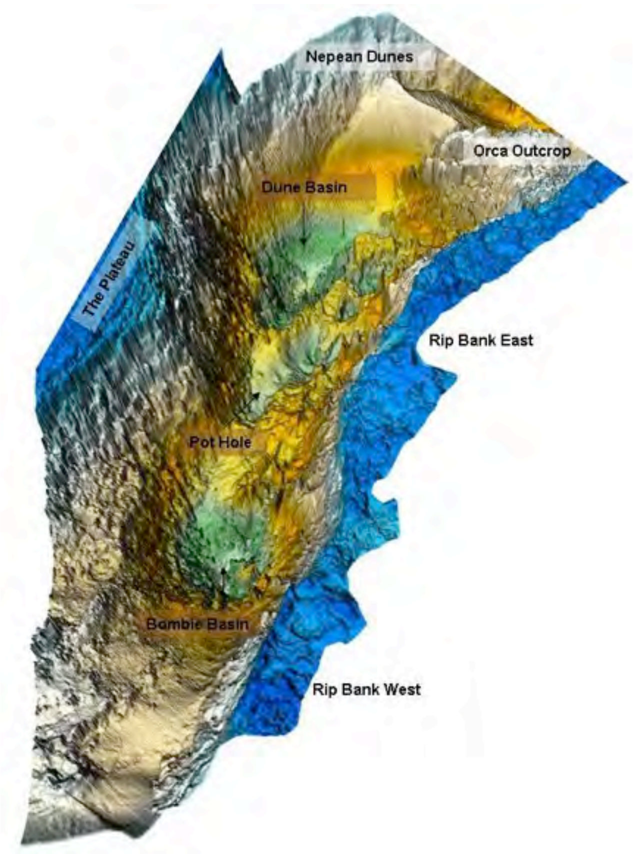



**Figure 22: Examples of locally relevant names associated with geoforms in The Entrance Canyon, Port Phillip Bay that are applicable at levels 1–3.**

## Substrate Component

The CBiCS Substrate component provides a classification of the physical composition of seafloor. Substrate type is a key factor controlling benthic community composition. The CBiCS Substrate component is based on the CMECS scheme, with two important modifications (Fig. 23):

1. Substrate origin (the entry point to CMECS) is removed from the CBiCS hierarchy because in practice substrate origin (e.g. geological versus biologic) is often difficult to determine from imagery; and
2. Substrate hardness is added to the top level of the hierarchy, dividing soft sediments and hard substrata and is aligned with the biotic component hierarchy. Note that hard substrates comprise both consolidated and unconsolidated (e.g. cobble beds) substrates. However, soft substrates can only be unconsolidated.

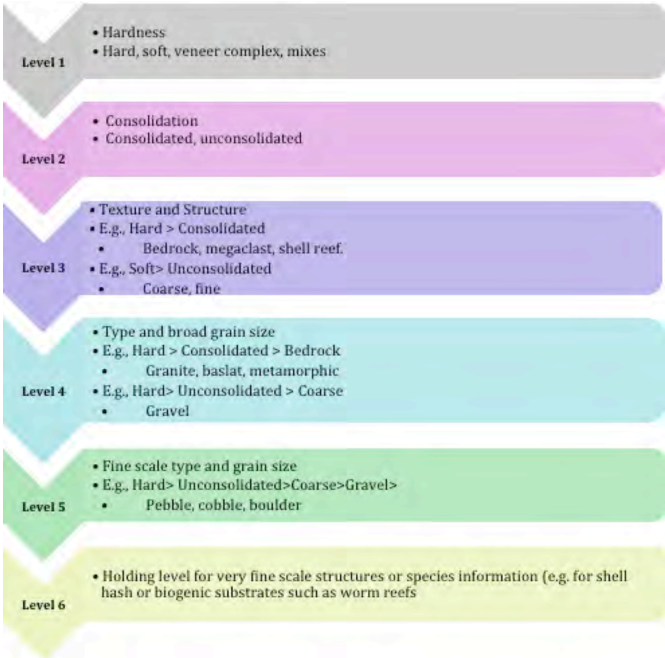



**Figure 23: CBiCS Substrate Component hierarchy.**

Similar to the geoform hierarchy, the six-level substrate classification hierarchy can be envisaged as levels of increasing 'resolution'. Available substrate classifications typically rely on descriptors of grain sizes that are often difficult to apply in practice using data from acoustic and optical sensors. However, these descriptors are standardised and have a long history of usage and therefore should not be replaced with new definitions without valid reason, regardless of their unfamiliarity to ecologists. For example, the term 'gravel' applies to sediments where > 80 % of grains are in the size range of 2 mm to ~4 m. Benthic ecologists previously may not have envisaged grains as small as 2 mm and rocks up to 4 m in size as residing in a 'gravel' parent class. However, there is a need to apply standard geological classifications rather than developing other classes that potentially orphan historical data from new analyses, hence the adoption of CMECS classes in CBiCS.

Familiarisation is required to operationalise the CBiCS substrate definitions, which themselves are adopted from CMECS. The definitions have a grain size component and relative dominance component, leading to classes such as 'shelly sand' (sand is dominant) as opposed to 'sandy shell' (shell is dominant). Classification projects should define what levels of the hierarchy can be expected to reliably classified given the parameters of image or acoustic acuity and observer skill levels.

Hardness is measurable from acoustics and provides a key high-level split that is directly linked to biota (Kloser et al. 2001, Kloser 2007) (Fig. 24). Hardness can be quantitative where data exist, or qualitative. Multibeam acoustic surveys are data rich and often the first indications of seabed habitat in new areas, particularly in the deep sea. As the national coverage of multibeam acoustics is expanded, and the tools for the analysis of backscatter improve, CBiCS recognises the potential value of this large data source to assist (and automate) classification of large areas.

The stability of unconsolidated substrates is dependent on the level of packing and bedding, disturbance levels from wave and currents and stabilisation or destabilisation of attached biota. Consequently, coarse sediments such as boulder, cobble and pebble can be classified within 'hard' substrata where they provide stable surfaces of biological attachment or be classified within 'soft' substrata where they are mobile and unconsolidated. Unconsolidated hard substrata include beds of coarse grains, such as boulders, cobble, pebble, shell rubble, shell hash and woody debris. These unconsolidated substrates tend to have strong acoustic reflectivity and often appear hard in acoustic surveys (Fig. 25). Biogenic hard substrate includes coral reefs, shell reefs and worm reefs. Anthropogenic hard substrates include materials of rock (rip rap), wood (e.g. piling, decking), concrete (such as in breakwalls) and metal (e.g. sheet piling). Wrecks, including ships, planes and other vehicles, are listed as a separate substratum class as they are comprised of multiple types of materials and usually occur as discrete mapped entities.

A key challenge to substrate classification is presented by sand-inundated hard substrata (i.e. 'soft' veneer over 'hard' substrate) (see Fig. 25) and patchy hard and soft substrates. CBiCS includes a 'veneer substratum' to classify and map complexes of hard substrata with soft sediment veneer, such as pavement reef and rhodolith beds that have a veneer of soft sediments. Similarly, the geoform component includes matching veneer reef categories. Multiple lines of evidence are required to identify this class, such as repeated observations over time, sub-bottom acoustic echograms and the presence of indicative species such as erect sessile invertebrates that attach to hard substrata but are protruding through soft sediments.

**Figure 24: Hard, consolidated substrates of different composition in different environments.**

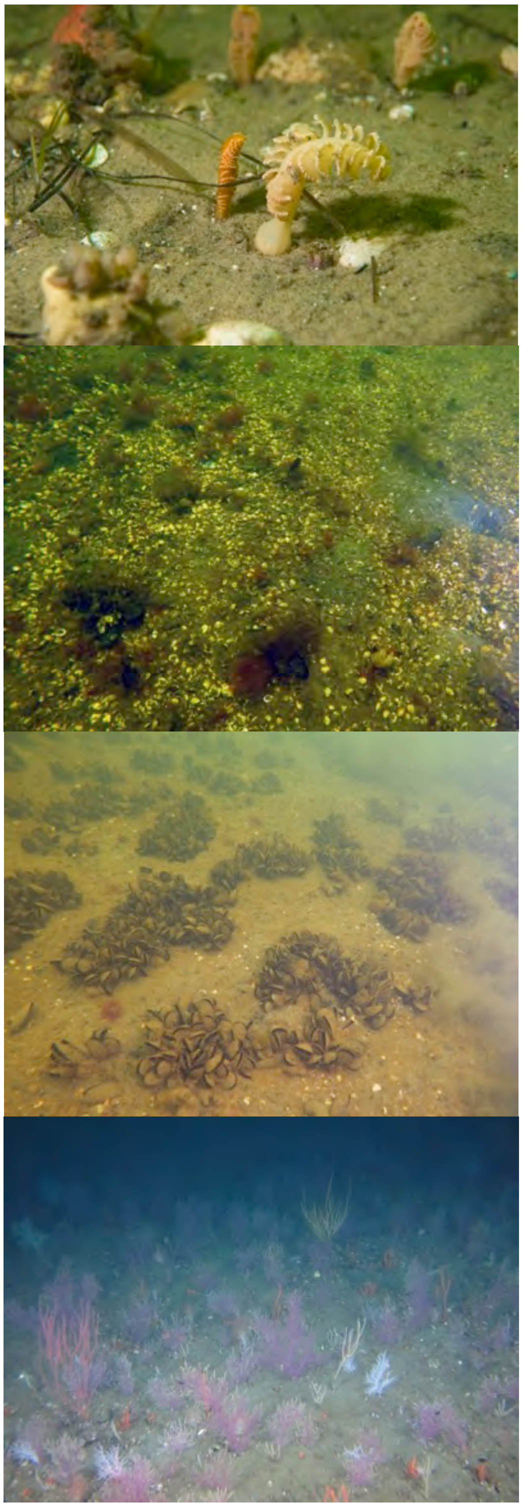


**Figure 25: Unconsolidated substrates of varying degrees of 'hardness'. Repeated remote sensing indicators such as acoustic reflectance and texture and sampling may be required to standardise classification.**

## Morphospecies Component

The mapping and monitoring of marine biotopes relies heavily on the use of visual observation and imaging techniques. The CBiCS Morphospecies component provides a scheme for the systematic classification of biological types. The use of morphospecies classification is particularly important where:

- the species cannot be identified confidently from imagery;
- organisms do not have taxonomic descriptions, particularly sessile invertebrates;
- there are ecologically important variants or morphs of a species, such as the kelp *Macrocystis* as overstorey and sub-canopy forms; and/or
- assemblages or biotopes are compared where there is no overlap in species – relatedness is provided through the morphospecies hierarchy.

The CBiCS morphospecies classification hierarchy (Fig. 26) is comprehensive, covering terrestrial plants through to all marine groups. The hierarchy is predominantly based biogenic structural and visual characteristics.

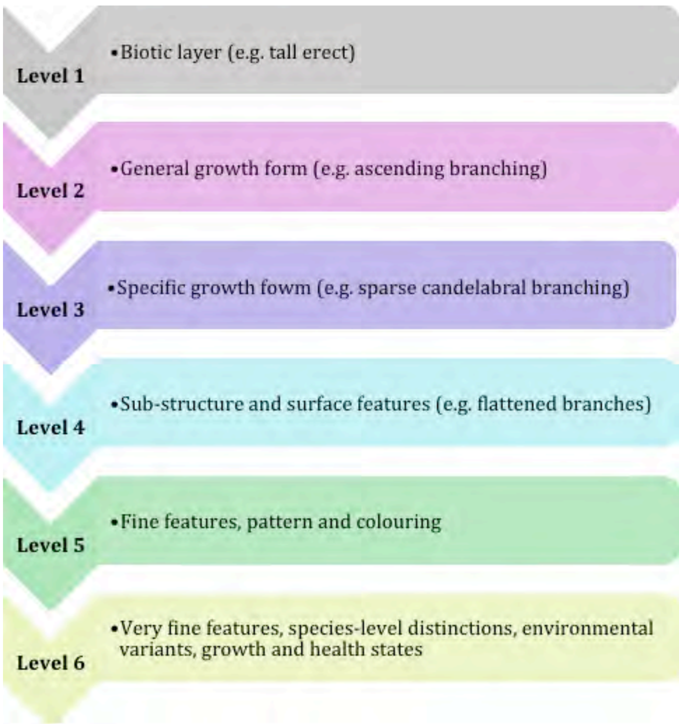



**Figure 26: CBiCS Morphospecies Component hierarchy.**

The CBiCS morphospecies classification scheme is structured around the concept of biotic layers or strata. This concept, borrowed from the established scheme of classifying terrestrial vegetation, is applicable to benthic species. The morphospecies component was designed to meet the following objectives:

- Standardised structure with universal application, from coastal vegetation and salt marshes to the deep sea, incorporating existing schema where appropriate (Fig. 27).
- Resolve organisms to near-species level to provide an adequate representation of biodiversity for monitoring.
- Include health and growth states, such as observations of diseased or damaged individuals and different structural forms of a species, such as sub-canopy, canopy and overstorey formations by *Macrocystis* kelp.
- Based primarily on visually-determined features but extensible to 3D structure properties (and not reliant on taxonomy at the upper levels).
- Strictly hierarchical in structure with nesting of subordinate morphological features.
- Hierarchical levels balanced across taxon groups.
- Hierarchical levels and classes structured in accordance with the biotic component with classes that reflect implicit ecosystem features and functional properties.
- Hierarchy tuned to levels of image acuity (e.g., sensor type, quality, lighting and resolution).
- Hierarchy calibrated to levels of observer capability, experience and expertise, ranging from citizen scientists, novice scientists to expert biologists.
- Facilitate machine learning and automated image processing.
- Include both sessile forms that generally describe biotopes and mobile forms occurring long term monitoring datasets.

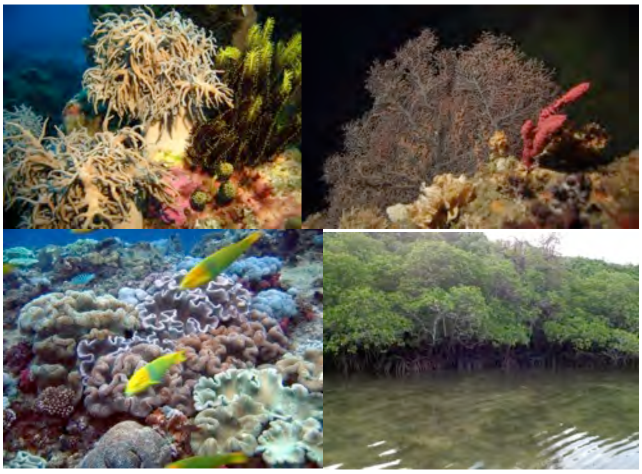


Figure 27: Example of the range of marine and coastal biota encompassed in the morphospecies classification scheme.

### Level 1 – Biotic Layer

At Level 1 of the morphospecies hierarchy, the nomenclature borrowed from terrestrial vegetative strata conveniently organises benthic species into structural classes that are easily interpretable from acoustic and optical data and that have immediate functional significance (Fig. 28). The suite of Level 1 biotic layers is shown in Table 4.

### Levels 2 and 3 – Growth Forms

The primary growth form classes for coastal and littoral biota follows standard botanical classes, such as tree, shrub, sub-shrub, fern, tussock grass, forb, etc. Secondary growth form characteristics include aspects such as branching habit, for example prostrate, decumbent and erect branching of ground layer vegetation.

Sessile invertebrates have diverse growth forms. Seabed erect examples include branching, globose, flabellate, palmate, tubular, cup-like and whip-like forms.  Growth form classes applied to particular taxa as appropriate and include cushion fauna (sponges and colonial ascidians), mesh fans (hydroids, gorgonians and sponges) and branching colonies (gorgonians and sponges).

Large brown seaweeds are divided into growth forms according to the nature of fronds, stipes and stems. Seabed erect thallose seaweeds are an exception in that they are first divided into colour groups, i.e. red, green and brown thallose algae, as these have implicit ecological values and align well with biotope distinctions.  The growth forms within thallose seaweeds include flat branching, filiform branching, filamentous, sheet-like, foliose and saccate forms.

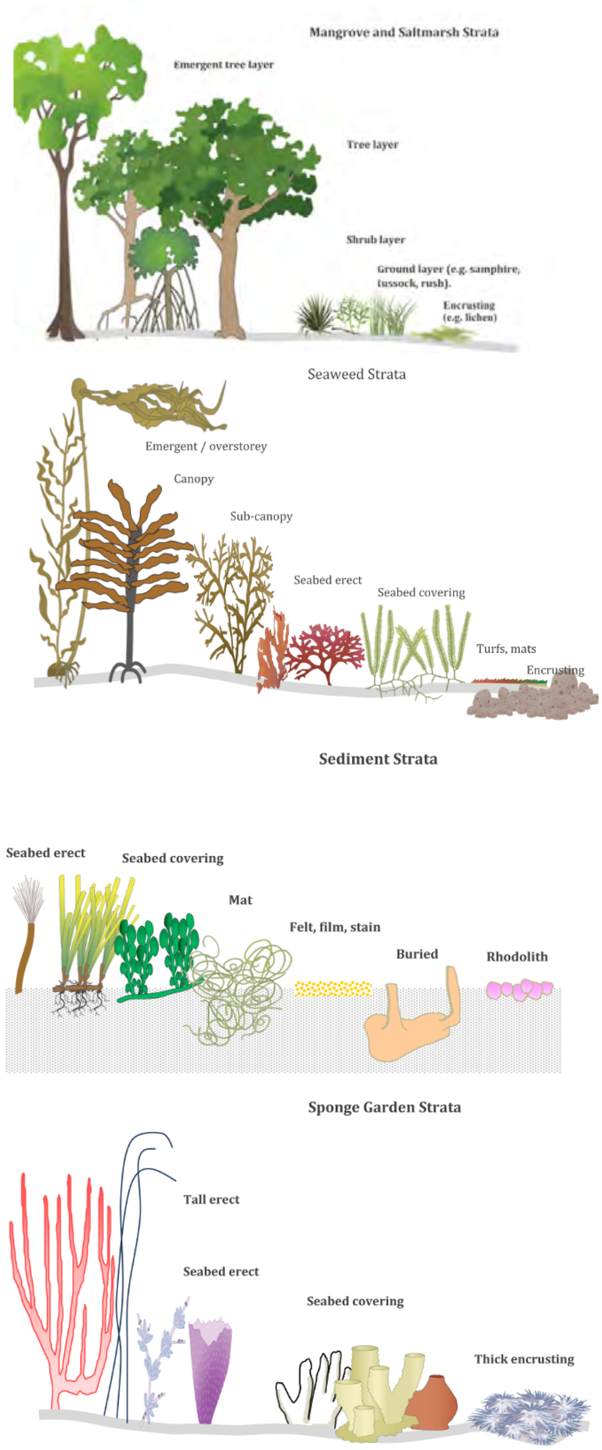



Figure 28: Examples of biotic layer classes at Level 1 of the CBiCS morphospecies hierarchy, a concept adopted from the terrestrial classification field and applied to the marine environment.

**Table 4: Level 1 biotic layers of the CBiCS Morphospecies component**

| Level 1 class | Description |
|---|---|
| **Coastal and littoral zone** | |
| Tree layer | Canopy layer formed by vegetation with the growth forms of trees, mallee trees and palms |
| Shrub layer | Middle or low canopy layer formed by shrubs, palms, grass trees etc. |
| Ground layer | Plants with vertical structures but limited in height and without forming a canopy layer above the substratum |
| Encrusting layer | Forms with little to no vertical structure, such as lichens, in the littoral and supralittoral zones in particular |
| **Marine environment** | |
| Overstorey | Vegetation, predominantly seaweeds, extending into a substantial portion of the water column and potentially to the surface |
| Canopy | Vegetation forming a layer at some height above the seabed, typically with open areas between the stipes and holdfasts beneath the canopy |
| Sub-canopy | Vegetation forming a partial or full canopy at or close to the seabed, substantial crowding of stipes and branches beneath the canopy |
| Seabed erect | Erect plants and animals, living close to the seabed with growth predominantly into the vertical plane, often with a distinct attachment point such as a holdfast |
| Sub-erect small | Small sessile biota, <10 cm, occurring in small clumps or patches that have one or multiple attachment points and erect, semi-erect, rhizomatous, tufting or prostrate growth habit |
| Seabed covering | Spreading or covering biota living close to the seabed with some vertical structure but base dimensions larger than the height – growth predominantly horizontal rather than vertical |
| Turf | Dense to tightly compacted thalli forming a low covering of the substratum with a homogenous appearance |
| | |
| Encrusting | Thin sheet-like structures following the contours of seabed. May have minor surface textural structures but no significant vertical mass, generally less than 5 mm |
| Mat | Multi-layered and/or inter-woven biota forming a cohesive layer. Includes microbial mats and drift algal mats |
| Felt | Microalgal or bacterial-derived fine layer of floc and gel with felt or velvety texture |
| Film/stain | Thin film or layer, sometimes pigmented, with smooth texture and translucent to transparent. |
| Buried | Present within sediments with indicative features apparent at the surface, such as fistula, papillae or tentacles |
| Benthic free-living | Animals that are free living or as individually recognisable non-colonial sessile animals on the seabed |
| Water column | Free living biota in the water column, including plankton and nekton |
| Sea surface | Free living or drifting biota at or on the sea surface |

### Levels 4 to 6 – Finer Level Features

Finer features used for morphospecies identification include finer-level branching characteristics, leaf or frond characteristics such as shape and edge features, surface sculpturing and texturing and colour, hue and patterning.

The CBiCS Morphospecies component was designed after a thorough review of existing terminologies used to described growth forms, structures and textures. This process standardised existing authoritative terminologies in preference to developing new project- or jurisdiction-specific terms for convenience. Terminology exists to describe growth forms and structures of trees and shrubs, sponges, hard coral, gorgonians (Fig. 29) and kelp. Where existing terminology did not exist, CBiCS provides a thesaurus for objectively describing new forms.

The terminology in some cases may differ from some current usage, particularly at the finer structural levels. For example, CBiCS makes specific distinctions between the terms branching, arborescent bushy and foliose, in line with authoritative precedence. Like all new efforts to standardise practices, training, continual improvement and quality assurance are considered important. To aid in uptake, CBiCS has placed a high priority on development of a catalogue populated with good quality images, providing users with a guide that is also georeferenced.

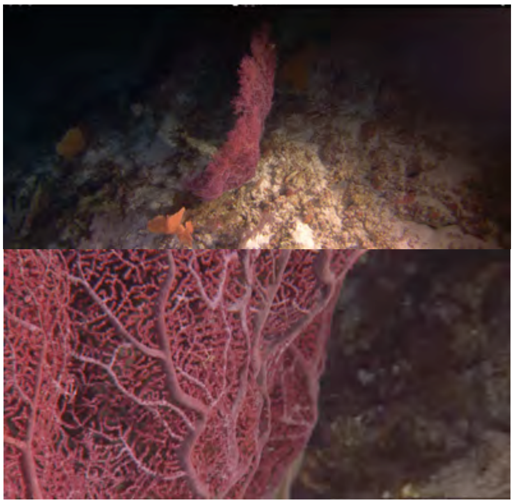


**Figure 29: Example of increasing structural information of a gorgonian fan from top, where growth form (Levels 1-3) can be distinguished, to bottom, where finer level features (Levels 4-6) can be classified.**

There are over 6300 morphospecies classified in the CBiCS scheme. Users are encouraged to study the hierarchy and catalogue. Working through illustrated examples, progressing systematically through a biotic layer group is the most useful way for users to orientate (Fig. 30). As part of the roll-out of CBiCS, additional materials such as guidance documentation and training courses will be held.

A key feature of the CBiCS morphospecies scheme is the resolution of taxonomic species at Level 6 of the hierarchy, where taxonomic species are known. In other words, the hierarchy was developed from an extensive library of taxonomic species, underwater imagery and taxonomic guides. Species known to occur throughout Australia were sorted into the hierarchy from the bottom-up, providing a form of testing and ground-truthing of the hierarchy as a whole. Therefore, there is confidence that many species encountered by users has a valid position in the classification structure, providing a robust comparative framework for the classification of unknown taxa.


**Figure 30: Classification of *Jania rosea*. This is an illustration of the morphospecies hierarchy resolving to taxonomic species level.**

## CBiCS Implementation

Users can implement morphospecies classification in various ways, tuned to the resolution of the input data, skill levels and project objectives. The core principles of the CBiCS implementation are:

- When working in new areas, where no previous data exist, the frequency distribution of morphospecies is used to build a biotope classification;
- Biodiversity is quantifiable in the absence of formal taxonomy;
- Citizen science interacts with the classification at pre-planned levels of the hierarchy;
- The information requirements for thorough classification guide the survey requirements (e.g., resolution, oblique vs planar imagery);
- The morphospecies scheme has led to an object-based image processing workflow, as opposed to a point-cover method, for scoring imagery scoring;

- The morphospecies scheme and its interoperability with biotope classification and modern remote sensing of physical habitats, have led to a renewed emphasis on the classification of contiguous imagery in patches, as opposed to sub-sampling image frames.

The CBiCS implementation of the morphospecies hierarchy is based around a design for application today and functionality for the future. The adoption of computer vision, machine learning and other artificial intelligence tools is expected to have higher uptake in ecology to deal with the increasingly large, open-source data sets. Directing human efforts to image scoring today needs to be carefully gauged and is likely only become more limiting in the future.

The construction of the morphospecies hierarchy and the image catalogues has resulted in the archiving of a significant georeferenced, fully classified training image-set.

The image training set has also been processed into a database of image features for machine learning and automated applications. The CBiCS morphospecies hierarchy has also been implemented in common national image scoring tools, such as Squiddle+.

The vision for the future is that imagery can be classified in near real-time, to at least some level in the morphospecies hierarchy, with annotations running through a classification algorithm comparing the frequency distribution of morphospecies against known ‘morphospecies assemblages’ in known biotopes. In a monitoring framework, this style of analysis would compare morphospecies assemblages (or parameters such as size, area, volumes) across survey times.

In this concept, the human interaction with morphospecies, and thus biotope classification is restricted to key decision points and quality checking, enabling much larger areas of mapping and more frequent monitoring activity per unit of cost (Fig. 31).

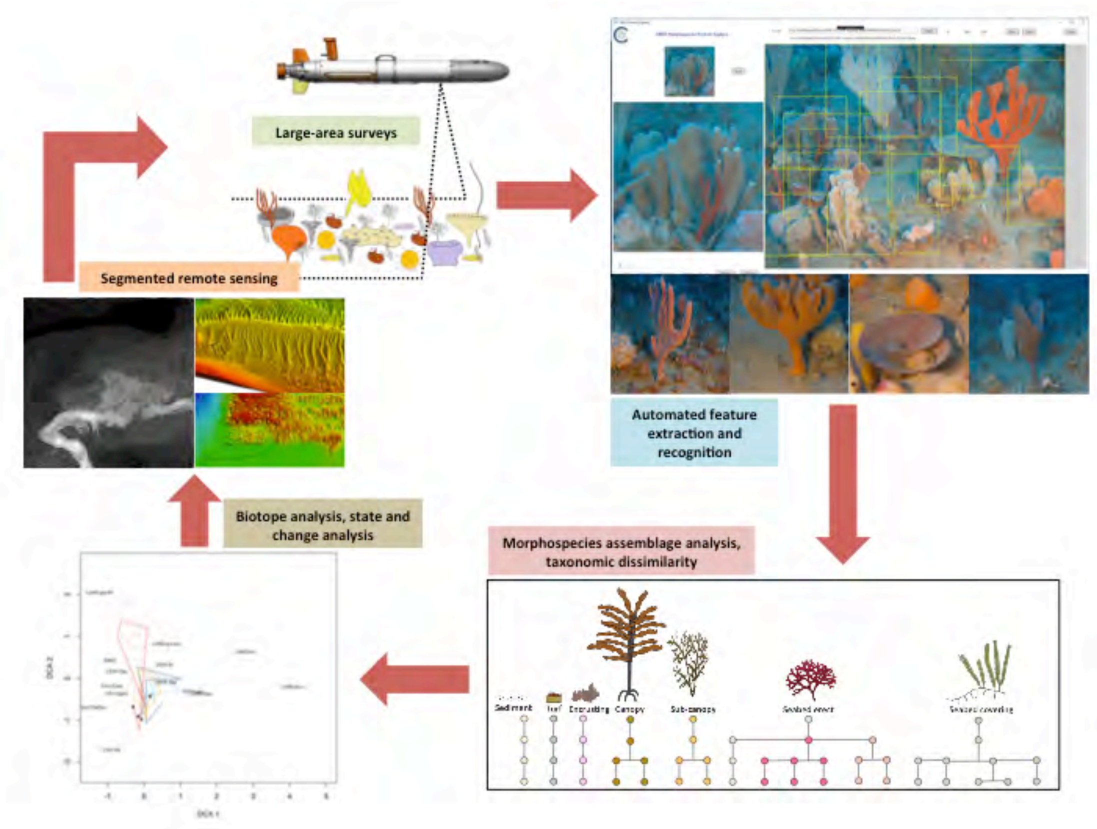



**Figure 31: Schematic illustration of the vision for morphospecies classification interfacing with biotope classification and monitoring. This functionality is built into CBiCS and many of these elements have been successfully tested already.**

## CBiCS Categories Component

The capture of qualitative descriptors has been formalised in CBiCS.  Lower levels of the biotope and morphospecies hierarchies capture information considered to be important to fully describe biotopes, such as observations of disease and growth form.  Known examples of the benefit of these sorts of observations include the decline in overstorey expression of *Macrocystis* stands and the presence of *Ecklonia* die-back that may have been missed if only species labels were used. CBiCS also recognises that there are a range of other observations that should be captured and may be found to be significant for biotope description or change monitoring at a later date (Fig. 32).

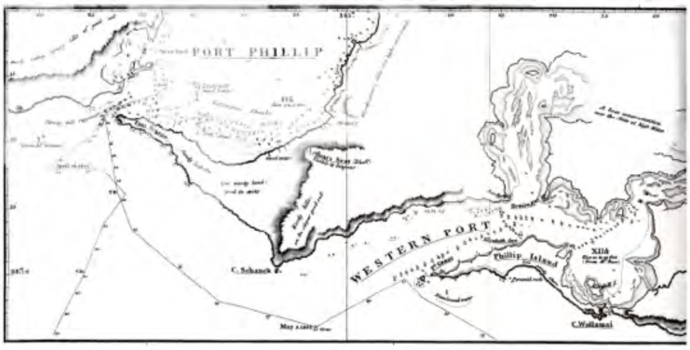
Further examples include unusual but significant observations that formerly may have been lost because that species was not listed as a monitoring species.  In the past this has included observations such as damaged biota (e.g. de-finned sharks) or species of conservation significance occurring at a benthic monitoring site.  There are also examples of needing to capture unexpected physical events such as dredging plumes, underwater noise, litter etc.

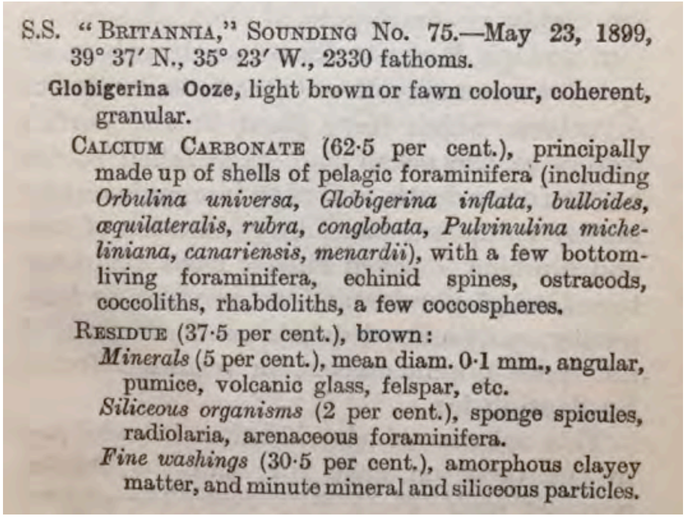
These descriptors are housed in the Categories component.  Rather than providing a collection of words that are uncontrolled, the descriptors are arranged in a pseudo-hierarchy.  They are grouped into the following Level 1 categories:

- Geoform: descriptors of geologic origin, physiographic settings, etc.
- Substrate: descriptors of substrate origin.
- Water column: descriptors of environmental conditions.
- Ecological status: descriptors of ecological relevance such as wilting, damage, early recolonisation, smothering, pest species etc.
- Morphospecies: descriptors relevant to the description of morphospecies including unusual variants, fine-scale structure etc.

The descriptors are arranged at the level which is expected to align with the 'resolution' at which the observations are likely to be able to be made.  New classes and be added and the hierarchy expanded to suite project requirements.

The descriptors include tags for categorisation of database studies and joining data with similar ecological contexts.



S.S. "Britannia," Sounding No. 75.—May 23, 1899, 39° 37′ N., 35° 23′ W., 2330 fathoms.

Globigerina Ooze, light brown or fawn colour, coherent, granular.

Calcium Carbonate (62·5 per cent.), principally made up of shells of pelagic foraminifera (including *Orbulina universa*, *Globigerina inflata*, *bulloides*, *æquilateralis*, *rubra*, *conglobata*, *Pulvinulina micheliniana*, *canariensis*, *menardii*), with a few bottom-living foraminifera, echinid spines, ostracods, coccoliths, rhabdoliths, a few coccospheres.

Residue (37·5 per cent.), brown:

*Minerals* (5 per cent.), mean diam. 0·1 mm., angular, pumice, volcanic glass, felspar, etc.

*Siliceous organisms* (2 per cent.), sponge spicules, radiolaria, arenaceous foraminifera.

*Fine washings* (30·5 per cent.), amorphous clayey matter, and minute mineral and siliceous particles.

**Figure 32: Examples of good observation that underpin good marine ecological classification. Top – Matthew Flinders' chart of Port Phillip and Western Port (1814).  Such early records have been used to recreate the distribution of shellfish biogenic reefs in Port Phillip.  Bottom – description of a sediment sample from a sounding on the S.S. Britannia (1899).  Note the abiotic and biotic elements and the important detail captured.**

Together with the other classification components, these categories reflect the approach of biotope classification adopted by CBiCS: that being one akin to the taxonomic description of a species.  Taxonomic description of a species requires an analysis of morphometric or genetic components, a thorough appraisal of the significance of observed variation and investigation of how new data relates across phyletic groups.  Furthermore, prior to describing a new species, collaboration with other experts dealing with related species and peer review is required.  The CBiCS adopts a similar approach to biotope classification and the CBiCS categories will aid in thorough description and collaboration into the future.

# Databases

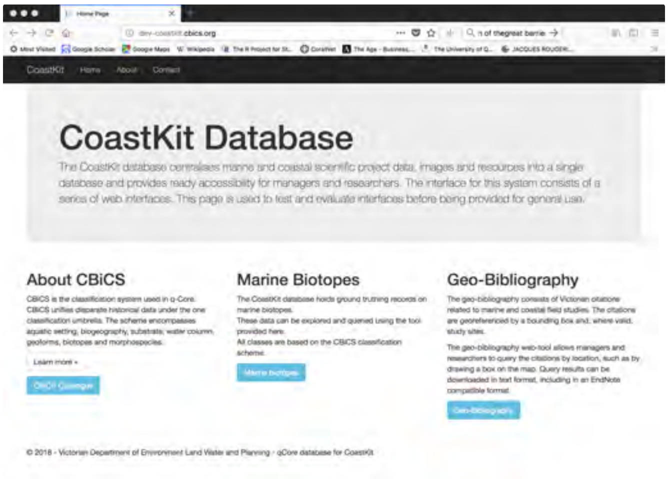
In the Victorian marine ecological classification and mapping context, CBiCS is deployed using two databases with a web interface: the CBiCS database holding the catalogue of classes and the qCore database holding classified field data (Table 5). Both of these databases interact with repositories of imagery and other raw data. For many users, the CBiCS database alone will house the information required to view and query hierarchies and catalogues, accessed by a web interface. However, key features of both databases are described here to illustrate how the system is deployed.

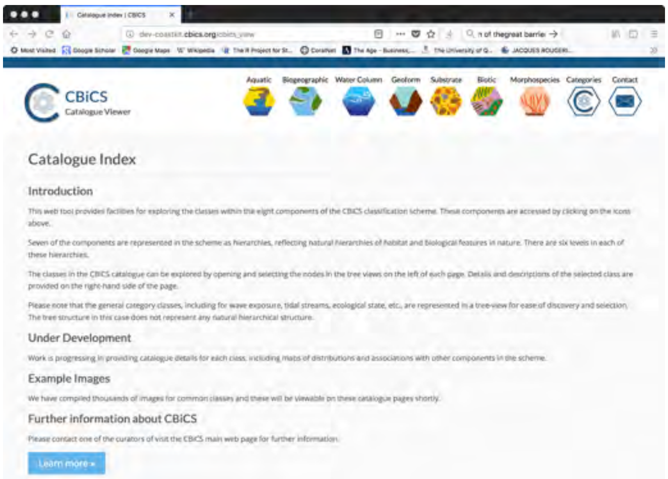
**Table 5: Description of CBiCS and qCore databases**

| Database | Description |
| --- | --- |
| CBiCS | **1. Holds catalogue tables**<br>Hierarchies for each component, with each record representing a class (a node in the hierarchy).<br>Classes are coded and referenced with a UUID and a title. Descriptions, and various labels are included.<br>The web interface to the catalogues organises the coded levels into a tree-view. |
| qCore | **1. Holds classified data records**<br>Classifications of georeferenced image frames, transects and polygons that are made using CBiCS are held as data records in qCore.<br>**2. Holds georeferenced literature, photographs, speciments and data study information**<br>Repository for geo-searchable literature (GeoBibliography), imagery, specimens and data for Victorian marine studies<br>**3. Holds collated historical data with CBiCS tags**<br>Holds collated historical marine data sets, archived and classified using CBiCS classes, labels and tags. |
| Imagery and other raw data | Conventional and cloud-based data storage.<br>Standardised folder structures and naming conventions.<br>Referenced from qCore |

# Access and Data Discovery

CBiCS hierarchies and Victorian biotope data are accessed via the Victorian Coastkit website (presently in public-access development). The databases are hosted on Amazon Web Services (AWS) cloud computing service.



# Next Steps

## Catalogues and definitions

Although the CBiCS catalogue is comprehensive with some 4000 images of biotic and morphospecies classes registered into the system, some classes are yet to be fully referenced with imagery. Again, the dual benefit of this imagery is the provision of a georeferenced ground-truthing data set. DELWP is continuing the process of collating and registering exemplar images and class descriptions into the catalogue.

DELWP is in a process of analysing biotope data available across the state, with further class additions and minor reorganisations of the lower levels of the hierarchies expected. The CBiCS catalogues are intended to be live documents particularly in this early stage of biotope discovery. The catalogues available online will be updated periodically and again, the focus on web implementation and API functionality will ensure that scientists have ready access to the most up to date information.

## Biotope Metrics, States and Condition Monitoring

Analysis is in progress to establish metrics on morphospecies composition related to states and condition of monitored biotopes. This information will further add to the description of biotopes and provide a quantitative basis for future comparisons while also facilitating some of the future developments of semi-automated biotope detection. The intent is to provide users with more decision-making tools to aid in biotope classification and further define ecosystem function and biodiversity values associated with mapped biotopes.

The use of indicator species of biotopes was extended from the JNCC approach (Fig 33).

## Workshops, Training, Implementation and Feedback

The CBiCS developers in conjunction with DELWP will will be implementing a range of workshops and training events to facilitate uptake and standardisation by various user groups in Victoria. CBiCS will be formally released online at the 2018 Australian Marine Sciences Association conference and a workshop will be held at that conference to introduce researchers and managers to the classification scheme. A process to formally seek feedback from introductory workshops will be put in place.

Sub-biotope (ba3.1141) Twofold Shelf Durvillaea, Phyllospora, and Ecklonia complex

| Morphospecies | IndVal | Abundance | Specificity | Fidelity | SAFCOR | Occurrence |
|---|---|---|---|---|---|---|
| Durvillaea potatorum - common form | 786 | 40 | 786 | 100 | S | ***** |
| Rhodymenia wilsonis | 478 | 3 | 558 | 85 | O | ***** |
| Crustose coralline algae - seaweed stands | 16 | 15 | 16 | 100 | C | ***** |
| Ecklonia radiata - common form | 11 | 25 | 11 | 100 | A | ***** |
| Phyllospora comosa - common form | 10 | 24 | 10 | 100 | A | ***** |
| Halopeltis australis | 8 | 1.1 | 19 | 42 | O | *** |
| Plocamium dilatatum | 3 | 0.7 | 8 | 35 | R | ** |
| Rhodymenia linearis | 2 | 0.2 | 11 | 21 | R | ** |
| Peyssonnelia novae-hollandiae | 2 | 0.2 | 12 | 14 | R | r |
| Erythrymenia minuta | 1 | 0.06 | 19 | 7 | R | r |

**Figure 33: Example of a morphospecies characterisation of a CBiCS biotope that lists species abundance, specificity and fidelity statistics. In this case the most 'diagnostic' species, *Durvillea potatorum*, is also the most abundant, but this is not necessarily the case for all biotopes.**

Implementation of CBiCS across multiple agencies is expected to require a phased program of uptake, testing and feedback. It is envisaged that training programs, targeting key areas of the classification scheme or key audiences will be required stepping into state-wide implementation.

The JNCC scheme provides a model for the implementation of a classification system and its interplay with policy and legislation at one end, and scientific developments and training at the other. Over several years of implementation of the JNCC scheme, workshops were held to deal with particular elements of the classification process that needed to be addressed. For example, special workshops were held on how 'reefs' are defined with respect to unconsolidated hard substrata, and how the scheme can be applied in the deep sea.

Alignment and standardisation of CBiCS use is expected to take some time. Taking the lessons from previous terrestrial and marine classification schema, we suggest that the success of CBiCS implementation will be contingent on acceptance of a transitional stage among the user community, adequate training and resourcing, and maintenance of quality-control procedures.

DEWLP will implement a gateway process to ensure that data finally made available through the web portal is quality assured. There are a range of options to consider to facilitate high quality implementation of CBiCS, ranging from ad-hoc training to accreditation. Other natural resource management and observer programs may offer useful precedent for how best to frame training and quality assurance through the implementation phases:

- Intra-agency training-style approaches
    - Underwater Visual Census of fishes and benthic species. Training programs implemented by research agencies to standardise observers and quantify biases.
- Inter-agency training and accreditation-style approaches
    - AUSRIVAS Australian River Assessment System extensive courses to achieve registered accreditation.
    - Victorian Native Vegetation assessor accreditation and DELWP's Vegetation Quality Assessment Competency Check (VQACC).
    - New Zealand Department of Conservation standards and training for Marine Mammal Observers for Seismic Surveys.
- Standards and codes of practice-style approaches
    - Australian code of electrofishing practice. Competency assessment, training and documentation.
    - Australian scientific diving standards.
    - Environment Institute of Australia and New Zealand practitioner for EIA.

The approach taken by DELWP and CBiCS will be devised in consultation with user groups as implementation of the scheme takes shape. The AMSA 2018 workshop is expected to be an important step in identifying the needs for training and tools to facilitate uptake in the short term.

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### Website

**CBiCS Information**

www.cbics.org

**CBiCS Hierarchy Explorer**

http://tools.cbics.org

**Victorian CoastKit Implementation**

http://coastkit.cbics.org

**Victorian CoastKit Catalogues**

http://coastkit.cbics.org/cbics_view

**Victorian CoastKit Biotope Atlas**

http://coastkit.cbics.org/vic_biotope/Atlas

# Further Reading


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