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Ningaloo Collaboration Cluster: Assessing invertebrate biodiversity on Ningaloo Reef: Validation of habitat surrogacy – Interim Final Report

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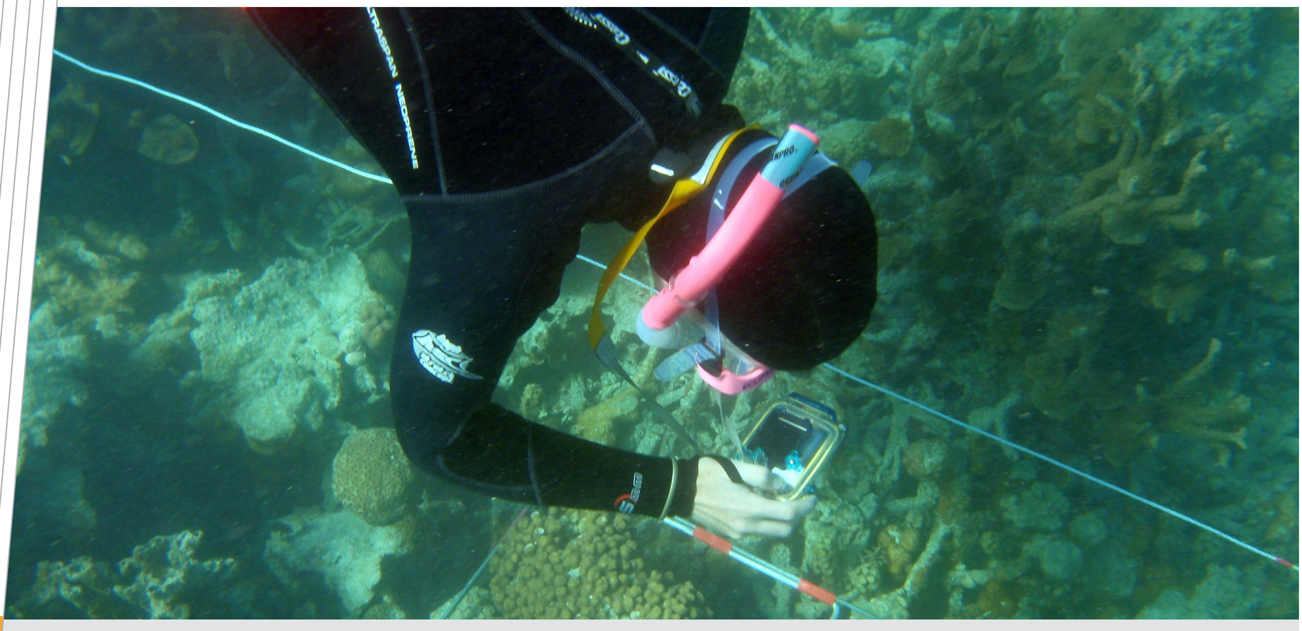

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This report is provided as an Interim Final Report because of changes in Project personnel and major illness in the team. The report provides an indication of the scope and broad findings of the research but not the detailed findings. Further information is available from Associate Professor Greg Skilleter (g.skilleter@uq.edu.au).

1 SUMMARY OF MAJOR FINDINGS AND THEIR IMPLICATIONS

1.1 Objectives

In this study, we examined the validity and efficacy of two easily characterised levels of surrogacy to predict the species or taxon richness. The two groups investigated were hard corals and benthic macro-invertebrates. The efficacy of surrogates was examined across two regions of Ningaloo Reef.

The core questions addressed were:

(i) Whether the defined combinations of habitats (mosaics), based on the physical composition of the habitat, represent the diversity of the hard corals and macroalgae that are the major contributors to the habitat. This is defined as Primary Level Surrogacy.

(ii) Whether the defined mosaics also represent the diversity of animals using the shallow water reef system, using one assemblage of the epibenthic macroinvertebrates as an example. This is defined as Secondary Level Surrogacy.

1.2 Outcomes

Based on preliminary analyses of the data, the habitat maps failed to provide a reliable surrogate for the composition of the (i) habitat-forming hard corals and macroalgae or (ii) the animals living on the sea floor. Hence maps predicting the distribution of major habitat types and the resultant mosaics (consistent and repeated combinations of particular groupings of habitats) may not at this stage provide adequate, reliable and repeatable representations of biodiversity within the shallow water lagoon of the Ningaloo reef system.

1.3 Non-technical summary

Effective management and monitoring of large marine protected areas is often based on detailed information about the distribution of marine habitats. This information has the potential to enable effective management, but only if it is actually a reliable indicator of marine biodiversity.

The concept of habitat surrogacy, or developing simplified measures of habitat to provide an indicator of habitats and their associated biodiversity, is widely established in terrestrial reserve planning and has also been applied in marine reserve planning, despite a lack of testing of the concept. However, if surrogates of habitat do not represent the habitats and their biodiversity in the field i.e. the surrogacy hypothesis is not upheld, decisions for the management and monitoring of the marine park, based on habitat information alone, may fail to protect a large proportion of the reef biodiversity. This may be a problem where the maps of habitat fail to reflect the distribution of rare and uncommon species.

High-resolution, geo-referenced habitat maps were developed as part of research on classifying habitats from remote sensing (Kobryn et al. 2011). These maps were used to identify specific combinations of habitats. Habitat maps are meant to provide the basis for identifying different areas of biodiversity. The development of zoning plans or other management actions are then, theoretically, able to make decisions on which areas to protect using information on habitat diversity and distribution. This is especially important for regions such as Ningaloo, where little detailed information is available for the distribution and abundance of most species.

Based on preliminary analyses of the data, these habitat maps failed to provide a reliable surrogate for the composition of the (i) habitat-forming hard corals and macroalgae and (ii) the animals living on the seafloor. Hence, maps depicting the distribution of major habitat types and the resultant mosaics (consistent and repeated combinations of particular groupings of habitats) may not at this stage provide adequate, reliable and repeatable representations of biodiversity within the shallow water lagoon of the Ningaloo reef system. Given the lack of detailed information about biodiversity in the shallow water lagoon along Ningaloo Reef, the high-resolution maps still provide the best possible information currently available for input into management and planning decisions. However, these results show that the maps need to be used cautiously and that zoning plans based solely on these maps should not be considered to represent all biodiversity on the reef.

Continued detailed sampling of different mosaics to test the surrogacy hypotheses would be valuable. Now that appropriate tests of these hypotheses have been devised, and the methods developed for collecting the appropriate data, it would be extremely cost-effective to continue this component of the project. Further detailed analysis of the relationship between the distribution of other groups of organisms (i.e. other components of biodiversity) and the different habitats and fine resolution analyses to generate the mosaics, incorporating factors such as depth and aspect into the selection of patches to be sampled would also be valuable.

1.4 Implications for Management

Given the lack of detailed information about biodiversity in the shallow water lagoon along Ningaloo Reef, the high-resolution maps still provide the best possible information currently available for input into management and planning decisions. However, the maps need to be used cautiously and zoning plans based solely on these maps should not be considered to represent all biodiversity on the reef.

1.5 Problems Encountered

The original hyperspectral imagery was collected in 2006, but the complications of the analysis, generation and validation of the maps showing the distribution of particular types of habitats and habitat mosaics, introduced a significant lag time before these maps could be assessed in the field. Our field studies were done in 2009 and it was evident that there had been significant changes in the distribution of some habitats, especially those in areas most exposed to human or natural disturbance. In some areas in the southern region, there had been major changes in the distribution of some habitat types. This suggests that field validation of the accuracy and reliability of the maps must be done, immediately prior to the application of surrogacy in conservation planning, if the intention is to use surrogacy to present the distribution, abundance and composition of species ostensibly occurring in those surrogates.

1.6 Further Developments

Continued detailed sampling of different mosaics to test the surrogacy hypotheses would be valuable. Now that appropriate tests of these hypotheses have been devised and the methods developed for collecting the appropriate data, it would be extremely cost-effective to continue this component of the project.

Further detailed analysis of the relationship between the distribution of other groups of organisms (i.e. other components of biodiversity) and the different habitats and fine resolution analysis to generate the mosaics, incorporating factors such as depth and aspect into the selection of patches to be sampled would also be valuable future work.

1.7 Acknowledgements

We thank Mike van Keulen and Fraser McGregor for the use of the North-West Marine Research station and advice on the logistics of sampling at Ningaloo. Ajax Diaz-Ruiz participated in some of the fieldwork and data validation. Ali McCarthy worked on this research as part of her Honours degree at the University of Queensland. We thank the CSIRO Collaboration fund for providing the funding for this research.

2 COMMUNICATION OF PROJECT RESULTS AND DATA

2.1 Publications and planned Publications

To be advised.

2.2 Communications

To be advised.

2.3 Presentations

Skilleter, G. McCarthy A., Loneragan, N. and Kobryn, H. (2010) Benthic biodiversity and surrogacy. Ningaloo Synthesis and Integration Workshop, Perth WA.

2.4 Student Projects

Alison McCarthy. 2010. Mapping coral reef biodiversity; Surrogacy at two levels. Honours Thesis. University of Queensland.

2.5 Data Accessibility

2.5.1 Who is the custodian of the data?

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2.5.2 Raw data and data products description

This project used the data products from Kobryn et al. (2011).

3 ASSESSING INVERTEBRATE BIODIVERSITY ON NINGALOO REEF: VALIDATION OF HABITAT SURROGACY

3.1 Summary

In this study, we examined the validity and efficacy of two easily characterised levels of surrogacy to predict the species or taxon richness in two specific groups, hard corals and benthic macro-invertebrates, across two regions of Ningaloo Reef. We used thematic maps showing the distribution of different types of habitat (e.g. sand, limestone pavement, rubble, macroalgae, hard and soft corals) and also different types of coral growth forms (e.g. branching, plate) (Kobryn et al. 2011). We elected to assess the value of these habitat maps as a surrogate for detailed information on the patterns of distribution of the biodiversity because such maps are easily understood, but flexible in the content and quantity of information they portray. For the first level of surrogacy, we determined whether the habitat maps accurately reflected the biodiversity of those organisms forming the primary structure on the reef. For the second level of surrogacy, we determined how well the maps identified the distribution of epibenthic, macro-invertebrates, including holothurians, sea stars, bivalves and gastropods.

The composition of the habitat-forming benthic assemblages in either of the mosaics (i.e. the hard-coral based mosaic and the macro-algal based mosaic) varied considerably between the two regions. The mosaics in each region were characterised by different species dominating the composition of those mosaics, therefore, the thematic maps could not be used to identify sites that consistently represented a defined set of species, the practical definition of a habitat surrogate. The selection of habitat mosaics in the two different management zones was more effective in representing the habitat-forming benthic species, although there was still a great deal of variability among the sites, especially for the macro-algal based mosaic.

The maps performed very poorly in representing the composition of the macro-invertebrate assemblages. First, the composition of the macro-invertebrate assemblages in either of the mosaics (i.e. the hard-coral based mosaic or the macro-algal based mosaic) was very different in each of the two regions, a function of the different numbers of species that were identified and/or the abundance of those species. The composition of the macro-algal based mosaic was extremely variable at the scale of sites in both regions. Thus, the thematic maps could not be used to identify reliably, sites belonging to a particular mosaic if the interest was on the macro-invertebrates. Second, in both regions, the two mosaics could not be distinguished from each other based on the composition of the macro-invertebrates. The numbers and types of macroinvertebrates found at any site were not reliably represented by the identification of that site as belonging to a habitat mosaic using the thematic maps. Again, the maps were not providing a consistent surrogate for the distribution or abundance of the macro-invertebrate assemblages.

Our tests of the validity of surrogacy, based on thematic habitat maps, were restricted to two specific types of mosaic, but the two mosaics examined were very common and widely distributed in the Ningaloo reef lagoon. At this stage, it is not clear whether habitat-based

surrogacy would be more or less effective for other types of mosaic, less common and less widely distributed than those based around hard-corals and macroalgae as the predominant components. The original hyperspectral imagery was collected in 2006, but the complications of the analysis, generation and validation of the maps showing the distribution of particular types of habitats and habitat mosaics introduced a significant lag time before these maps could be assessed in the field. Our studies here were done in 2009 and it was evident that there had been significant changes in the distribution of some habitats, especially those in areas most susceptible or exposed to human or natural disturbance. In some areas in the southern region, there had been major changes in the distribution of some habitat types, so much so, that areas shown as comprising one type of mosaic on the maps, were dominated by a completely different type of mosaic when sampling was done in 2009. This alone, requires that field validation of the accuracy and reliability of the maps must be done, immediately prior to the application of surrogacy in conservation planning, if the intention is to use surrogacy to present the distribution, abundance and composition of species ostensibly occurring in those surrogates.

3.2 Introduction

Marine Protected Areas (MPAs) are widely recognised as an effective and essential approach to conserving biodiversity. When successfully implemented, MPAs contribute to the conservation of living resources by protecting and maintaining essential ecological processes, preserving genetic diversity and ensuring sustainable use of species and ecosystems. The design of networks of marine protected areas is preferably based on detailed knowledge of each species' distribution, abundance and key life history characteristics plus information on how these species interact with each other and the biophysical environment in which they exist. In Australia and elsewhere in the world, there are however serious gaps in our knowledge of these biological characteristics for the greater proportion of species in the marine environment. This lack of information has required managers and scientists working on the conservation of biodiversity to make use of *surrogates* for the required information and these surrogates are often biophysical components of the system. One of the most commonly applied surrogates for biodiversity in the marine environment is the use of maps showing the distribution of core habitats. The degree of complexity of these maps is often quite variable, depending on the availability of the required data. In biogenic habitats, such as coral reefs, live organisms provide the primary structure of the habitat. On reefs this is primarily the corals, but also macroalgae and other benthic invertebrates such as sponges.

The concept of habitat surrogacy was introduced to facilitate the management of systems where there was inadequate data available on the distribution and abundance of the primary species and/or the collection of such data would be inappropriately expensive and complicated. The most appropriate method to determine whether surrogacy based on habitat maps is accurate would be to record the distribution and abundance of species within the different habitats and then compare this to the classification based on the broader categories of habitat. This, however, is not usually possible for the very reason that habitat surrogacy was introduced – the collection of such data on the distribution and abundance of the species is not practical, either because of cost or the scarcity of scientists with the necessary levels of taxonomic experience. We therefore devised a specific set of hypotheses that provided appropriate critical tests of the two levels of surrogacy.

First, if maps of habitat composition provide an effective and accurate surrogate for detailed information on the distribution of various reefal communities, different sites selected from these maps, as representing specific mosaics, should comprise ecologically similar assemblages of organisms. Second, sites belonging to one mosaic should be ecologically different from sites of a different mosaic. If these two conditions are met, then the thematic maps of habitat can be used as surrogates for the specific composition of the ecological communities. That is, an analysis of the composition of the ecological assemblages comprising (1) the habitat-forming benthic organisms and (2) the macro-benthic invertebrates, would show that sites within a particular mosaic were more similar to each other than they were to sites from a different mosaic and that this pattern was spatially and temporally consistent and recurring.

3.3 Materials and methods

In this study, we examined the validity and efficacy of two easily characterised levels of surrogacy to predict the species or taxon richness in two specific groups, hard corals and benthic macro-invertebrates, across two regions of Ningaloo Reef. We used thematic maps showing the distribution of different types of habitat (e.g. sand, limestone pavement, rubble, macroalgae, hard and soft corals) and also different types of coral growth forms (e.g. branching, plate) (Kobryn et al. 2011). These maps were generated from detailed analyses of data on bottom reflectance and bathymetry and subsequently supported by field validation, to identify sites for sampling. The specific thematic maps that were used were derived from the potential combination of 46 different classes of benthic habitat that had been characterised from the original spectral data (Kobryn et al. 2011). We elected to assess the value of these habitat maps as a surrogate for detailed information on the patterns of distribution of the biodiversity because such maps are easily understood, but flexible in the content and quantity of information they portray.

For the first level of surrogacy, we determined whether the habitat maps accurately reflected the biodiversity of those organisms forming the primary structure on the reef.

For the second level of surrogacy, we determined how well the maps identified the distribution of epibenthic, macro-invertebrates, including holothurians, sea stars, bivalves and gastropods. We elected to focus only on the large macro-invertebrates as they are easy to identify and count in the field, some of them support either commercial or recreational fisheries (e.g. holothurians or sea cucumbers) or have been subjected to illegal harvesting (e.g. *Trochus* - topshells and *Tridacna* – giant clams).

To make the task manageable, we focused on two specific types of mosaic (combinations of different types of habitat) from the range that were possible from combinations of the 46 classes of habitat. The two mosaics that were selected were widely distributed along Ningaloo Reef and, importantly, were abundant in the two regions where we were focusing our sampling efforts. The two mosaics differed primarily on the dominance of either hard coral or macro-algae, in association with limestone pavement and sand. Specific areas for sampling, representing each of the two mosaics, were located at random from maps showing the distribution of the mosaics in the two regions: Coral Bay and Warroora Station in the south and the Cape Range National Park in the north. The sites that were sampled were all located within the lagoon, extending from the mean high water mark to approximately 600m offshore. Sampling occurred on two occasions. In April – May 2009, data were collected to assess the validity of the two levels of surrogacy in the southern and northern regions of the Reef. In June-July, 2009, we assessed the validity of the two levels of surrogacy in different management zones in the southern region. This second component, examining differences among management zones, was done to assess the question of whether habitat map-based surrogates were effective when applied to areas of reef that may been in different condition, a consequence of varying levels of protection from human activity.

Surrogate Level 1: Composition of benthic biogenic habitat: At each site, a 9 m x 9m rope quadrat was laid out across the substratum. The quadrat was positioned within the chosen mosaic so that it was at least 15 m from the nearest boundary with another mosaic type. Digital photography was used to record the composition of the benthic cover within the rope quadrat. The quadrat was divided into nine, 3 m x 3 m sub-quadrats, four of which were photographed in detail using 1 x 1 m photo-quadrats, so that a total of 36 m^2 of the potential 81 m^2 of the rope quadrat was photographed. A total of 144 photos, taken at the same scale, were collected in each of the 9 x 9 m rope quadrats, using a digital camera in an underwater housing.

Surrogate Level 2: Macro-Invertebrates. After the digital photographs were collected, the 9 x 9 m rope quadrat was searched exhaustively for large sessile and mobile macro-invertebrates. All species of macro-invertebrates were identified and counted during parallel transects swum across the 81 m^2 area. As much as possible, the substratum and the habitat-forming cover were not disturbed during sampling. When a specimen could not be identified in the field, close-up digital photographs were taken and a specimen was collected for later identification. Further individuals of that species recorded in the quadrat were described using a distinctive notation that could be later related to the digital record and the voucher of the species. A reference collection of voucher specimens for all the species was also compiled.

Processing of the photographs of benthic cover was done using Coral Point Count (CPCe) software to identify and determine the composition (percent coverage) of the substratum. The point-count intersect method, using 50 cross-points within each 0.5 m x 0.5 m photograph, was used to determine the abundance of each of the species forming the benthic cover. The substratum below each of the points was allocated to a customized code file containing assigned values specific to the range of corals, soft-corals and macroalgae found on Ningaloo Reef. A photo catalogue of species of hard coral inhabiting Ningaloo Reef was also used to aid in identification. In cases where a specimen could not be identified to the generic level, that taxon was identified to family. Corals of the dominant genus *Acropora* were further classified based on their growth form as either branching, tabulate or digitate.

3.4 Results

Surrogate Level 1: The composition of the habitat-forming benthic assemblages in either of the mosaics (i.e. the hard-coral based mosaic and the macro-algal based mosaic) varied considerably between the two regions. The mosaics in each region were characterised by different species dominating the composition of those mosaics, therefore, the thematic maps could not be used to identify sites that consistently represented a defined set of species, the practical definition of a habitat surrogate. There was a great deal of variability in the composition of each mosaic at the spatial scale of sites (within each of the two regions). The selection of habitat mosaics in the two different management zones was more effective in representing the habitat-forming benthic species, although there was still a great deal of variability among the sites, especially for the macro-algal based mosaic.

Surrogate Level 2: The maps performed very poorly in representing the composition of the macro-invertebrate assemblages. First, the composition of the macro-invertebrate assemblages in either of the mosaics (i.e. the hard-coral based mosaic or the macro-algal based mosaic) was very different in each of the two regions, a function of the different numbers of species that were identified and/or the abundance of those species. The composition of the macro-algal based mosaic was extremely variable at the scale of sites in both regions. Thus, the thematic maps could not be used to identify reliably sites belonging to a particular mosaic if the interest was on the macro-invertebrates.

Second, in both regions, the two mosaics could not be distinguished from each other based on the composition of the macro-invertebrates. The numbers and types of macroinvertebrates found at any site were not reliably represented by the identification of that site as belonging to a habitat mosaic using the thematic maps. Again, the maps were not providing a consistent surrogate for the distribution or abundance of the macro-invertebrate assemblages

3.5 Discussion

The results of this study indicate that the thematic habitat maps produced from the hyperspectral imagery for Ningaloo Reef do not provide a reliable and repeatable surrogate for species-level biodiversity. As such, their application and utilisation in management and conservation plans for habitat-forming (biogenic) species of corals and benthic macro-invertebrates is premature. First, the identification of habitat mosaics (combinations of commonly occurring habitat types) did not provide a reliable representation of the species that formed the primary benthic substratum. Second, the mosaics identified from the maps did not provide a surrogate for the distribution, abundance or composition of benthic macro-invertebrates, with greater or equal variation occurring at the scale of sites (within a specific mosaic) than occurred between the different types of mosaic. Third, clearly other environmental (biophysical) and biological processes that are not incorporated into the development of the thematic habitat maps are having large effects on the composition of the biogenic and macro-invertebrate assemblages, although this study did not attempt to identify what those other factors and/or processes are. Our tests of the validity of surrogacy based on thematic habitat maps were restricted to two specific types of mosaic, but the two mosaics examined were very common and widely distributed based on the mapping done for Ningaloo Reef. It is not clear at this stage whether habitat-based surrogacy would be more or less effective for other types of mosaic, less common and widely distributed than those based around hard-corals and macroalgae as the predominant components.

The lack of consistency between the regions (north and south) of Ningaloo Reef does not necessarily present a major problem in the use of surrogacy for conservation planning and management. Clearly, the composition of both types of assemblage (biogenic and macro-invertebrate) varied considerably at the scale of regions (See also van Keulen and Langdon 2011). If the data behind the construction of the thematic maps provide sufficient resolution, the first step in the application of habitat surrogates would be to identify naturally occurring boundaries in the distribution of components of major taxonomic groups. In the case of the maps for Ningaloo Reef, possible candidates for these boundaries might represent the boundaries in the distribution of key taxa of hard corals and/or macroalgae. The use of surrogates derived from the thematic maps could then be constrained so that they were independently applied in different regions. The selection of mosaics to be protected may be consistent among regions, but the species being protected by these surrogates would vary at a regional scale.

There is a critical temporal component that must be considered when making use of habitat-based thematic mapping for conservation and planning. The original hyperspectral imagery was collected in 2006, but the complications of the analysis, generation and validation of the maps showing the distribution of particular types of habitats and habitat mosaics introduced a significant lag time before these maps could be assessed in the field. Our studies here were done in 2009 and it was evident that there had been significant changes in the distribution of some habitats, especially those in areas most susceptible or exposed to human or natural disturbance. In some areas in the southern region, there had been major changes in the distribution of some habitat types, so much so that areas shown as comprising one type of mosaic on the maps were dominated by a completely different type of mosaic when sampling was done in 2009. This alone requires that field validation of the accuracy and reliability of the maps must be done immediately prior to the application of surrogacy in conservation planning if the intention is to use surrogacy to present the distribution, abundance and composition of species ostensibly occurring in those surrogates.

The critical role these organisms play on coral reefs suggests that one use of habitat maps may be to monitor the extent and condition of the reef structure and therefore the reliability and accuracy of the maps as surrogates for biodiversity would be of great importance.

3.6 Acknowledgements

We thank Mike van Keulen and Fraser McGregor for the use of the North-West Marine Research station and advice on the logistics of sampling at Ningaloo. Ajax Diaz-Ruiz participated in some of the fieldwork and data validation. Ali McCarthy worked on this research as part of her Honours degree at the University of Queensland. We thank the CSIRO Collaboration fund for providing the funding for this research.

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