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Supplementary Report to the Final Report of the Coral Reef Expert Group:

S1. Practical taxonomy for RIMReP Coral Reef Monitoring

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The Great Barrier Reef Marine Park Authority acknowledges the continuing sea country management and custodianship of the Great Barrier Reef by Aboriginal and Torres Strait Islander Traditional Owners whose rich cultures, heritage values, enduring connections and shared efforts protect the Reef for future generations.

Published by the Great Barrier Reef Marine Park Authority

ISBN 9780648589266

A catalogue record for this publication is available from the National Library of Australia

This publication should be cited as:

Babcock, R., and Bridge, T. 2020, *Supplementary Report to the Final Report of the Coral Reef Export Group: S1 Practical taxonomy for RIMReP Coral Reef Monitoring,* Great Barrier Reef Marine Park Authority, Townsville.

Front cover image: Close-up of bright yellow polyps of a Turret coral at night.

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Contents

1.0 Executive Summary

Current approaches used in benthic monitoring programs, particularly with respect to classifying benthic substrata and biota, were reviewed to provide the basis of recommendations in relation to the practical application of standardised and easily integrated approaches. The basis for these recommendations are that they are appropriate in terms of generating information that is both fit-for-purpose and cost-effective in terms of informing management decisions, providing for consistent current and future reporting mechanisms, and for generating new scientific understanding through its application in longitudinal ecological observations. Importantly, consideration was also given to applications that had the potential to be used in or applied to provide a common basis for integrating disparate current monitoring programs within the Reef 2050 Integrated Monitoring and Reporting Program (RIMReP). Such integration can only be achieved when data standardisation and compatibility among methodologies is assured. Furthermore, the standardisation of classifications will be important in facilitating machine learning and helping monitoring programs transition to automated image processing which has the potential to greatly expand the scope and timeliness of monitoring programs on the Great Barrier Reef (the Reef).

Candidate classification schemes are discussed and it is recommended that a scheme such as CATAMI (Collaborative and Automated Tools for Analysis of Marine Imagery) which is already widely used in Australia, be adopted and tailored using input from all stakeholders for use by Reef monitoring programs.

2.0 Introduction

A range of coral reef monitoring programs are currently being conducted within the Great Barrier Reef World Heritage Area (World Heritage Area), including fifteen initiatives (Cheal and Emslie 2018). These programs use a range of methods and record and/or report using differing metrics (quantitative vs qualitative, transect vs point, in-water vs photographic, species vs functional group) developed to address criteria or based on the history of each program's development. Due to the size of the Great Barrier Reef (the Reef) it is unlikely that any single program would be able to address all the monitoring needs within the GBRWHA, and so the existence of multiple programs presents a potential benefit in terms of the overall breadth and depth of coverage across multiple reefs and diverse taxa.

It is one of the roles of RIMReP to harness this potential, yet one of the key obstacles to achieving this is the use of a common classification and data reporting framework that can be used by all parties. Given that these various monitoring programs have been established for different purposes and are independently funded, it is unrealistic to expect them to fundamentally change the way they record and report data. What is therefore required is an overarching classification framework into which each program's data can be translated in an unambiguous and ecologically valid way. In considering this, it needs to be acknowledged that it is unlikely to be possible for records to be classified post-hoc to finer levels of taxonomic resolution (i.e. from family to species). Instead, common ground must be found at higher taxonomic or functional levels of classification (i.e. from species to family or functional group).

Decisions about appropriate levels of classification involve several trade-offs. Typically, finer taxonomic resolution at the species level is aspired to as it would provide the greatest amount of detail, however it is not always achievable due to factors such as image resolution and observer expertise (Carleton and Done 1995), the lack of which can lead to greater error rates in identification. Conversely, coarser levels of classification may be less prone to error due to image quality, and require less expertise and training to implement. The concern with these approaches to classification is that they may not include important information on benthic biodiversity and composition with the result that important trends and processes may be overlooked. The question asked by ecologists has therefore been what level of taxonomic resolution is sufficient to address the ecological and/or management questions at hand.

Studies of so-called "taxonomic sufficiency" have generally concluded that similar ecological patterns are revealed whether they are conducted at species level or at higher taxonomic levels such as genus or even family (Bates et al. 2007, Bevilacqua et al. 2008). This pattern holds across a range of ecosystem types (intertidal rocky shores; Bates et al. 2007, Soft sediments; Ferraro and Cole 1992, Fontaine et al. 2015), including coral reefs (Denis et al. 2017) and for taxa including not only corals (Madin et al. 2016, Denis et al. 2017) but also algae and sponges (Bell and Barnes 2002, Díez et al. 2010). Furthermore, there is a growing trend in benthic ecology to use growth form or other morphological grouping (Carleton and Done 1995), or functional or trait-based groups of taxa with similar ecological properties but potentially with diverse taxonomic affinities, when interpreting ecological patterns and benthic ecological processes (Bell et al. 2006 Cadotte et al. 2011, Mouillot et al. 2013, Madin et al. 2016, Darling et al. 2017). Studies of both taxonomic sufficiency and the utility of functional group approaches therefore conclude that while species-level identifications may be the gold standard, any loss of information due to the use of higher level classification schemes is likely to be relatively minor. Similar conclusions have also been drawn in relation to the classification of mobile organisms such as fish (Richardson et al. 2017). In this context it is important to remember that the results of even the most rigorous ecological studies and monitoring programs do not usually report at the species level, but at higher levels such as family, growth form or functional group (e.g. LTMP, MMP) – particularly for benthic biota. Consequently, there should not be any major conceptual obstacles to implementing common frameworks for classification and reporting on coral reefs.

It is important that any classification scheme be structured so that it is flexible and can, as much as possible, accommodate existing classifications within it. Fortunately, most such classifications are structured hierarchically in a way such that detailed species level classifications can be aggregated as necessary at higher taxonomic levels (e.g. Fig. 1). The next question is therefore to decide whether a classification scheme needs to be devised to provide this framework or if existing schemes can be used effectively and, if so, which scheme provides the best potential for integrating coral reef science and monitoring on the Reef in the context of RIMReP.

Most Reef monitoring programs (Table 1) include representatives of fish, sessile benthos and mobile invertebrates, though some do not include fishes (e.g. MMP). Some groups such as fish are identified to species level, though even these programs include only a subset of taxa (e.g., LTMP does not include cryptic fishes). While all programs include recording and reporting of sessile benthos, there appear to be several levels of classification employed and, even where taxa such as corals are identified to nominally the same level (such as growth form), it is not always explicit whether the growth forms employed are actually the same. The lack of focus on the importance of standardised classification approaches is evident even in literature prepared as guidance for planning and executing monitoring programs (Hill and Wilkinson 2004), which essentially ignore this issue.

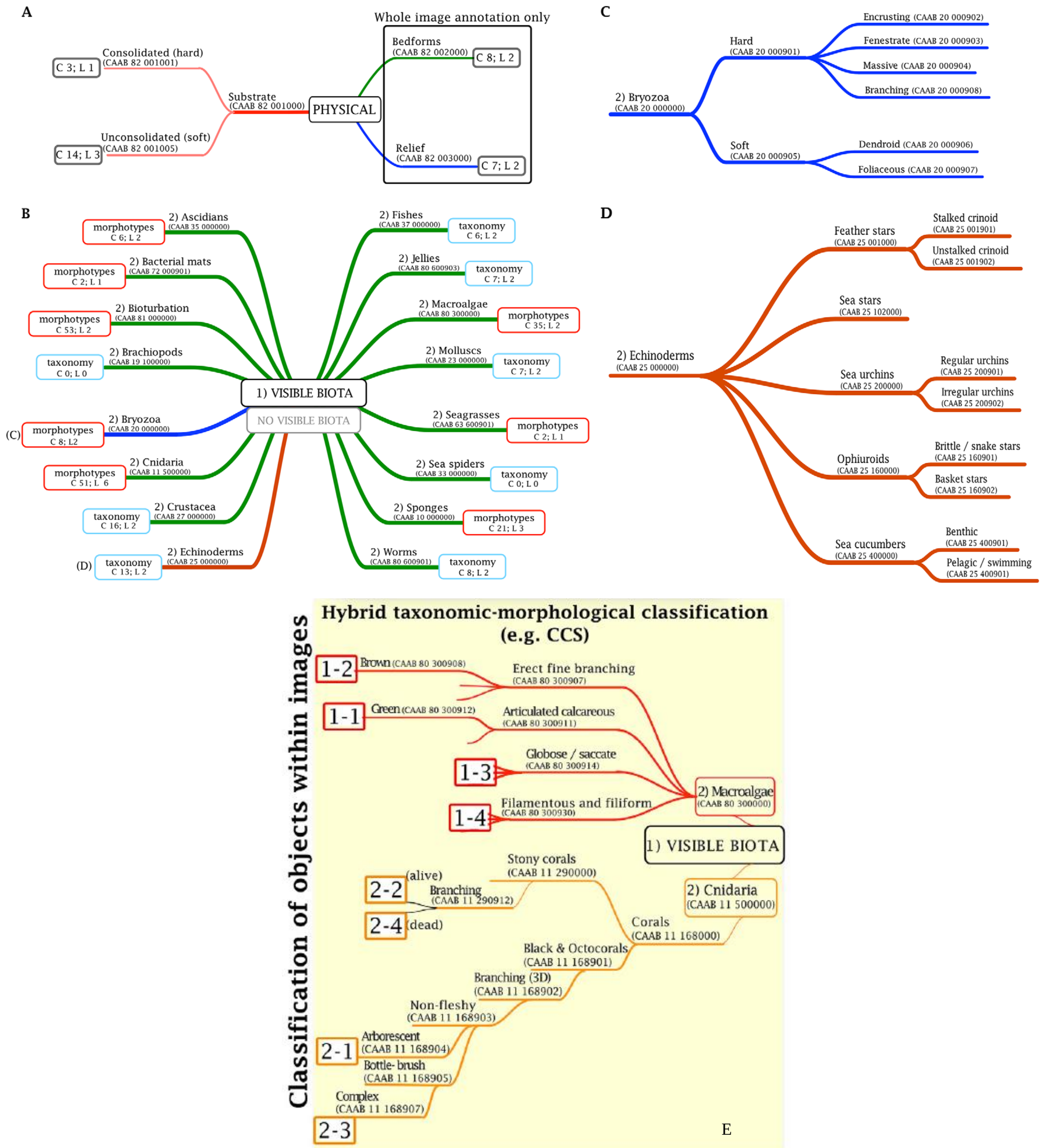

Figure 1. Diagrammatic Schema of the CATAMI classification (From Althaus et al. 2015). A-D, general levels of classification, E; schema detail relating to corals. Further specificity classifying taxa to genus or species level can be added, as required.

Table 1 Synthesis of Great Barrier Reef monitoring programs

INSHORE ZONING EFFECTS	LTMP: HISTORICAL	LTMP: ZONING EFFECTS	EYE ON THE REEF: RAPID MONITORING	EYE ON THE REEF: RHIS	EYE ON THE REEF: TOURISM WEEKLY	REEF CHECK	MMP	GLADSTONE HARBOUR	NQBP: ABBOT PT, MACKAY & HAY PT.	REEF LIFE SURVEYS	CORAL WATCH	CROWN-OF-THORNS STARFISH OUTBREAK	CATLIN SEAVIEW SURVEYS	RECOVERY OF THE GBR
Fish Species Sessile benthos growth forms	Fish Species Sessile benthos genera, growth form, juveniles,	Fish Species Sessile benthos genera, growth form, juveniles,	Fish Some iconic species, functional groups & families. Sessile benthos coral, algae, rubble Mobile inverts: crown-of-thorns starfishs, Drupella, other inverts	Fish None Sessile benthos growth forms,	Fish Herbivores, iconic species, shark species Sessile benthos growth forms,	Fish Family, some iconic species. Sessile benthos growth forms	Fish None Sessile benthos genera, growth form	Fish None Sessile benthos genera, growth form	Fish None Sessile benthos genera, growth form	Fish Species Sessile benthos growth form, debris categories, macro-invert species	Fish None Sessile benthos four coral forms	Fish None Sessile benthos coral and algal growth forms Mobile inverts:	Fish None Sessile benthos coral and algal family and growth forms Mobile inverts:	Fish None Sessile benthos coral and algal growth forms, four size classes Mobile inverts: none

Mobile inverts: none	Mobile inverts: genera Manta hard & soft cover, Crown-of-thorns starfish, Shark species, Coral trout	Mobile inverts: genera Manta hard & soft cover, Crown-of-thorns starfish, Shark species, Coral trout		Mobile inverts: crown-of-thorns starfish Other rubbish, disease	Mobile inverts: crown-of-thorns starfish, Drupella, other inverts.	Mobile inverts: genera, species Other debris categories, Fishing line, megafauna	Mobile inverts: none	Mobile inverts: none	Mobile inverts: none	Mobile inverts: none	Mobile inverts: none	crown-of-thorns starfish, Drupella	macro-inverts (Crown-of-thorns starfish, Sea cucumber etc grouped)	

3.0 Classification methodologies used in ecological monitoring programs on the Great Barrier Reef

3.1 Fish

Currently only seven of the Reef monitoring programs monitor fish and, of these, four routinely classify fish to species level (Table 1). The other three programs collect data on some "iconic" species, some shark species, and some families and functional groups. None of the programs consider small-bodied but highly diverse 'cryptic' taxa (e.g., Gobiidae, Bleniidae) due to detectability issues. Two of these programs are variants of Eye on the Reef, and use identical classifications, however it is not clear to what extent they are compatible with the third program, Reef Check. There may be scope to align the classifications of these programs to provide a more consistent overall data set.

3.2 Sessile benthos

All reef monitoring programs record sessile benthos, commonly using growth form as a core level of classification. In some cases (LTMP, MMP, Gladstone and NQBP) classification of coral (but presumably not all taxa) is completed to genus level in addition to recording growth form, and this is presumably achieved post hoc by allocating a particular growth form to each genus. While there is likely to be a high level of consistency among these programs since they are conducted by the same organisation (Australian Institute of Marine Science), there may not be consistent classification among the other programs in terms of the allocation of growth forms or the levels of classification of corals. For algae and sponges, no program routinely classifies taxa at anything but growth form level, with the possible exception of some highly characteristic genera (e.g. the brown alga *Turbinaria*).

3.3 Mobile invertebrates

Eight monitoring programs record mobile macroinvertebrates, with most focusing on charismatic or problematic coral feeding species (Crown-of-thorns starfish and *Drupella*). Only the two LTMP programs record mobile invertebrates to genus level (Table 1).

3.4 Hierarchical classification schemes

Standardised classification schemes or "vocabularies" have been developed in a number of regions around the world including Australia (Althaus et al. 2015). These schemas have been developed with a view to providing common approaches that will lead to improved understanding and outcomes for all participants. As stated by Althaus et al.,

> *"annotations can be re-used or re-analysed, and amalgamated across datasets to address new questions at broader scales. Not only does this maximise the return on investment in collecting and processing imagery, it also allows the generation of amalgamation data sets necessary for state of the environment reporting and for addressing conservation and ecosystem-based questions at the broad scales most relevant to management."*

Ideally such classifications can be flexible enough to include useful high resolution classifications where possible while also providing a consistent common framework at more general levels. One such approach recently developed in Australia is the Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) scheme (Althaus et al. 2015). The CATAMI scheme is flexible and has been rapidly taken up by the marine science community in Australia. This is a strength of the CATAMI scheme as it is important that whatever scheme is adopted by the RIMREP program is compatible with and easily integrated into ecological programs and databases at the national level such as those conducted within the Marine Biodiversity Hub and the Australia Ocean Data Network. While other schemes such as the Combined Biotope Classification Scheme (CBiCS) are being used in Australia (Ierodiaconou. 2017), these are specifically tailored with respect to greater taxonomic detail in particular biogregions. Clearly, such schemes may offer advantages in local applications but would have to be heavily modified for use in coral reef ecosystems. Additional levels of taxonomic specificity can be added to the CATAMI scheme as required, with the advantage that these sit within a well-established and well supported general schema. Other approaches to classification such as Reef Finder also exist (http://www.russellkelley.info/print/reef-finder/) however these are designed for non-expert users and based on common visual attributes rather than starting from taxonomic principles. As such they are more of an identification tool rather than a classification scheme. Reef Finder is not currently being used as a classification scheme in any monitoring programs within Australia. In addition, it is applicable only to corals, and relies on the identification of features that may not be visible in benthic images, limiting its utility for autonomous monitoring. Neither CATAMI or CBiCS schemes have been evaluated with coral reef biota in mind, therefore a quantitative evaluation of available options could be considered prior to broad adoption across the Reef. This could consist of comparisons of several classifications based on a simulation study using a common data set. International classifications are not recommended as the primary use of Reef data sets is likely to be for inter-regional comparisons within the Reef and northern Australia.

An important consideration when deciding on the classification approach to be used within RIMReP benthic monitoring is that there are parallel initiatives to develop and implement computerised image processing programs that would greatly accelerate the speed with which images can be processed and data made available to users. RIMReP would greatly benefit from such tools if they were routinely available for image data from the Reef. The development of these tools is based on machine learning processes in which expert classifications are used to train computer programs to achieve required levels of accuracy. These programs rely on large numbers of images and must utilise a common classification scheme. A number of such programs (Bewley et al. 2015, Mahmood et al. 2016) are ongoing around Australia, mostly based around CATAMI classifications. RIMReP would derive significant synergies if it were to align itself with these programs.

4.0 Summary and recommendations

In the interests of advancing the integration of coral reef monitoring schemes on the Reef, it is important that steps are taken to explicitly align and, where possible, standardise, classifications used in separate monitoring programs, and the terminology used within these programs. In most cases this is not likely to require material changes to the monitoring programs themselves, though in certain cases this may be desirable.

We recommend that the CATAMI classification scheme is considered for adoption, based on the flexibility across a wide range of taxonomic groups and already widespread adoption of the CATAMI schema within Australia. A further consideration is the potential for use of the CATAMI classification to provide significant synergies with parallel initiatives both within RIMReP and nationally for machine-learning-based automated image processing tools. A workshop including representatives of all monitoring programs should be convened in order to arrive at a consensus around exactly how to implement a standardised approach and integrate it into RIMReP reporting mechanisms.

5.0 References

Althaus F, Hill N, Ferrari R, Edwards L, Przeslawski R, Schönberg CHL, et al. (2015) A Standardised Vocabulary for Identifying Benthic Biota and Substrata from Underwater Imagery: The CATAMI Classification Scheme. PLoS ONE 10(10): e0141039. doi:10.1371/journal.pone.0141039

Bates CR, Scott G, Tobin M, Thompson R (2007) Weighing the costs and benefits of reduced sampling resolution in biomonitoring studies: Perspectives from the temperate rocky intertidal. Biological Conservation 137 617–625

Bell JJ, Barnes DKA (2002) Modelling sponge species diversity using a morphological predictor: a tropical test of a temperate model Journal of Nature Conservation 10, 41–50

Bell JJ, Burton M, Bullimore B, Newman PB, Lock K (2006) Morphological monitoring of subtidal sponge assemblages Marine Ecology Progress Series. 311: 79–91,

Bevilacqua S, Claudet J, Terlizzi A (2013) Best Practicable Aggregation of Species: a step forward for species surrogacy in environmental assessment and monitoring. Ecology and Evolution; 3(11): 3780–3793

Bewley M, Friedman A, Ferrari R, Hill N, Hovey R, Barrett N, Marzinelli EM, Pizarro O, Figueira W, Meyer L, Babcock R. (2015) Australian sea-floor survey data, with images and expert annotations. Scientific data. 2:150057.

Cadotte MW, Carscadden K, Mirotchnick N, (2011) Beyond species: functional diversity and the maintenance of ecological processes and services Journal of Applied Ecology, 48, 1079–1087

Carleton JH. Done TJ (1995) Quantitative video sampling of coral reef benthos: large-scale application Coral Reefs 14:35-46

Cheal AJ, Emslie MJ (2018) Synopsis of current coral reef monitoring on the Great Barrier Reef RIMReP report 35pp.

Denis V, Ribas-Deulofeu L, Sturaro N, Kuo CY, Chen CA. (2017) A functional approach to the structural complexity of coral assemblages based on colony morphological features Scientific Reports 7: 9849 DOI:10.1038/s41598-017-10334-w

Díez I, Santolaria A, Gorostiaga JM (2010) Different levels of macroalgal sampling resolution for pollution assessment Marine Pollution Bulletin 60 1779–1789

Ferraro SP, Cole FA (1992) Taxonomic Levels Sufficient for Assessing a Moderate Impact on Macrobenthic Communities in Puget Sound, Washington, USA Canadian Journal of Fisheries and Aquatic Sciences, 48:1184-1188

Fontaine A, Devillers R, Peres-Neto PR, Johnson LE. (2015) Delineating marine ecological units: a novel approach for deciding which taxonomic group to use and which taxonomic resolution to choose Diversity and Distributions 21:1167–1180

Hill, J Wilkinson C. (2004) Methods For Ecological Monitoring Of Coral Reefs A Resource For Managers Australian Institute Of Marine Science, Townsville Australia, 117pp.

Ierodiaconou D. (2017): Victorian Benthic Habitats - Port Phillip Bay (CBICS). Institute for Marine and Antarctic Studies, University of Tasmania.

http://metadata.imas.utas.edu.au:/geonetwork/srv/en/metadata.show?uuid=9737f03b-8e6b-4a93-b530-d7687d1a8a01

Madin JS, Hoogenboom MO, Connolly SR, Darling ES, Falster DS, Huang D, Keith SA, Mizerek T, Pandolfi, JM, Putnam HM, Baird AH. (2016) A Trait-Based Approach to Advance Coral Reef Science. Trends in Ecology & Evolution, 31:419-428

Mahmood A, Bennamoun M, An S, Sohel F, Boussaid F, Hovey R, Kendrick G Fisher RB (2016) Automatic annotation of coral reefs using deep learning. In: *Oceans 2016 mts/IEEE Monterey* (pp. 1-5). IEEE.

Mouillot D, Graham NAJ, Villeger S, Mason NWH, Bellwood DR (2013) A functional approach reveals community responses to disturbances Trends in Ecology & Evolution 28:167-177

Richardson LE, Graham NAJ, Pratchett MS, Hoey AS (2017) Structural complexity mediates functional structure of reef fish assemblages among coral habitats. Environ Biol Fish 100:193–207

5.1 Works consulted

Costello MJ, Bouchet P, Boxshall G, Fauchald K, Gordon D, Hoeksema BW, et al. (2013) Global coordination and standardisation in marine biodiversity through the World Register of Marine Species (WoRMS) and related databases. PloS ONE. 8(1):e51629. doi: 10.1371/journal.pone.0051629 WOS:000313551500006. PMID: 23505408

Davies CE, Moss D, Hill MO. (2004) EUNIS habitat classification, revised 2004. Report to the European Topic Centre on Nature Protection and Biodiversity. European Environment Agency; European Topic Centre on Nature Protection and Biodiversity,DarlingES, Graham NAJ, Januchowski-Hartley FA, Nash KL, Pratchett MS, Wilson SK (2017) Relationships between structural complexity, coral traits, and reef fish assemblages Coral Reefs 36:561–575

Galparsoro I, Connor DW, Borja A, Aish A, Amorim P, Bajjouk T, et al. (2012) Using EUNIS habitat classification for benthic mapping in European seas: Present concerns and future needs. Marine Pollution Bulletin 64:2630–8. doi: 10.1016/j.marpolbul.2012.10.010 WOS:000313380800016. PMID: 23117202

Mount R, Bricher P, Newton J. (2012) National Intertidal/Subtidal Benthic (NISB) Habitat Classification Scheme. Hobart, Australia: Australian Greenhouse Office; National Land & WaterResources Audit; School of Geography and Environmental Studies, University of Tasmania, 2007. CMECS Team. Coastal and Marine Ecological Classification Standard. Marine and Coastal Spatial Data Subcommittee of the Federal Geographic Data Committee (FGDC), FGDC-STD-018-2012.