Port Beach Sand Nourishment via Dredging – Benthic Communities and Habitats Mapping

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Acronyms and Measurement Units

Acronyms	
BCH	Benthic communities and habitats
CoF	City of Fremantle
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
SFR	Seafloor reflectance
Measurement units	
ha	Hectares
km	Kilometre
km^2	Square kilometre
m	Metre
m^3	Cubic metre
%	Percent

1 Introduction

1.1 Background

City of Fremantle (CoF) are developing a management response to the imminent coastal erosion risk at Port Beach located in Fremantle, Western Australia. Sand nourishment via dredging (hereafter; the Project) has been identified as the preferred management response for providing protection from the coast erosion risk in the short-term (~10 years). To implement the Project, CoF proposes to source the required volume of sediment (~150,000 m^3) to nourish Port Beach from dredging within the bend area of Fremantle Ports' Deep Water Channel.

1.2 Purpose of this document

The dredging and sand placement activities associated with the Project have the potential to result in direct and/or indirect impacts to benthic communities and habitats (BCH) occurring within or surrounding the proposed dredging and placement area. BCH mapping of a 12,515.40 ha (125.15 km^2) area encompassing the proposed dredging area, placement area and surrounds was undertaken to determine the type, distribution and extent of BCH occurring in the defined study area (Figure 1-1). The methods and results of the BCH mapping are outlined within this document. The produced BCH map is intended to inform potential environmental impact, monitoring and management in the Project Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP).

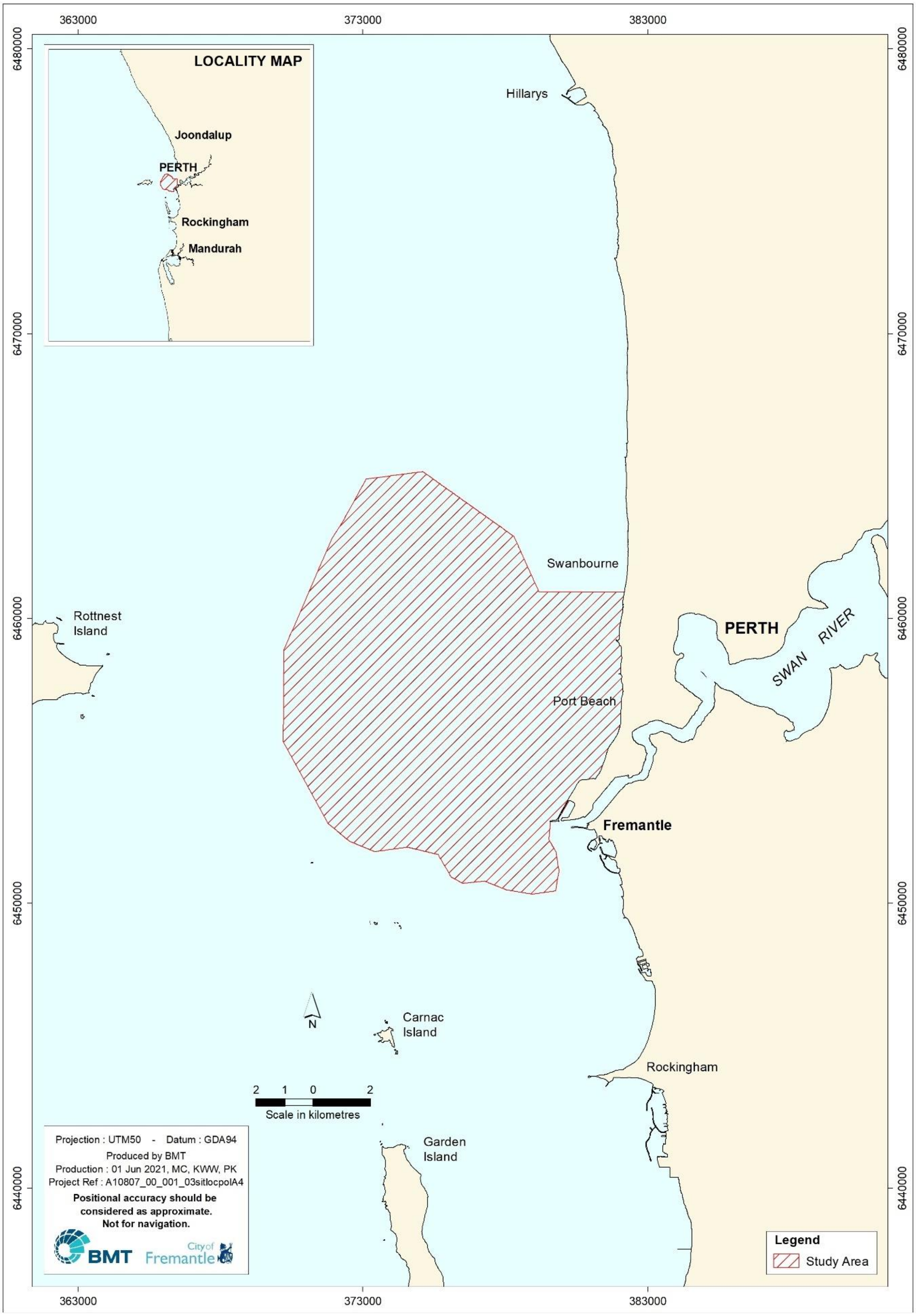

Figure 1-1 Study area for the benthic communities and habitats mapping

2 Description of the Marine Environment

2.1 Benthic communities and habitats

Perth coastal waters support a diverse range of BCH including mixed assemblages of tropical and temperate species from the influence of the Leeuwin Current. The varied geomorphology of the marine environment, which is predominately characterised by sand and reef platform substrates, also promotes diversity for BCH.

The nearshore marine environment predominately consists of sand overlying limestone pavement. The dominant benthic primary producers occurring on the sand are seagrasses, including perennial (*Amphibolis antartica*, *Amphibolis griffithii*, *Posidonia angustifolia*, *Posidonia australis*, *Posidonia coriacea*, *Posidonia sinuosa*, *Syringodium isoetifolium*, *Thalassodendron pachyrhizum* and *Zostera tasmanica*) and ephemeral (*Halophila ovalis*) species (Kendrick et al. 2002; Kirkman and Kirkman 2000). The dominant seagrass genera are *Amphibolis* spp. and *Posidonia* spp. (Kirkman and Kirkman 2000).

Intertidal reef platforms and low and high relief subtidal reef platforms reefs are distinctive features of Perth's marine environment. These platform reefs are typically dominated by assemblages of macroalgae including red, brown and green species. The closest intertidal reef platforms in the vicinity of Fremantle are located ~1.5 km to the north of Port Beach within the Cottesloe Reef Fish Habitat Protection Area. Subtidal reef platforms in the vicinity of Fremantle occur near Rous Head and extend from the nearshore area to ~1 km offshore.

Coral can also occur in the nearshore and offshore areas of Perth, with the largest percent cover occurring at Hall Bank located ~3 km to the northwest of the Swan River entrance in Fremantle. Hall Bank is ~250 m long and ~50–100 m wide and rises up to ~6 m water depth with surrounding waters ~15 m in depth. A study by Thomson and Frisch (2010) documented fourteen coral species in 11 genera from 10 families (*Coscinaraea mcneilli*, *Cyphastrea serailia*, *Favia favus*, *Favites abdita*, *Goniastrea aspera*, *G. australensis*, *G. palauensis*, *Montiporamollis*, *Plesiastrea versipora*, *Pocillopora damicornis*, *Porites lutea*, *Symphyllia wilsoni*, *Turbinaria frondens* and *T. mesenterina*) occurring at Hall Bank. The average coral cover from seven transects was 52.6% and the maximum coral cover from one transect was 72.5% which is the highest ever recorded coral cover at or beyond 32°S (Thomson and Frisch 2010). It is noted that a potential decline in coral cover at Hall Bank has been anecdotally observed since the study by Thomson and Frisch (2010), potentially associated with the marine heatwave event during the summer in 2010-11 that resulted in large-scale declines in coral along the WA coastline (DEC 2012). Regardless, Hall Bank is one of the limited known areas to contain significantly high abundance and cover of coral in the marine environment in the vicinity of Fremantle (for the location of Hall Bank, refer to the coral habitat depicted in Figure 3-1, Figure 4-1 and Figure 4-2).

3 Methods

3.1 Data acquisition

Available marine and intertidal spatial data (bathymetry, satellite imagery, existing ground truthing and existing habitat mapping products) from within the defined study area were collated and all layers were overlaid in ArcGIS 10.6.1 and QGIS 3.4.15 for the BCH mapping. The existing ground truthing data was collated from different sources from 2007 to 2012 (Table 3-1).

Satellite data (World View-2; 2 m resolution) was processed by EOMAP to generate seafloor reflectance (SFR) imagery by applying atmospheric, surface and water-column corrections. An uncorrected true colour (red/green/blue) image and subsurface reflectance image was also provided to assist with map production. The SFR images used for the analysis are from 28 May 2019 and 30 December 2020. These images were selected based on the high quality of defining features (e.g. images contained minimal visible turbidity, sun glint, shading etc.) for the analysis from a review of recent available imagery between 2019–2021.

Table 3-1 Description of the existing ground truthing data from within the defined study area for the benthic communities and habitats mapping

Custodian of the ground truthing data	Timing[1]	Description
Fremantle Ports	December 2007	Benthic habitat raster data and classification layer collected by SKM Consulting, based on Autoclassification of Digital Globe image from July 2007 and ground truthing data from December 2007
Fremantle Ports	24 November 2009	Ground truthing results from video transects collected at Fremantle, Western Australia
Fremantle Ports	2009-2010	Habitat information derived from field sheets and experience gained during habitat mapping and water quality, sediment quality and mussel monitoring works.
Fremantle Ports	29 April 2010	Ground truthing results from video transects collected at Fremantle, Western Australia
Fremantle Ports	23 July 2010	Not available
Fremantle Ports	15 December 2010	Actual seagrass health monitoring sites at and around the Inner Harbour Deepening Spoil Ground
Fremantle Ports	2 November 2011	The dataset was collected during a transect field habitat survey at the Inner Harbour Deepening Spoil Ground
Fremantle Ports	5 April 2012	Substrate mapping by Oceanica Consulting over the Inner Harbour Deepening Spoil Ground, Fremantle Marine Region, Western Australia
Fremantle Ports	13 November 2012	Actual seagrass health monitoring sites at and around the Inner Harbour Deepening Spoil Ground

3.2 Classification of ground truthing data

The ground truthing dataset was analysed and classified according to the BCH categories listed in Table 3-2. During the process of filtering the BCH categories, a density (e.g. percent cover) category was also applied to the dataset for some of the BCH categories, ranging from sparse (<30% cover) to dense (>70% cover; Table 3-2). The location of the ground truthing survey data with BCH classification categories is depicted in Figure 3-1. The ground truthing survey data extends over ~25 km.

Table 3-2 Preliminary benthic communities and habitats classification categories

BCH categories	Density		Description
Coral	N/A		Coral includes hard and/or soft coral species, filter feeders and/or sponges
Macroalgae	N/A		Macroalgae includes a range of red, green and/or brown species colonising platform reef
Rock with algae	N/A		Rock/rubble substrate with macroalgae including a range of red, green and/or brown species
Seagrass	Sparse	<30% cover	Seagrass includes perennial (e.g. *Amphibolis* spp., *Posidonia* spp.) and/or ephemeral (e.g. *Halophila* spp., *Zostera* spp.) species
	Dense	>70% cover	
Wrack	N/A		Wrack includes detached and unliving seagrass and/or macroalgae
Sand	N/A		Bare sand substrate
Unknown	N/A		Not able to be identified from ground truthing image

Note:

1. 'BCH' = benthic communities and habitats; 'N/A' = not applicable.

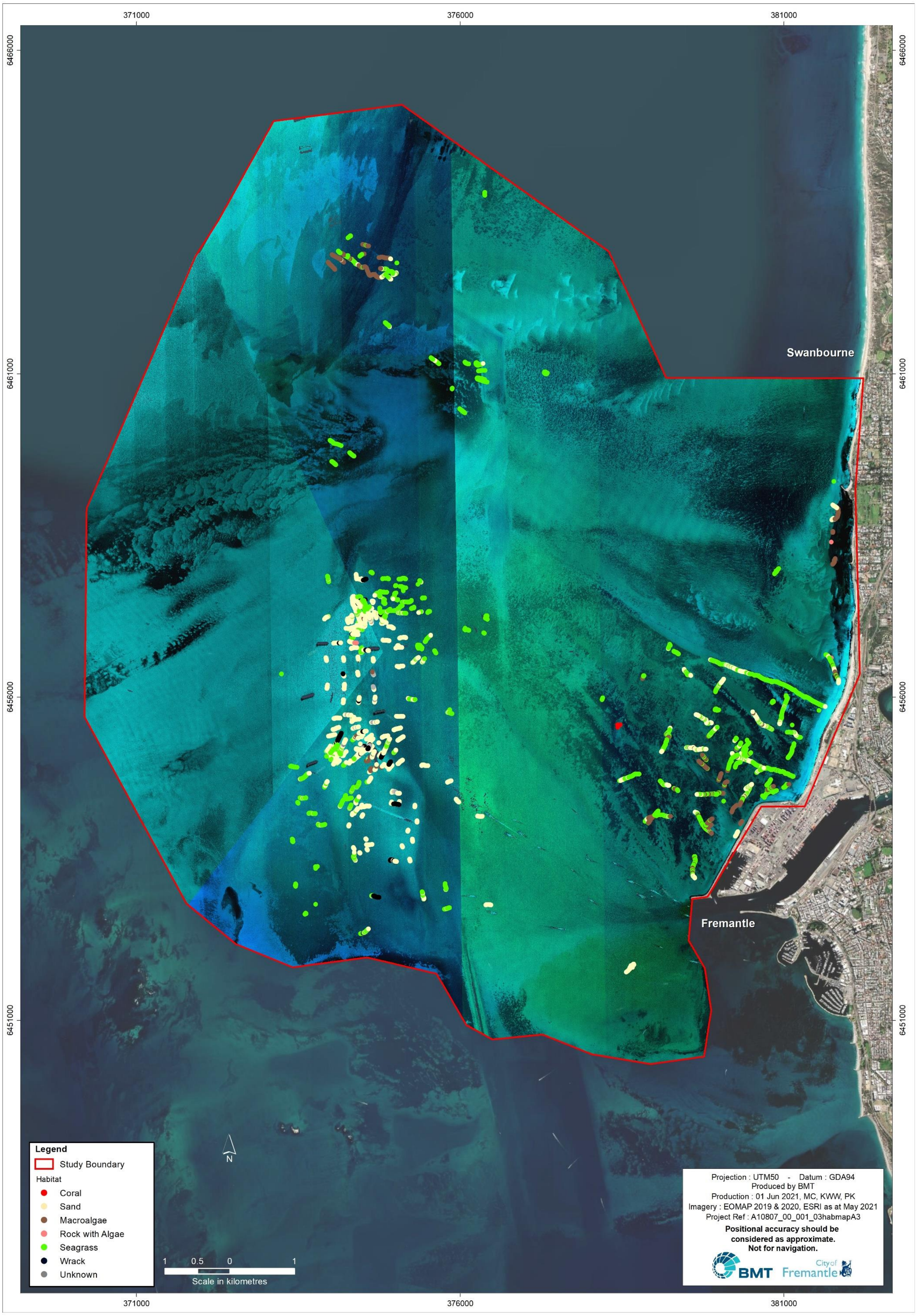

Figure 3-1 Location of ground truthing survey data with benthic communities and habitats classification categories

3.3 Classification and mapping procedures

Habitat mapping was performed using a supervised classification approach, Maximum Likelihood Classifier, to classify the SFR images using ERDAS IMAGINE (Hexagon Geospatial 2021). The ground truthing dataset was used in ERDAS IMAGINE (Hexagon Geospatial 2021). Due to the depths in the study area (ranging from 0 m to >22 m), parts of the SFR imagery only returned two spectral bands in the lower wavelengths (this was an issue for depths >12 m) and those spectral bands were used for the supervised classification.

A random split was applied to the ground truthing dataset to split the dataset into classification (70%) and validation (30%) data. The spectral image bands with the highest water penetration, and the 70% withheld classification ground truthing data, were used to generate spectral signatures for the classification. As a result of the high spectral similarity between seagrass, macroalgae and other vegetated areas, habitats could only be reliably divided into vegetated cover of varying density, and unvegetated areas. They could not be further classified into seagrass and macroalgae categories. Therefore, vegetated, and non-vegetated categories were mapped at first.

Vegetated areas included sparse to dense seagrass, macroalgae, coral, and wrack cover while non-vegetated areas included sand and bare rock pavement/reef. Seagrass and macroalgae categories were manually assigned at a later stage. Vegetated areas were defined as either dense (having no obvious gaps in the vegetation cover based on visual assessment of the imagery and ground truthing data) or sparse (containing areas of bare sand or bare rock pavement/reef in between the vegetation cover). After the supervised classification had been performed, the classified images were visually assessed for accuracy and consistency across the study area using ArcGIS 10.6. Bathymetric charts were also used to help delineate reef and non-reef areas based on visual assessment of the depth differences between features. The bathymetric information was then integrated with the habitat classification to allow for the separation of vegetated areas, according to reef or non-reef substrate. Habitat layers from 2007–2012 were also used as validation inputs to confirm the separation of classes in the classified images.

Ground truthing data (Figure 3-1) were used to manually define seagrass and macroalgae habitats over the vegetated areas using ArcGIS 10.6, resulting in the categories described in Table 3-2. Post-processing was then applied to improve the classification over areas of noise or misclassification resulting from spectral similarities between the categories (especially in more sparsely vegetated areas) and to smooth the boundary between classified habitats. A minimum mapping unit of ~4 m^2 was used as a basis to remove small classified areas and merge them with neighbouring polygons. Low confidence categories were mapped based on the absence of ground truthing data and/or areas of misclassification due to factors such as depth, spectral similarities and/or artefacts from the SFR imagery processing.

3.4 Assessment of accuracy

It is noted that there may be spatial inaccuracies in the imagery from artefacts after atmospheric, water column or orthorectification uncertainty when the algorithms are applied. There may also be spatial inaccuracies in the ground truthing data from geographic positioning system uncertainty and from assigning existing ground truthing data to the analysis that may have resulted in error when training areas for the classification were created if the position of habitats have shifted since the ground truthing.

An accuracy assessment was performed on the habitat classification using the 30% withheld validation ground truthing data for the vegetated and non-vegetated categories (Table 3-3; Appendix A). One hundred points of the 30% withheld validation ground truthing data was used to perform the accuracy assessment (Table 3-3; Appendix A). No accuracy assessment could be performed for the detailed habitat categories, as these categories were derived manually with no supervised classification approach and final categories deviated slightly from the final ground truth categories. However, a visual assessment showed good agreement between the detailed habitat categories, imagery and ground truthing data.

The assessment of accuracy for vegetated and non-vegetated categories achieved an overall accuracy of 82% and Kappa statistic of 0.59 (Table 3-3; Appendix A). The overall accuracy of 82% suggests a good agreement between the classified image and the ground truthing. The Kappa statistic provides a measure of the agreement between the classification of categorical data and recognises the agreement that could occur by chance. A Kappa statistic of over 0.40 is considered to represent a moderate to strong agreement (Congalton 1991, 2001).

Table 3-3 Accuracy assessment of the benthic habitat categories

Habitat type		Reference data			User's accuracy[1]
		Vegetated	Non-vegetated	Total	
Classified data	Vegetated	58	7	65	89.23%
	Non-vegetated	11	24	35	68.57%
	Total	69	31	100	–
	Producer's accuracy[2]	84.06%	77.42%	–	82.00%

Notes:

1. User's accuracy, or reliability, indicates the probability that a pixel classified in the image actually represents that class on the ground (error of commission). It is calculated by dividing the total number of correct pixels in a class by the total number of pixels that were classified in that class (Congalton 1991).
2. Producer's accuracy indicates the probability of a reference pixel being correctly classified (error of omission). It is calculated by dividing the total number of correct pixels in a class by the total number of pixels of that class as derived from the reference data.
3. The output of the classification accuracy assessment is provided in Appendix A.

4 Results

Within the study area, the dominant BCH categories included (Table 4-1 and Figure 4-1):

- sand (67.01%)
- seagrass sparse (13.07%)
- seagrass dense (10.26%)
- macroalgae low confidence (6.60%).

Additional subdominant BCH categories that occurred within the study area were macroalgae (0.79%), seagrass sparse low confidence (0.41%), sand low confidence (0.33%), wrack (0.31%), rock with algae (0.26%), seagrass dense low confidence (0.08%) and coral (0.02%; Table 4-1 and Figure 4-1). A small proportion of the study area was also unknown (0.86%; Table 4-1 and Figure 4-1). Unknown areas are considered to be likely attributable to the combination of habitat structure type and quality of imagery obtained, limiting the ability to decipher habitat boundaries. The distribution and extent of mapped BCH are depicted in Figure 4-1.

A comparison of the distribution and extent of BCH from historical mapping products (2007/2012) and the contemporary mapping update (2019/2020) is provided in Figure 4-2. While no new types of BCH were identified in the contemporary mapping update, there was more detail provided in the contemporary map for BCH categories (e.g. sparse vs dense categories, low confidence category) and mapping of BCH was achieved for deeper areas (depth >22 m) within the study area (Figure 4-1). Further, a greater cover of vegetated BCH types were mapped during the contemporary update (Figure 4-1). From a review of previous satellite imagery, it is considered likely that these vegetated BCH types were already colonising the areas at the time the historical maps were prepared but were undetected. This is suggested to be due to the progression in habitat classification methodologies and accessibility of high definition satellite imagery allowing for greater detection of habitat boundaries at smaller scales.

Table 4-1 Area and proportion of mapped benthic communities and habitats in the study area

BCH categories	Area (ha)	Area (km^2)	Proportion (%)
Coral	1.99	0.02	0.02
Macroalgae	99.16	0.99	0.79
Macroalgae low confidence	826.25	8.26	6.60
Rock with algae	32.78	0.33	0.26
Sand	8386.13	83.86	67.01
Sand low confidence	41.85	0.42	0.33
Seagrass dense	1284.28	12.84	10.26
Seagrass dense low confidence	9.55	0.10	0.08
Seagrass sparse	1635.46	16.35	13.07
Seagrass sparse low confidence	51.09	0.51	0.41
Unknown	108.21	1.08	0.86
Wrack	38.66	0.39	0.31
Total	**12515.40**	**125.15**	**100.00**

Note:

1. BCH = benthic communities and habitats.

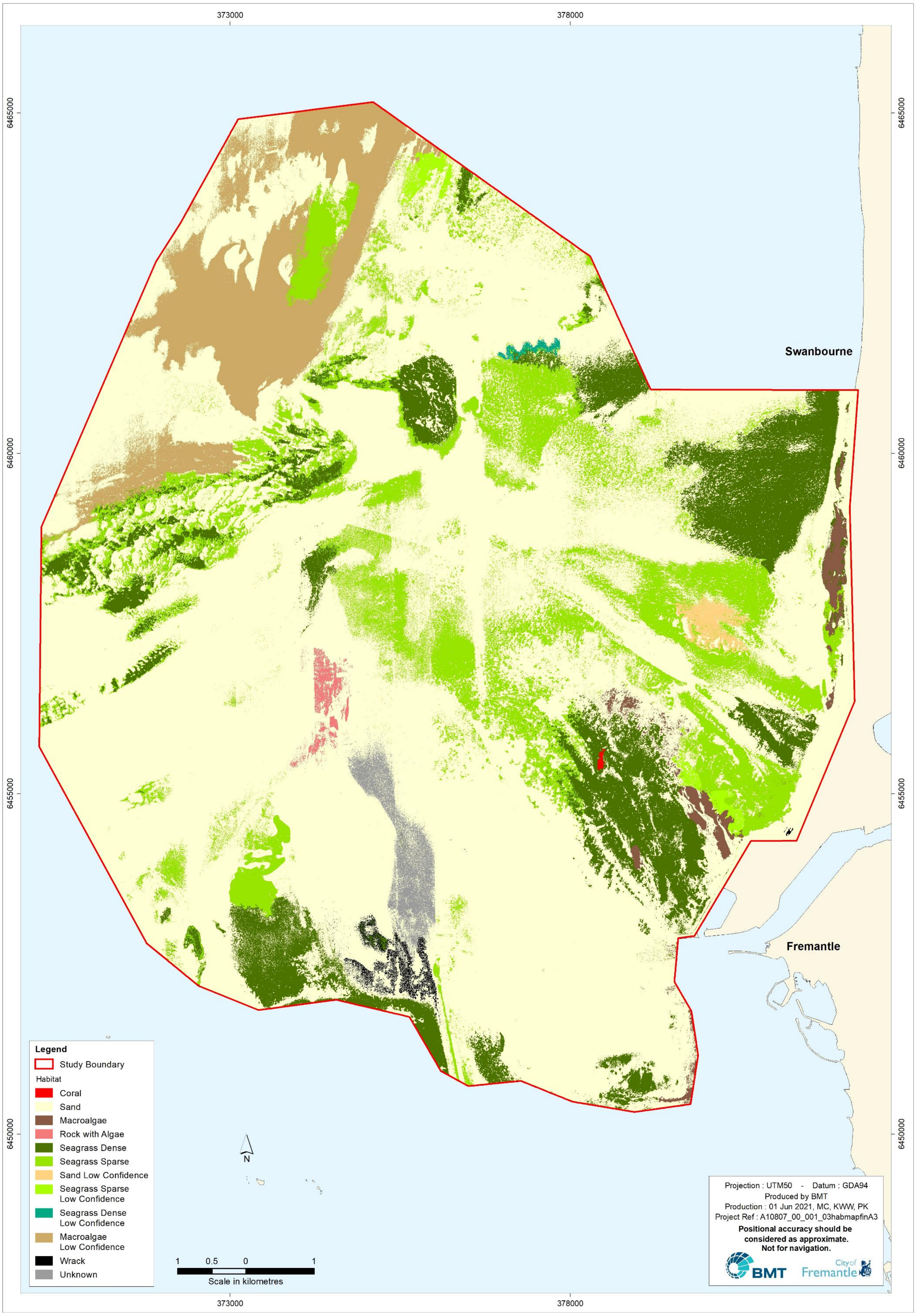

Figure 4-1 Distribution and extent of mapped benthic communities and habitats in the study area (2019/2020)

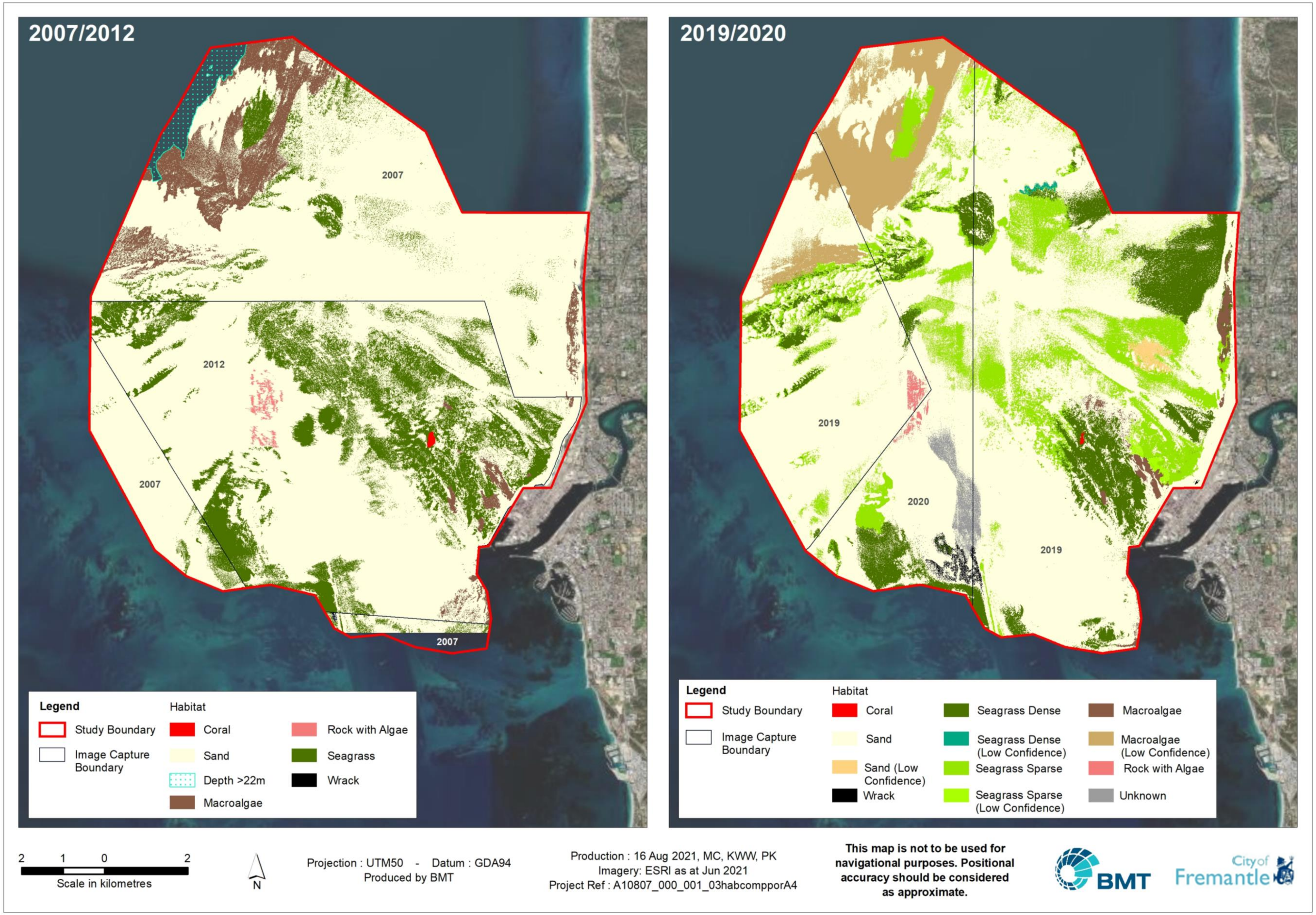

Figure 4-2 Comparison of the distribution and extent of historical (2007/2012) and contemporary (2019/2020) mapped benthic communities and habitats

5 Conclusion

BCH mapping of a 12,515.40 ha (125.15 km^2) area encompassing the Project's proposed dredging area, placement area and surrounds was undertaken to determine the type, distribution and extent of BCH occurring in the defined study area.

The methods to undertake the BCH mapping were based on a desktop assessment, whereby previous ground truthing and mapping data available for the study area were updated with recent high-resolution satellite imagery to redefine habitat edges.

Mapped BCH within the study area was predominantly sand (67.01%), seagrass sparse (13.07%), seagrass dense (10.26%) and macroalgae low confidence (6.60%). Additional subdominant BCH categories that occurred within the study area were macroalgae (0.79%), seagrass sparse low confidence (0.41%), sand low confidence (0.33%), wrack (0.31%), rock with algae (0.26%), seagrass dense low confidence (0.08%) and coral (0.02). A small proportion of the study area was also unknown (0.86%). No new types of BCH were identified in the contemporary mapping update.

The produced BCH map will be used to inform potential environmental impact, monitoring and management in the Project EIA and EMP.

6 References

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Appendix A Assessment of Accuracy Classification Report

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File: m:/cof/a10807_port beach env approvals 2021/001_projectmanagement/2exectn/1data/gis/001_01/proc/habitat/accuracyassessment/finalhabv3rasfinal.img

User Name: avega

Date: Sat May 22 19:55:11 2021

ERROR MATRIX

Reference Data

Classified Data	Background	Class 1	Class 2	Class 3
Background	0	0	0	0
Class 1	0	24	11	0
Class 2	0	7	58	0
Class 3	0	0	0	0
Column Total	0	31	69	0

----- End of Error Matrix -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Class 0	0	0	0	---	---
Class 1	31	35	24	77.42%	68.57%

Class 2	69	65	58	84.06%	89.23%
Class 3	0	0	0	---	---
Totals	100	100	82		

Overall Classification Accuracy = 82.00%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.5937

Conditional Kappa for each Category.

Class Name	Kappa
Class 0	0.0000
Class 1	0.5445
Class 2	0.6526
Class 3	0.0000

----- End of Kappa Statistics -----

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