National Intertidal/Subtidal Benthic (NISB)

Habitat Classification Scheme

Version 1.0

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Principal Authors

Richard Mount[1, 2], Phillippa Bricher[2] and Jenny Newton[2]

[1] National Estuarine, Coastal and Marine Information Coordinator, NLWRA
[2] Spatial Science Group, School of Geography and Environmental Studies, University of Tasmania

Contributors

David Ball, Kevin Bancroft, Ewan Buckley, Alan Jordan, Vanessa Lucieer, Len McKenzie, David Miller, Elvira Poloczanska, David Ryan, Neil Smit, and Rob Thorman

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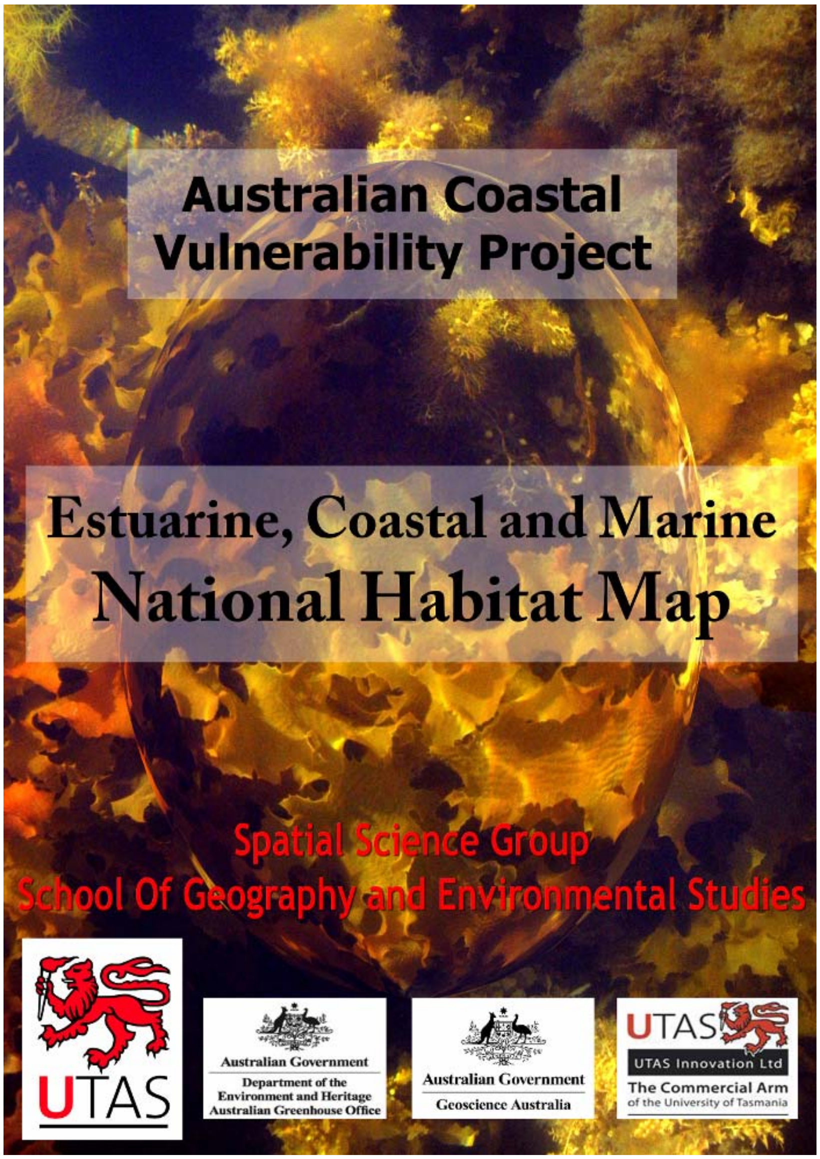
School of Geography and Environmental Studies, University of Tasmania



National Land & Water Resources Audit

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Contents

Executive Summary

- There are a series of uses for a national intertidal/subtidal benthic habitat classification scheme. These include supporting the assessment of the vulnerability of Australia's shores to climate change impacts. Currently, a number of habitat classification schemes are in use around Australia. These schemes have many characteristics in common, though they are implemented differently to reflect current practise and management needs within each state and territory.
- The scheme is focused on the surface of the land and the seafloor between the highest astronomical tide (HAT) and the maximum depth at which approximate outer limit of the photic benthic zone (approximately 50-70 m deep). It is concerned with defining local scale "habitats" or "communities" for mapping purposes.
- The national scheme was developed by decomposing the state schemes into their component parts, establishing a conceptual model for habitat mapping and then synthesising a national scheme. This scheme is designed to be applied around the nation; be consistent with the existing schemes; and meet the requirements of producing a national map.
- It should be noted that while there are a large number of habitat properties that could be mapped, this scheme has focused on a subset of properties that are both feasible to map and are ecologically relevant; i.e. substrate and habitat-forming macrobiota. Mapping biodiversity or mobile biota is resource intensive and not usually undertaken across large areas. Environmental properties, such as depth, tidal limits, exposure and temperature are more available but are treated as "modifiers" rather than core properties for this classification. This provides simplicity in the core scheme and the flexibility to include them if required.
- A new term, *structural macrobiota* (SMB), was developed to more accurately describe the marine biota that fulfil the habitat-forming role played by vegetation in terrestrial environments. SMB covers macroalgae (protists), corals and other filter feeders (animals with algal symbionts), and marine plants (macrophytes such as seagrasses).
- The resulting scheme is hierarchical in structure with class descriptions defined for the higher level classes and the capacity to add classes further down the hierarchy. The **classes** are defined at the highest levels of the hierarchy by substrate properties, such as rock and sediment, and, at the lower levels, by the presence and dominance of various SMB. The SMB classes targeted for the national map include mangroves, saltmarsh, coral, macroalgae and seagrass. **Decision rules** are defined for most boundaries between classes, though further refinement is required, in particular the definition of reference areas for some classes. If required, attributes of any observed substrate, biotic and environmental properties can be added at any level of the hierarchy in the form of "**modifiers**". There are a very large number of potential modifiers and a small subset is addressed here.
- Great flexibility is conferred by the hierarchical nature of the scheme as maps can be produced that represent classes from differing levels of the hierarchy. This means that where greater resolution data is available, or particular purposes need to be met, the maps can display a matching amount of detail.

Acronyms

AGO	Australian Greenhouse Office
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ECM	Estuarine, Coastal and Marine
ISB	Intertidal/Subtidal Benthic
NISB	National Intertidal/Subtidal Benthic
NISBHCS	National Intertidal/Subtidal Benthic Habitat Classification Scheme
NLWRA	National Land and Water Resources Audit (Audit)
NOO	National Oceans Office
NRM	Natural Resource Management
SMB	Structural Macrobiota

1. Introduction

Intertidal and shallow water benthic habitat mapping is conducted in all Australian states and the Northern Territory by a variety of agencies and for a range of purposes. The various classification schemes used are designed for these specific purposes and there is not necessarily consistency between the resultant mappings. Typically, the States and NT have focused their mapping efforts on defining habitat extent at various resolutions (see discussion below), while Commonwealth Government agencies have been focused on bioregionalisation at very broad extents and resolutions, such as biomes, bioregions and upwards to provinces (Butler et al., 2001). A series of national initiatives would benefit from access to finer resolution estuarine, coastal and marine (ECM) key habitat maps that have a nationally consistent classification and, ideally, national coverage. These include the Australian Greenhouse Office's *Australian Coastal Vulnerability to Climate Change* project and the Audit's national ECM resource condition assessments (see Project Aims below). At the same time, a nationally consistent system would enable comparisons among state and regional habitat maps.

Given the continuing development of many states' and NT's mapping programs and the increasing interest of NRM regions (CMAs) in the marine environment, a nationally consistent classification scheme is considered a useful tool for habitat reporting. The primary focus is on achieving consistency at a high level of the intertidal/subtidal benthic habitat classification hierarchy (e.g. mangrove, reef, sediment and seagrass) rather than the more detailed levels (e.g. species, modifiers, etc). However, a nationally consistent scheme needs to be flexible enough that the existing habitat classification schemes can be mapped across to it, so as to avoid undermining the substantial and valuable body of habitat classification work that has been completed and is continuing around Australia.

The wide variety of benthic sensing techniques used across Australia poses an additional challenge to creating a consistent scheme. For example, definitions of seagrass density vary according to whether the seagrass is mapped from aerial photographs, acoustic soundings, underwater video or dive samples (Bancroft, 2003; Ball et al., 2006). The decision rules associated with the various classes need to be framed so that they are as independent of platform sensor as possible.

1.1. Background to the development of the scheme

The development of a national habitat classification scheme has been pursued for a number of years in many different forums…

[More needed here re current schemes and the previous workshops and the reports by Bancroft (2003) and Ball (2006).]

1.2. Classification scheme objectives

The objective of this scheme is to enable the **creation of a national level map** including the National Habitat Map identified by the AGO/NLWRA Partnership Project. Thus agreement by the various state and NRM regions is not needed on all levels within the national scheme; though classes lower in the hierarchy (i.e. more detailed classes) needed to be considered to ensure that the existing data produced with state classification schemes could map across to a national scheme.

This objective requires the definition of both **habitat classes** and d**ecision rules** for differentiating classes in the resulting scheme.

The key estuarine, coastal and marine (ECM) intertidal/subtidal benthic **habitat types** identified for inclusion in the National Habitat Map include, at least:

a. mangroves
b. saltmarshes
c. seagrasses
d. macroalgae
e. rocky reefs
f. coral reefs
g. unconsolidated sediments

The National Intertidal/Subtidal Benthic (NISB) Habitat Classification Scheme will support the AGO/NLWRA partnership project by providing a nationally consistent scheme for those habitats between the highest astronomical tide mark (HAT) and the approximate outer limit of the photic benthic zone (approximately 50 – 70 m depth contour). This area is broadly equivalent to the “inner” and “mid-shelf” regions identified by Geoscience Australia (REFS XXXX).

1.3. *Purposes for habitat mapping:*

At a workshop held in Hobart in August 2007, attended by representatives of state marine habitat mapping agencies, the following groups of purposes were identified:

Low Resolution Mapping (<1:40 000):

- Marine regional planning

Medium Resolution Mapping (1:25 000 – 1:40 000):

This resolution of mapping is regarded as "**general purpose**" mapping and has many uses, including

- Aquaculture planning
- Emergency response (for example, oil spills)
- Natural Resource Management Regions
- Marine Protected Areas (planning
- Fisheries Management

High Resolution Mapping (>1:25 000):

- Environmental Impact Assessment
- Environmental monitoring

2. Definitions

Accuracy: The closeness of an observed value to a true value. This term is here used in two ways:

- *Positional accuracy:* The difference between observed and true location (usually expressed as ± X distance).
- *Attribute accuracy:* The likelihood that the attribute label is correct at any location.

Extent: The total area under consideration. This term is here used in three ways:

- Observational extent: The area covered by a given sensor.
- Representational extent: The area covered by a map/data layer.
- Management extent: The area of interest to a particular management body (e.g. all of Australia's coasts, or all the waters in a particular NRM region).

Habitat: This term is used in two primary senses.

(1) Most strictly, "habitat" is an environment used by a particular organism or assemblage, e.g. habitat *for* dugongs or habitat *for* seagrass (Kvitek et al., 1999).

(2) "Habitat" can also be used to denote a relatively homogeneous environment that is inhabited either permanently or temporarily by organisms. This is the sense in which generalised habitat mapping is conducted by Australian government agencies (e.g. Ball et al., 2006; Rule et al., 2007) and the meaning which is used throughout this document, unless otherwise stated. Diaz et al (2004) identify habitat as the intersection of three components:

- *The substrate* (i.e. topography and textural characteristics)
- *The biota* (species life histories and preferences)
- *The environmental processes* acting on the location (e.g. temperature, salinity, pressure, exposure, etc.)

It should be noted that habitats are repetitive physical or biophysical units found within ecosystems, so the same habitat could be found in more than one bioregion (Kvitek et al., 1999). For the purposes of this scheme, "habitat" is broadly equivalent to Biotope (primary or secondary) and Biological Facies (Butler et al, 2001).

Habitat mapping: This term can refer to either species-specific habitat mapping (e.g. seagrass beds as dugong habitat) or, as in this scheme, generalised mapping of broad habitat types, as is practised by state and territory agencies around Australia and the world. This involves classifying landscape into relatively homogeneous units (Bancroft, 2003; Ball, 2006).

Habitat mapping classifications: The classification schemes that are applied at state, territory and Natural Resource Management (NRM) Region scales.

Modifiers: Attributes of a habitat or ecosystem that are not used for primary classification. This may be because they are considered to be less significant ecological forcers, or because they are not so easily mapped and hence data are only available for some areas of the total extent to which a classification scheme is being applied.

Resolution: A measure of the closest distance between two unique identifiable features or the size of the smallest feature that can be mapped or sampled (Burrough and McDonnell, 2000; Delaney and Van Niel, 2007). It is here divided into four subcategories:

- *Observational resolution:* the size of the smallest feature that can be mapped or sampled (also known as Ground Resolution Unit (GRU) or Minimum Discernable Unit (MDU)).
- *Representational resolution:* The smallest object that can be shown in a map/data layer (also known as the Minimum Mapping Unit (MMU)).
- *Management resolution:* The smallest unit of relevance to a given management consideration (e.g. a biotope or a microcommunity).
- *Temporal resolution:* The frequency of observations through time.

Scale: Within habitat mapping circles many different and often contradictory meanings are given to the term “scale”. Scale generally involves some kind of measure of extent, area and/or resolution. For clarity, this document uses the terms extent, resolution and accuracy in place of scale.

Scale ratio: Many available datasets do not contain specific metadata on accuracy or resolution. Instead, data is described as being mapped at “1:25,000 scale” or “1:1,000,000 scale”. In the absence of more explicit metadata, it is assumed that this refers to a paper map scale ratio. As a rule of thumb, the smallest object that can be drawn on a paper map is 0.5 mm wide (Longley et al., 2005). Thus the accuracy of data can be calculated as ½ the second integer in the scale. For example, a 1:25,000 scale map is likely to be accurate to ±12,500 mm (or ±12.5 m). This assumes that the data was originally gathered at an appropriate level of accuracy, and this assumption often cannot be assessed.

Structural Macrobiota (SMB): Sessile habitat-forming species that, by their presence, increase spatial complexity and alter local environmental conditions, often facilitating a diversified assemblage of organisms (Lilley and Schiel, 2006). This class is similar to the “vegetated” class used in terrestrial habitat classifications. In the marine environment, this class includes seagrasses, macroalgae, stromatolites, corals, sponges and other macroinvertebrates that form large enough patches to provide places for other organisms to live (Cocito 2004). These structures and patches may be monospecific; formed by a single primary species such as serpulid reefs, or may consist of a number of primary species such as coral reefs. More specifically, the term “macrobiota” implies that an organism must be visible to the naked eye. The structuring role of SMB can include both three dimensional structure, as provided by coral or macroalgae, and two-dimensional structure, as provided by crust- or mat-forming biota (e.g. turfing algae and encrusting sponges).

Environment	**Structural Macrobiotic Groups**
Terrestrial	Plants
Aquatic	Plants (macrophytes), Protists (macroalgae), Animals (e.g. corals, sponges, ascidians and tunicates)

3. Conceptual Basis of the Scheme

It is widely recognised that ecosystems and their management need to be viewed as multi-scale processes (Butler et al., 2001). It has also long been recognised that any classification system involves an attempt to impose artificial boundaries on natural continuums for the purposes of inventory, evaluation and management (Cowardin, 1979). However, classification provides a valuable framework that allows habitats to be quantified and monitored.

Habitat and land cover classification maps are widely used in both terrestrial and marine environments and a large range of schemes have been created for specific purposes and environments. These are most strongly developed for terrestrial environments. In Australia, such schemes include the National Vegetation Information System (NVIS) and the Land Cover classification scheme (DEWR, 2007; ACLUMP, 2006). Globally, the UN's *Land Cover Classification System* (Gregorio, 2005) is used to classify land, including those areas of land that are permanently or regularly flooded (e.g. wetlands, shallow marine waters).

In its strictest sense, the term habitat mapping refers to habitat *for* a particular species or assemblage (e.g. shark habitat). However, in a more general sense, habitat mapping is used to refer to a system of classifying landscape into relatively homogeneous units (Bancroft, 2003; Ball, 2006). This definition is used here, so that an area which is spatially dominated by seagrass is classed as "seagrass dominated habitat" whereas an area which contains small amounts of seagrass is classed as "sediment dominated habitat". For a particular species, e.g. dugongs, both of these sites may form valuable habitat.

In the marine environment, the difficulty of gathering data about the benthos means that many of the environmental and biotic attributes that contribute to a habitat cannot be readily quantified or mapped. Therefore, a mixture of geomorphological and structural macrobiotic attributes form the basis of most aquatic habitat classification schemes, including the one presented here.

Conceptually, a number of steps are involved in the creation of any kind of classification scheme can be created. Gregorio (2005) warned against conflating land use, habitat and land cover classifications, despite their superficial similarities. While they all involve the classification of the "real-world" into relatively uniform units, the purposes are different. As a result, the classification rules differ, as do the final maps. After a comparison of existing classification schemes from around Australia, we came to a similar conclusion. The way in which any kind of classification scheme is created can be conceptualised as:

1. With a given purpose in mind,
2. Make observations (with sensors) of "real world" properties (attributes) in time and space
3. Map observations using decision rules as
   - discrete (polygon) maps via
     - Categorising (classification scheme), OR

– continuous field (surface) maps via
    - Modelling
    - Interpolation
    - Categorising (classification scheme)

"Real world" properties are grouped along the lines of Diaz et al. (2004) into substrate, biotic and environmental processes. Note that some sensors allow more properties to be observed. The collected observations can then be classed in many ways including into habitat, geomorphological or land cover classes. Some worked examples of this conceptual model are presented in Appendix B.

3.1. Current classification systems

3.1.1. National approaches

In Australia, national approaches to classifying coastal and marine ecosystems have involved very coarse spatial resolutions and have been limited by lack of data (Hilbert et al., 2007). These have typically involved bioregionalisation rather than habitat mapping. Bioregionalisation involves dividing up the environment into large (3000 – 240 000 km²) units, each of which is unique (IMCRA 1997). However, in a recent national review of biodiversity conservation research in the face of climate change, Hilbert et al (2007) argue that the mesoscale IMCRA bioregions are "too coarse to detect change or loss of individual habitats and communities". The authors recommended a need:

- To identify a "uniform definition of communities, habitats and ecosystems", and
- To "define 'ecoregions' to provide spatial units suitable for integrating both science and management around critical climate change issues".

Habitat mapping, in contrast, is focused on finer resolutions and smaller extents –from 10s m² to multiple km². It attempts to identify non-contiguous areas of similar substrate, biota and environment. The definition of habitats as "repetitive physical or biophysical units found within ecosystems" means that individual habitats may be found in more than one biogeographical province (Kvitek et al., 1999).

3.1.2. State approaches

Habitat classification schemes have been individually developed in several Australian states and these have been tailored to local conditions and needs (e.g. Bancroft, 2003; Ball et al., 2006; SEAMAP, 2007). It should be noted that there are many ways to explore, measure and describe the marine environment, and that there is no single best method for dividing it into homogeneous regions (Butler et al., 2001). One result of the diversity of schemes is that existing habitat maps cannot be compared among the states, territory and regions.

Scheme Similarities:

The available schemes are typically hierarchical – both in terms of the detail of the categories and in terms of the spatial extent and resolution (e.g. Banks and Skilleter, 2002; Bancroft, 2003; Ball et al, 2006). There are commonalities between many of the systems, especially at the more general levels of the classification. For example, the distinction between consolidated substrate (rock/reef) and unconsolidated substrate (sediment) is typically the first step in a classification process (e.g. Butler et al., 2001; Banks and Skilleter, 2002; Bancroft, 2003; SEAMAP, 2007). However, some schemes recognise three distinct classes at this level – consolidated, unconsolidated and mixed (Ball et al., 2006). Most schemes also make use of so-called "modifiers", which are properties of the habitat under observation that are not central to the chosen classification scheme. Note that any of the modifiers *could* be used to derive distinct classification schemes (e.g. a geological map of marine habitats). The properties chosen as key classifiers for the habitat classification scheme, rather than modifiers, are typically those that are strong ecological forcers and that are readily observed and mapped using existing technologies.

Scheme Differences:

There are also some key differences between the available schemes. These include the relative importance assigned to variables such as:

- Water depth (including intertidal/subtidal divisions)
- continuity/patchiness,
- high/low profile (reefs),
- geology and
- biotic groups.

These variables are considered to be primary classifiers in some schemes and either modifiers or subsidiary classifiers in others. For a national scheme, primary classifiers need to be features that are readily mapped for all or most of Australia's marine environments as well as being ecologically significant. A key characteristic of habitat classification schemes is the respective contribution of biotic and abiotic features. For example, Diaz et al. (2004) point out that it is relatively easy to conduct broad mapping of geomorphic structure with remote sensing techniques but harder to detect biological features (e.g. video drops may be required). The variety of sensing techniques used around Australia creates a range of mapping methods that will allow greater or lesser detail in reporting the ecological condition of any specific mapping unit.

Extent:

Another issue that limits comparisons among existing classification schemes is that they are designed for different spatial extents. Some schemes investigate the transition zone between terrestrial and marine environments, including the intertidal zone (e.g. Bancroft, 2003; Gregorio, 2005; Ball et al., 2006) while others are concerned exclusively with the subtidal zones (e.g. Butler et al., 2001; SEAMAP). The outer depth limit also varies significantly, and is dependent on water clarity, sensing techniques and the extent of the area of interest for a particular mapping agency. It may not be specified (Bancroft, 2003) but can be anywhere between 25 m and 100 m (D. Ball, V. Lucieer and D. Miller, pers. comm.).

There is also considerable overlap with terrestrial vegetation classification schemes, especially for the mangrove and saltmarsh classes (DEWR, 2007).

Resolution:

No state in Australia relies on a single sensing technique for its benthic habitat mapping efforts. Therefore, all mapping efforts involve an amalgamation of data with different resolutions. This variation within and among states and NT means that decision rules on classifiers need to be drafted in such a way that they can be mapped using all, or at least the majority of the available sensing techniques.

Geographic consistency of classes:

Each scheme is designed for a particular geographical area, purpose and set of available data. Each of these criteria potentially limits the applicability of an individual scheme to other areas, datasets and uses. For example, the SEAMAP scheme does not classify coral, because there is so little coral in Tasmania. A national scheme needs to be drawn broadly enough to encompass all possible habitats occurring in Australia, as well as the range of mapping purposes and the wide variety of sensing equipment used around the coast.

3.2. Ideal characteristics of a marine habitat classification scheme

In a review of habitat classifications, Ball et al. (2006) identified the following characteristics of successful classification schemes:

- The scheme should be hierarchical (to avoid duplication of categories)
- Classes should be mutually exclusive and exhaustive at each level in the hierarchy (so that each habitat type is accounted for and unique)
- The scheme should be comprehensive (at least at the upper levels of the scheme)
- The scheme should provide a common and easily-understood language for descriptions
- All sensing techniques should result in the same classifications, though the level to which a habitat can be classified will be dependent on the resolution of the sensor
- Habitat variables that change slowly (e.g. substrate) should be placed higher in the scheme than those that change rapidly (e.g. biota)
- Classes should be sufficiently fine to be of practical use for local managers, but also be sufficiently broad (through the hierarchy) as to allow summary information to be presented at national or international scales or to non-specialists
- The scheme should be flexible enough that it can be modified when new information is presented, but also be stable enough that it can support ongoing use. Changes should be clearly documented and related back to earlier categories.

3.3. The basis for a national approach

The proposed National Intertidal/Subtidal Benthic Habitat Classification Scheme (NISBHCS) has been designed to integrate the existing classification schemes. It does this by creating a common system for the highest levels of hierarchy. These broad classes meet the criteria of being hierarchical, comprehensive, mutually exclusive, relatively sensor independent and well defined. It is designed to allow national reporting and comparisons, while leaving space for states, NT and regions to define finer levels of classifications for local condition reporting. Thus the scheme meets the criterion of being both sufficiently broad and (by proxy of the states/NT) detailed enough to meet a range of uses. At the same time, it is designed to operate in parallel with the existing schemes, so that each state and region can continue to use the classifications it has already developed.

Marine habitat mapping is conducted in both vector and raster data models. It is anticipated that the new classification can be implemented as extra attributes in vector-based data models or as straightforward reclassifications of existing raster datasets.

Extent:

The proposed scheme covers all of Australia's territorial waters between the High Astronomical Tide (HAT) mark and the approximate outer limit of the photic zone (50 – 70 m depth). It thus incorporates data from all existing shallow-water benthic habitat classification schemes. It also covers some vegetation classes already by NVIS. To maintain consistency, the proposed scheme will use the NVIS class descriptions for mangrove and salt marsh habitats.

Resolution:

Decision rules for the classes have been framed so as to be as sensor-independent as possible. A reference area of $9m^2$ is used for determining dominance of substrate or biota. At the Hobart workshop (the workshop report is in Appendix A), this area was determined to be appropriate for a range of sensing techniques, either as a 3 m by 3 m quadrat, or its equivalent in transect mapping.

Geographic consistency of classes:

Because the proposed scheme was designed for use in all Australian intertidal and shallow water subtidal areas, the classes were created to account for all the major habitat types that are known to occur in these waters.

4. The National Intertidal/Subtidal Benthic (NISB) Habitat Classification Scheme

The National Intertidal/Subtidal Benthic Habitat Classification Scheme (NISB Habitat Classes) is designed to support the production of maps for the purpose of representing areas of marine and coastal habitats at the national scale. To achieve this, the scheme must be compatible with the mapping classification schemes used by the major producers of habitat maps in Australia, that is, state and NT agencies and, more recently, NRM regional bodies.

The scheme is hierarchical and initially divides habitats according to broad substrate type, and then according to whether they are spatially dominated by “structural macrobiota” (SMB) or by the substrate (i.e. largely “bare” of visible biota).

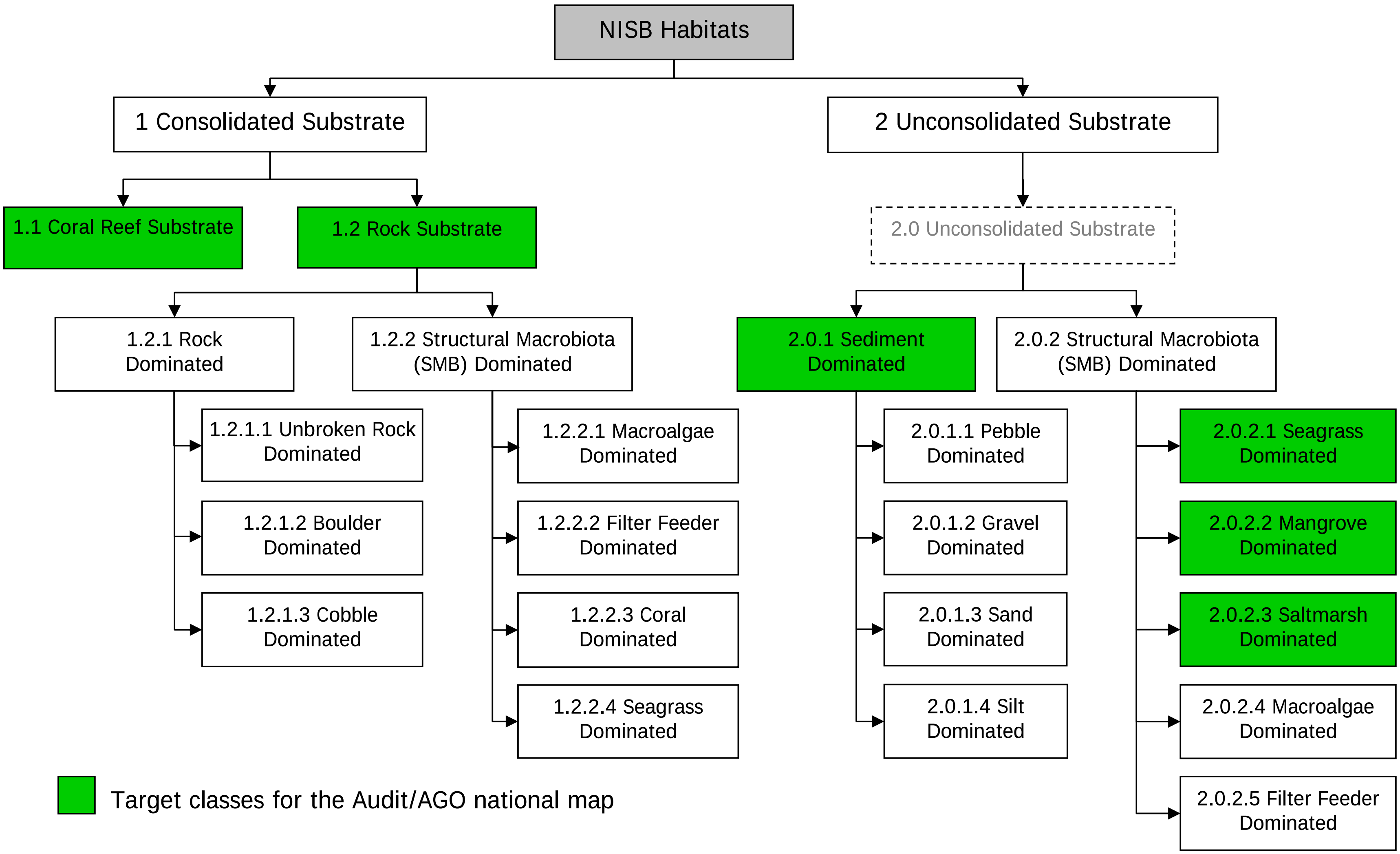
For **consolidated substrates**, there is a primary division between coral reef and rocky substrates. This split is determined on the substrate or structure of the reef, rather than its ecology. The rocky substrates are divided into SMB dominated or rock dominated habitats. The SMB dominated category is divided into classes according to the dominant habitat-forming life forms of macroalgae, sponges, corals, ascidians or seagrass respectively.

For **unconsolidated substrates**, the SMB dominated class is then divided according to the spatially dominant life form (seagrass, mangrove, saltmarsh, macroalgae or filter feeders). The non-SMB dominated class is also divided, this time according to particle size using the Wentworth Scale.

The **modifiers** can be applied at any level of the hierarchy and can be used as the basis of other classification schemes. It is worth noting that maps can legitimately be created using virtually any combination of classes and modifiers to meet a required purpose. Indeed, the intention of defining this national scheme is to provide some consistency for national mapping projects.

The scheme is presented as a flow chart and then a series of tables listing the class descriptions, the decision rules dividing the classes and a partial list of the “modifiers” used by various mapping agencies.

4.1. *Draft National Intertidal/Subtidal Benthic (NISB) habitat classification scheme*



4.2. *Class descriptions and decision rules for the classification scheme*

Table 1: **Class descriptions** for habitats on **consolidated** substrates

Class No.	Class Name	Description
1	Consolidated	Any habitat in which the substrate is predominantly made up of particles of cobble size (>64 mm diameter) or larger. This includes coral reefs, solid rock and boulders
1.1	Coral reef	Any habitat in which the structure is predominantly formed by a coral framework. As all coral reef has some kind of rock substrate, coral reef is here defined as an object that has more than 50% coral cover.
1.2	Rock substrate	A structure that is predominantly formed by a rock framework. Here it is defined as a consolidated substrate that has 50% or less coral cover
1.2.1	Rock dominated	A rocky substrate on which there is less than 5% seagrass or 10% other SMB cover
1.2.1.1	Unbroken rock dominated	A rock dominated substrate where the cover is dominated by continuous outcropping rock.
1.2.1.2	Boulder dominated	A rock dominated substrate where the cover is dominated by rocks larger than 256 mm diameter.
1.2.1.3	Cobble dominated	A rock dominated substrate where the cover is dominated by rocks between 64 mm and 256 mm diameter.
1.2.2	Structural macrobiota (SMB) dominated	A habitat in which seagrass covers more than 5% of the substrate or one or more groups of other SMB cover more than 10% of the substrate
1.2.2.1	Macroalgae dominated	SMB dominated habitat in which macroalgae has greater substrate cover than other SMB
1.2.2.2	Filter feeder dominated	SMB dominated habitat in which sessile filter feeders (e.g. sponges, ascidians and tunicates) have greater substrate cover than other SMB
1.2.2.3	Coral dominated	SMB dominated habitat in which coral has greater substrate cover than other SMB
1.2.2.4	Seagrass dominated	SMB dominated habitat in which seagrass has greater substrate cover than other SMB

Important note: definitions that include **percent cover** or **predominant cover** imply a reference extent within which the percent cover is estimated. For the purposes of the NISB Habitat Classification Scheme, the reference extent is 9 m² - either a 3 x 3 m quadrat, a 9 x 1 m transect or an equivalent - unless otherwise stated. This area equates to a practical measure that can be easily made in the field with the current observation sensors and methods, such as videography and diver observations.

Table 2: **Decision rules** for dividing habitat classes on **consolidated** substrates

Class Names	Decision Rule
Consolidated / Unconsolidated	These classes are separated according to the size of the particles with majority cover, using the Wentworth scale. Particles the size of cobbles or larger (>64 mm diameter) are consolidated, while pebbles and smaller particles are unconsolidated.
Coral reef / Rock substrate	These classes are separated according the substrate, as determined by the relative cover of corals. If corals cover > 50% of the surface, the substrate is classed as coral reef. If there is any doubt about the dominance of coral, then the habitat is to be classed as rock substrate.
SMB dominated / Rock dominated	SMB dominated habitat is classed as habitat with 10% or more of the rocky substrate covered by structural macrobiota. Less than 10% SMB cover is classified as rock dominated. (Note: as this classification sits at a lower level in the hierarchy than the split between coral reef and rock substrates, any habitat with more than 50% coral cover would be classified as coral reef, not SMB dominated rock.)
Unbroken rock / Boulder / Cobble dominated	These classes are separated according to the size of the substrate particles with majority cover, according to the Wentworth scale. Unbroken rock is defined as a habitat predominantly covered by a continuous rock surface.
Macroalgae / Seagrass / Coral / Filter feeder dominated	In an SMB dominated habitat, the group (macroalgae / seagrass / coral / filter feeders) with the greatest proportion of cover determines the class into which a habitat is placed.

Table 3: **Class descriptions** for habitats on **unconsolidated** substrates

Class Number	Class Name	Description
2	Unconsolidated	A substrate that is predominantly made up of particles of pebble size (<64 mm diameter) or smaller. This includes gravels, sands and silts
2.0	Unconsolidated substrate	A dummy class "holder" at the second level of the hierarchy to enable consistency in the numbering throughout the class hierarchy
2.0.1	Sediment dominated	An unconsolidated habitat with either <5% seagrass cover or <10% other SMB cover
2.0.1.1	Pebble dominated	A sediment dominated habitat which predominantly consists of particles 4 to 64 mm diameter
2.0.1.2	Gravel dominated	A sediment dominated habitat which predominantly consists of particles 2 to 4 mm diameter
2.0.1.3	Sand dominated	A sediment dominated habitat which predominantly consists of particles 63 μm to 2 mm diameter
2.0.1.4	Mud dominated	A sediment dominated habitat which predominantly consists of particles <63 μm diameter
2.0.2	Structural macrobiota (SMB) dominated	A habitat in which >= 5% the substrate is covered by seagrass or >=10% by any other SMB (Seagrass has a lower threshold than other SMB because a significant amount of the biomass occurs below the surface (Duarte and Chiscano, 1999).
2.0.2.1	Salt marsh dominated	Extensive damp and water-logged flats, mostly in near-estuarine areas. The vegetation is dominated by hardy low shrubs, especially samphire communities (DEWR, 2007).
2.0.2.2	Mangrove dominated	Intertidal tall forests to shrublands, in areas with low wave energy. This habitat comprises more than 30 species, with most concentrated in Australia's north (DEWR, 2007). NB: Even though mangroves can occur on rocky shores, the substrate under mangroves is rarely mapped. Therefore, an arbitrary decision has been made here to class all mangroves as occurring on unconsolidated substrates.
2.0.2.3	Seagrass dominated	An SMB dominated habitat in which seagrasses have greater substrate cover than other SMB. For seagrass, dominance is defined at 5%, compared with 10% for other SMB.
2.0.2.4	Macroalgae dominated	An SMB dominated habitat in which macroalgae have greater substrate cover than other SMB.
2.0.2.5	Filter feeder dominated	An SMB dominated habitat in which filter feeders have greater substrate cover than other SMB.

Table 4: **Decision rules** for habitats on **unconsolidated** substrates

Class Names	**Decision Rule**
Consolidated / Unconsolidated	These classes are separated according to the size of the particles which cover the majority of a habitat. Particles larger than cobbles (>64 mm diameter) fit in the consolidated class, while pebbles and smaller particles are considered to be unconsolidated.
SMB / Sediment dominated	These classes are separated according to the proportion of SMB cover. If either seagrasses cover 5% or more of the substrate, or other SMB cover more than 10% of the substrate then the habitat is classed as SMB dominated. Otherwise, the habitat is classed as sediment dominated.
Pebble / Gravel / Sand / Mud dominated	Sediment dominated habitats are classified according to the particle size, as defined on the Wentworth scale. The classification is applied to the particle size with the greatest cover.
Mangrove / Saltmarsh / Seagrass / Filter feeder / Macroalgae dominated	SMB dominated habitats are classified according to the SMB group with the greatest cover.

4.3. *Modifiers*

This section presents a list of the most common modifiers used by existing Australian habitat classification schemes, along with decision rules, where these could be agreed at the Hobart workshop. The modifiers and their decision rules vary significantly among agencies, so this list is provided here as a guide to the kinds of modifiers available.

Table 5: Geomodifiers

Class	Modifier Group	Potential Descriptors	Comments
Rock (> 64 mm grains; basement outcrop)	Profile/Morphometry/Texture/etc (geomorphology?)	High/low; gutters, cracks, crevices, cliff, platform, peak, pit, ridge, pass etc etc. *Could include Vanessa's scheme or other quantitative texture descriptors/measurements.*	The scale of the texture is also important – a crack could be 1 mm across or 100's metres!!
	Slope	Angle in degrees; or slight, moderate, steep classes.	
	Composition	The sky's the limit here: e.g.'s sandstone, calcarenite, granite, concrete breakwall etc. Or even more detailed such as Ordovician turbidites, or garnet schist….. *Origins and some properties are implied in name*.	
	Spatial distribution	Continuous/patchy; % cover?	
Sediment (<64 mm)	Grain size	Udden-Wentworth size classes; actual quantitative grain size descriptors	
	Sorting	Poor, moderate, well etc., or quantitative grain size standard deviation.	
	Composition	%CaCO3, quartz, feldspar etc; fossil content e.g. mollusc fragments, foraminiferal ooze	
	Density/geotechnical properties	Bulk Density (g/cc); penetrometer readings; inferred from acoustics.	
	Geomorphology	Ripples/dunes, ridges, ribbons, channels, gutters, flats, mounds, pits/depressions etc etc.	

		Sediment areas could also be described using quantitative textural analyses.	
	Slope	Angle in degrees; or slight, moderate, steep classes.	

Table 6: Biomodifiers

Biomodifiers	
DENSITY	Dense
	Moderate
	Sparse
SPATIAL DISTRIBUTION (BIOTA)	Continuous
	Patchy
SPONGE	
CORAL	
RHODOLITHS ETC ETC	

Table 7: Environmental modifiers

Environmental Modifiers	
EXPOSURE	High
	Medium
	Low
WATER CLARITY PLUS DEPTH	
CURRENT FLOW	
DEPTH ZONE	Intertidal
	Subtidal
ESTUARINE/RIVERINE PLUMES	Plume influenced
	Not plume influenced
TEMPERATURE	Tropical
	Subtropical
	Warm Temperate
	Cold Temperate
ETC ETC	

4.4. *Decision rules for the modifiers*

Table 8. Decision rules for Geomodifiers

Geomodifier	Decision Rule
Origin	Geology maps
Spatial Distribution (substrate)	[TBC]
Topography / Macropattern / Morphometry (consolidated substrates)	[TBC]
Topography / Macropattern / Morphometry (unconsolidated substrates)	Ripples are defined as dune systems with a wavelength =< 0.6 m. If the wavelength > 0.6 m and the height >= 0.075, the substrate is classed as a dune (Ashley, 1990).
Slope	[TBC (Wilson et al. (2007) talk about multi-scale slope analysis, but do not provide guidelines on an appropriate rise/horizontal distance ratio.)]
Profile / Morphometry	[High profile reefs are >=1 m above the surrounding substrate. Low profile reefs are <1 m above the surrounding substrate. Is this correct?]
Texture	Wentworth Scale
Complexity	[The scheme used in Vanessa Lucieer's PhD (to be published soon)]

Table 9. Decision rules for Biomodifiers

Biomodifier	Decision Rule
Density	[This varies between species and agencies. For Victorian seagrass, dense = benthos cannot be seen; medium = leaves of adjacent plants touch but benthos can be seen; sparse = leaves of individual plants do not touch. For SA: sparse = 0-25%; Medium = 26-85%; Dense = >85% cover]
Spatial Distribution (biota)	[Continuity/patchiness is driven by resolution of mapping units. TBC]
Sponge	[These categories were listed as biomodifiers. However, we are unsure as to how they'd be used to modify the categories listed in the classification scheme.]
Coral	
Rhodoliths	

Table 10. Decision rules for Environmental modifiers

Environmental Modifier	Decision Rule
Wave Exposure	[TBC]
Water Clarity + Depth	[TBC]
Current Flow	[TBC]
Depth Zone	Inner-shelf: 0-20 m; Mid-shelf: 20-60 m; Outer-shelf: 60-200 m.
Estuarine / Riverine Plumes	[TBC]
Temperature	These categories are distinguished using the IMCRA bioregionalisation (IMCRA, V 4.0, 2006)

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National Land & Water Resources Audit
An Initiative of the Natural Heritage Trust

An Australian Greenhouse Office and NLWRA Partnership project

Workshop Report

National Intertidal/Subtidal Benthic Habitat Classification Workshop

August 7/8 2007, CSIRO Headquarters, Castray Esplanade, Hobart

Executive Summary

There were two objectives for the workshop. The first was:

- To identify a practical, valid habitat classification scheme (including the decision rules) that will enable the collation of data sets into a national map of key intertidal and subtidal estuarine, coastal and marine (ECM) habitat types, including mangroves, saltmarshes, seagrasses, macroalgae, rocky reefs and coral reefs.

The second objective was:

- To identify a pathway towards the adoption and application of such a scheme, including identifying ECM habitat data sets and their custodians and identifying a work plan.

The scope of the workshop subject matter was limited to the habitats between the highest astronomical tide (HAT) and approximately 50 - 70 m depth. The classes of the scheme are those typically used for habitat mapping and are conceptually similar to terrestrial land cover mapping. They are not bioregionalisation or ecosystem classes though they may contribute to the development of both. They are also not micro-community classes, as the intention is to limit the scheme to habitat mapping rather than species mapping.

Participants came from each of the states, the NT and the project partners: the Australian Greenhouse Office, the National Land and Water Resources Audit, Geoscience Australia and the CSIRO (See Appendix A for a complete list). Each participant identified the purposes (uses) of a habitat classification scheme within the state or territory that they represented. Common definitions were established, conceptual models of habitat mapping were outlined and a benthic habitat classification scheme synthesised from existing state schemes was presented as a starting point. The participants then proceeded to develop a new national scheme including decision rules to assist with defining the boundary between classes.

The outcomes of the workshop included:

- A draft national intertidal/subtidal benthic habitat classification scheme with decision rules.
- In principle agreement by the participants to the national classification scheme.

- The agreement of the participants to form a reference group for the continued development and oversight of the national classification system.
- A work plan was formed for establishing the national scheme and implementing the scheme through the collation of a national habitat map.

Note: the national scheme itself will be written up in detail in the scheme documentation – the following is a brief record of the workshop.

Workshop Preparation

During the preparation phase of the workshop, key habitat mapping experts were contacted and consulted besides the workshop participants including Chris Simpson, Kevin Bancroft, Gary Kendrick, Doug Fotheringham, Bryan McDonald, Rob Williams, Ray Lawrie, Malcolm Dunning and John Beumer. This group provided input into the collation of habitat classifications and their decision rules. Potential workshop participants were also identified. Prior to the workshop, participants were asked to provide resource documents and respond to questions about both the purposes to which habitat mapping is put in their state or territory as well as the sensors used to map the habitats. Based on this knowledge, a habitat mapping conceptual model was produced to assist the workshop. A draft national classification scheme was synthesised from the existing state schemes by identifying both the commonalities and ambiguous or unresolved aspects of the schemes. A discussion paper was distributed to all participants prior to the workshop.

Workshop Agenda

Day 1:

- Introduction
- Discussion of purposes for habitat mapping (AGO, NLWRA, GA, state agencies, research)
- Workshop scope (physical and thematic)
- Definitions
- Presentation of conceptual model for habitat, geomorphological and biotic mapping
- Presentation of proposed national habitat classification scheme
- Group discussion of proposed national habitat classification scheme

Day 2:

- Group discussion about decision rules for the classification scheme
- In principle agreement on classification scheme and decision rules?
- Identification of a work plan for adoption and implementation

Purposes for Habitat Classification

Collation of responses from participants resulted in the following broad categories:

Low Resolution Mapping (<1:40 000):

- Marine regional planning

Medium Resolution Mapping (1:25 000 – 1:40 000):

- This resolution of mapping is regarded as "**general purpose**" mapping and has many uses, such as aquaculture planning and emergency response (for example, oil spills)
- Natural Resource Management Regions
- Marine Protected Areas (planning
- Fisheries Management

High Resolution Mapping (>1:25 000):

- Environmental Impact Assessment
- Environmental monitoring

Workshop Presentations, Processes and Discussions

Please note: the entire scheme will be written up in detail in the scheme documentation – the following is a brief record of the workshop.

<u>Workshop Scope:</u>

Benthic habitats from the Highest Astronomical Tide (HAT) to a depth of approximately 50 - 70 metres were recognised as the scope of the scheme. This is commonly regarded as the most productive region biologically and is broadly related to the photic zone or "inner shelf".

In terms of the broad Australian hierarchal classification scheme for marine habitats presented by the National Oceans Office (NOO, 2002; adapted from Butler et al, 2001), the workshop focussed on the primary and secondary biotope and biological facies levels. This is the usual domain of "habitat mapping" as carried out on a broadscale by state and territory governments. The conceptual similarity of this form of mapping to terrestrial land cover mapping was noted a number of times during the workshop, and assisted in making decision about classes and decision rules.

<u>Definitions:</u>

To establish common understandings among the workshop participants the workshop discussed and adopted some common definitions. These will be presented in the Scheme documentation. A key definition introduced a new term – "structural macrobiota", which is, in essence, an attempt to define the marine version of the role that terrestrial vegetation (i.e. plants) plays in forming habitats. Structural macrobiota are habitat-forming species (i.e. those that create habitats for other species by significantly altering the spatial complexity of a site) and include plants (e.g. seagrasses, mangroves), attached protists (e.g. macroalgae) and attached macrofauna (e.g. corals, sponges, ascidians).

<u>Habitat Mapping Conceptual Model:</u>

After a comparison of existing classification schemes from around Australia, a conceptual scheme was synthesised using the component parts of the schemes. The model is defined verbally as:

4. With a given purpose in mind,
5. Make observations (with sensors) of "real world" properties (attributes) in time and space
6. Map observations using decision rules as

- discrete (polygon) maps via
  - Categorising (classification scheme)
- continuous field (surface) maps via
  - Categorising (classification scheme)
  - Modelling
  - Interpolation

"Real world" properties were grouped along the lines of Diaz et al (2004) into substrate, biota and environmental processes. Note that some sensors allow more properties to be observed. The collected observations can then be classed in many ways including into "habitat map" classes.

National Habitat Classification Scheme:

The synthesised national scheme was proposed to the workshop as a starting point for discussion. The participants then proceeded to evaluate the proposed scheme and modify it to make it consistent with their respective individual schemes. This process was designed to enable the collation of the various agencies' data into a national data set. It involved identifying the scheme **classes** and their position in the hierarchy. A key point to note here is that almost any of the observable properties (attributes) could be used at any point in the classification. For example, reef profile could be placed high in the hierarchy or be simply added to the list of modifiers. Those attributes incorporated into the scheme are those that are easily and widely mapped as well as being ecologically significant.

A suggestion was made to develop a national catalogue of reference images that would hold images that represented clear examples of the agreed classes

Decision rules were defined to provide guidance on where the class boundaries should occur. This is a particularly challenging process as most classes intergrade, and specific examples can often be found that confound the rules. This is the nature of crisp classification systems and some divisions are more arbitrary than others. Boundaries between the classes were defined using observable or readily mapped properties. These properties included, primarily, percentage coverage and particle size. Note that percent cover estimates require a reference size for the area used to define the percent cover – in most cases reference areas were also set.

The following morning, the National Tidal/Subtidal Benthic Habitat Classification Scheme for habitats between the HAT and 50 – 70 metres, was agreed to in principle. Decision rules to separate classes were also agreed upon. Extensive discussion of properties (referred to as modifiers) identified national standards wherever possible. Further work is required on the definition of these modifiers.

The participants all identified the most suitable data sources and custodians.

Colour schemes for mapping were discussed, though no firm conclusions were reached – however it was noted that there was a preference for colour schemes that were intuitively easy to interpret i.e. greens for seagrass, yellows for sand and browns for rock.

Work Plan:

1. The workshop participants agreed to form a reference group for the further development of the national scheme.

2. The NLWRA/AGO partnership will be the secretariat to the reference group and will facilitate the creation of the National Scheme, including:
    - Documenting the national scheme (classes, decision rules, modifiers),
    - Facilitate the development of a national habitat mapping reference image catalogue. This could be modelled on, for example, the representative photos on the SEAMAP web page (http://www.utas.edu.au/tafi/seamap/).
3. The NLWRA/AGO partnership will generate a National ECM Habitat Map. Firstly, they will collaborate with the workshop participants and the key custodians to collate a national ECM data set. Then, the national classification scheme will be applied to the data set to produce a National ECM Habitat Map. It was noted that some participants anticipated applying the scheme to their own data sets as simply another set of attributes.

Workshop Outcomes

1. Unanimous agreement, in principle, to the adoption of the National Intertidal/Subtidal Benthic Habitat Classification Scheme developed at the workshop.
2. A reference group to oversee the documentation of the National Habitat Classification Scheme was established.
3. A Work Plan for creating the National Habitat Map was produced.

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Diaz, R. J., M. Solan and R. Valente (2004). "A review of approaches for classifying benthic habitats and evaluating habitat quality." Journal of Environmental Management(73): 165-181.

Appendix A. Workshop Participants:

Name	**Org**	**State**	**Phone**	**email**
Richard Mount	UTAS/NLWRA	Tas	03 6226 2106	Richard.Mount@utas.edu.au
David Ball	PIRVic	Vic	03 5258 0210	David.Ball@dpi.vic.gov.au
Alan Jordan	NSW	NSW	02 4916 3874	alan.jordan@environment.nsw.gov.au
Vanessa Lucieer	TAFI, UTAS	Tas	03 6227 7219	v_halley@utas.edu.au
Neil Smit	NRETA	NT	08 8920 9271	Neil.Smit@nt.gov.au
Len McKenzie		Qld	07 4057 3731	Len.McKenzie@dpi.qld.gov.au
Ewan Buckley	DEC	WA	08 9336 0108	Ewan.Buckley@dec.wa.gov.au
Elvira Poloczanska	CSIRO	Tas	03 6226 1708	Elvira.Poloczanska@csiro.au
David Miller		SA	08 8124 4899	miller.david2@saugov.sa.gov.au
Rob Thorman	NLWRA, AG	ACT	02 6263 6039	Rob.Thorman@nlwra.gov.au
David Ryan	Geoscience Australia, AG	ACT	02 6274	David.Ryan@ga.gov.au
Phillippa Bricher	UTAS	Tas	03 6226 1981	pbricher@utas.edu.au
Jenny Newton	UTAS	Tas	03 6226 1981	jbnewton@utas.edu.au

Appendix B

Appendix B. Components of the habitat mapping process, which moves from left to right across the table.

"Real world"	Potentially observable properties (i.e. attributes)			Sensor/s	Observed properties	Decision Rules	Classifications A = Assumed, O = Observed		
	Substrate	**Biota**	**Processes**				**Habitat Mapping**	**Biodiversity**	**Geomorphology**
Sand Habitat	Soft sediment fine sand calcareous macropattern/ relief etc	benthic microalgae diatoms invertebrates vertebrates etc	depth temperature exposure hydrology salinity light offshore/ nearshore	e.g. aerial photography	Soft sediment	Re feature detection (i.e. with depth)	1- Soft sediment (O) 2 - no structural macrobiota (O) 3 – sand (A)	soft bottom assemblage (A)	Fabric: sand (A)
				e.g. u/water video	Soft sediment Sand Fine sand Benthic microalgae invertebrates	Re particle sizes Re biota	1- Soft sediment (O) 2 - no structural macrobiota (O) 3 – sand (O) Mod – fine sand (O)	soft bottom assemblage (O)	Fabric: fine sand (O)
				e.g. acoustic swath mapper	Soft sediment macropattern	Re hardness/ roughness Re topographic definitions	1- Soft sediment (O) 2 - no structural macrobiota (A) 3 – sand (A)	soft bottom assemblage (A)	Fabric: sand (A) Form: mega ripples (O) Processes: paleo inundation (A)
Seagrass Habitat	Soft sediment fine sand silicaceous macropattern/ relief etc	seagrass algae invertebrates vertebrates fish etc	depth temperature exposure hydrology salinity light	e.g. aerial photography	Submerged aquatic vegetation (SAV)	Re density, patchiness, percent cover	1 - Soft sediment (A) 2 - structural macrobiota (O) 3 – seagrass (A)	seagrass associated assemblage (A)	Fabric: sand (A)
				e.g. u/water video	Soft sediment Sand seagrass seagrass spp. Epiphytic macroalgae vertebrates	Re epiphytic loading Re density, patchiness, percent cover Re biota	1 - Soft sediment (A) 2 - structural macrobiota (O) 3 – seagrass (O) Mod – seagrass spp. (O)	seagrass associated assemblage (O)	Fabric: fine sand (A)