Cooperative Research Centre for Coastal Zone Estuary and Waterway Management

Cape Byron Marine Park

Habitat Mapping

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The University of Western Australia

Marine Parks Authority

CRC for Coastal Zone Estuary & Waterway Management

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The Cape Byron Marine Park (CBMP) was declared on 1st November 2002 under the *Marine Parks Act 1997* and is one of four such marine parks in NSW. The primary purpose of a marine park is the conservation of biodiversity. Recognising that both recreational and commercial activities can occur within a marine park, the management of the marine resources within the park is most appropriately undertaken by identifying suitable zones in the park where each of these activities are permitted and where special, or sensitive areas, require protection. To support such a plan, a 'habitat' map is required showing the locations and extents of the various types of seafloor, as well as the predominant plants and animals in each of these.

The production of maps of the seabed requires techniques that are different to those used to produce maps on land. Aerial photography can be used to initially map the coastline, but only provides information to a water depth of between 5 and 10m. However, sound travels well in water and sonar systems are used in deeper areas to gain information about the depth and nature of the seabed.

In late 2003, the NSW Marine Parks Authority contracted the Coastal CRC to map the areas of CBMP not covered by their existing aerial photography for the purpose of providing information that would contribute to the preparation of zoning plans for the CBMP. Sophisticated towed equipment known as sidescan sonar was used to provide images of the seafloor at a distance of up to 200m each side of the vessel. Once processed by computer, these appear similar to a black and white aerial photograph. In November 2003, the NSW Fisheries Vessel *Ngaarru* was used to perform the sidescan survey of the marine park. By combining the sidescan tracks obtained over five days, an image of the seabed was constructed from which the boundaries between reefs and different types of sediment could be distinguished. To gain more detailed information about the different types of seabed and communities that had been identified, a towed video system was then used for 'ground-truthing'. Video surveys were carried out in January 2004 on board the charter vessel *Cavanbah*. Positions were recorded using a GPS (Global Positioning System) throughout all surveys so that both sidescan and video information could be accurately positioned. All the recorded information was integrated into a computer based GIS (Geographical Information System). Using the GIS, simplified maps of the marine habitats of the CBMP were prepared, using a classification system devised to represent the diversity of seabed types and communities of the area.

The maps prepared were used extensively in the preparation of the draft zoning plans of the marine park and provide invaluable information for directing future more detailed surveys.

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EXECUTIVE SUMMARY

The Cape Byron Marine Park (CBMP) was declared on 1st November 2002 under the *Marine Parks Acts 1997* and is one of four such marine parks in NSW. The CBMP covers approximately 220 sq km of marine and estuarine environments between Lennox Head and the Brunswick River mouth, with its seaward boundary being defined by the 3nm limit of NSW State waters.

Previous maps of the seabed of the CBMP have been produced using mainly aerial photographs with detailed information being available only in shallow water up to depths of between 5 to 10m. In late 2003, the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC) was contracted by the NSW Marine Parks Authority to provide a rapid assessment and map of all of the subtidal marine habitats of the CBMP including those in deep water. The habitat map was to be used in preparing zoning plans within the park. The mapping was to be based on information collected by sidescan sonar and underwater video cameras to produce a classified map of the subtidal habitats and to combine this with existing mapping previously carried out by aerial photography.

The sidescan survey was carried out in November 2003 using the NSW fisheries vessel *Ngaarru.* Over 90% cover of the area within the CBMP boundaries was achieved using the sidescan sonar system. The sidescan sonar survey was extended to cover areas of interest to the north and south of the marine park boundaries. In early 2004, the sidescan imagery was validated using an underwater video system which was towed close to the seafloor from the charter vessel *Cavanbah*. A total of twelve hours of video data was obtained.

The sidescan and video information were processed and interpreted based on a habitat classification system suitable for use in zoning the marine park that had been agreed on by NSW Marine Parks Authority and the Coastal CRC. Maps of the areas surveyed were produced showing a range of different types of reef and unconsolidated sediment, together with existing classifications of terrestrial, estuarine and intertidal features. The habitat maps produced showed clear and significant differences between the previously mapped extents and positions of the Julian Rocks, Mackerel Boulder and Cape Pinnacle reef systems of the area.

The level of detail obtained from these surveys and depicted in the habitat maps represent significant improvement on previous knowledge which will contribute substantially to the development of zoning plans for the marine park.

It is recommended that the accuracy of both mapping and classification could be enhanced with the acquisition of more detailed bathymetry. The recent purchase by the NSW Department of Environment and Conservation of a GeoSwath system will allow the acquisition of more detailed and accurate bathymetry and side-scan imagery simultaneously. Future surveys should be directed towards areas of particular interest, such as the deep offshore reef east of Cape Byron supplemented by detailed studies of the habitats classified and mapped. Fine scale surveys of the substrate, flora and fauna carried out by grab, corer, ROV and diver are also required to test and refine the classification system used.

The techniques used by the Coastal CRC in these surveys have resulted in the rapid production of a habitat map for the CBMP, greatly improving the knowledge of the extent and diversity of the habitats of the area. In addition to a report and map showing the various marine habitats within the park, the Coastal CRC provided the NSW Marine Parks Authority with underwater video footage used to confirm the various habitats shown in the map. All the information was presented in a Geographic Information System (GIS) with video footage provided as video clips linked to their positions. These products will be invaluable in preparing a zoning plan for the Marine Park, and for monitoring marine habitats into the future.

The classification system developed during the project and used in the report was seen as a significant improvement on previous classification schemes by virtue of the technologies used.

Future developments of mapping and classification of habitats of the CBMP should focus on covering the full suite of marine communities found on the NSW coast and to work towards a standardised and comparable system for the classification of marine habitats along the NSW coast.

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1. INTRODUCTION

1.1 NSW MARINE PARKS

The NSW Marine Parks Authority is charged with the responsibility of administering the *Marine Parks Act 1997.* Included in the objectives of the *Marine Parks Act* is to conserve marine biological diversity by declaring, and providing for the management of, a comprehensive system of marine parks. To aid in meeting this objective, four marine parks along the NSW coast have been formally declared. These are:

- Solitary Islands Marine Park;
- Jervis Bay Marine Park;
- Lord Howe Island Marine Park; and
- Cape Byron Marine Park.

1.2 CAPE BYRON MARINE PARK (CBMP)

The Cape Byron Marine Park (CBMP) was declared on 1st November 2002 under the *Marine Parks Act 1997*. It covers an area of about 22,000 hectares of estuarine and marine environments and extends from Lennox Head in the south, for a distance of approximately 37km along the coast to the northern bank of the Brunswick River mouth. On the shore it is limited by the mean high water mark and the upper tidal limits of coastal estuaries. Its seaward boundary is defined by the 3 nautical mile (nm) limit of NSW State waters (Figure 1.1).

The locations and boundaries of marine parks are normally selected based on a combination of physical and biological attributes of areas, and are also chosen to be representative of the marine characteristics of the bioregion. An outline of the processes utilised to decide on locations of marine parks in NSW are discussed in Breen et al. (2003).

The CBMP lies in the Tweed – Moreton bioregion, one of five of such regions recognised in NSW. Fine scales of classification have identified fifteen distinct marine ecosystems in the Tweed – Moreton bioregion. The CBMP includes/supports ten of these ecosystems: mature barrier estuary, saline lagoons and coastal creeks, rocky shores/platforms, sandy beaches, subtidal sediment (in three depth zones) and subtidal reefs (in three depth zones) (Marine Parks Authority, 2003).

A habitat map of the CBMP out to the 3nm limit was produced prior to this survey by the NSW Marine Parks Authority (Marine Parks Authority, 2003). The limited information upon which this map was based, especially for areas deeper than 5-10m, prompted the NSW Marine Parks Authority in late 2003 to seek advice and to collect information to enable a more accurate and detailed habitat map of the area to be prepared for the purposes of zoning and managing the marine park. The systematic collection of biological information and mapping of the marine environment of the area has been consistently identified by assessments carried out in the area to be necessary for this management to be successful (Avery, 2000; Mau, 1998).

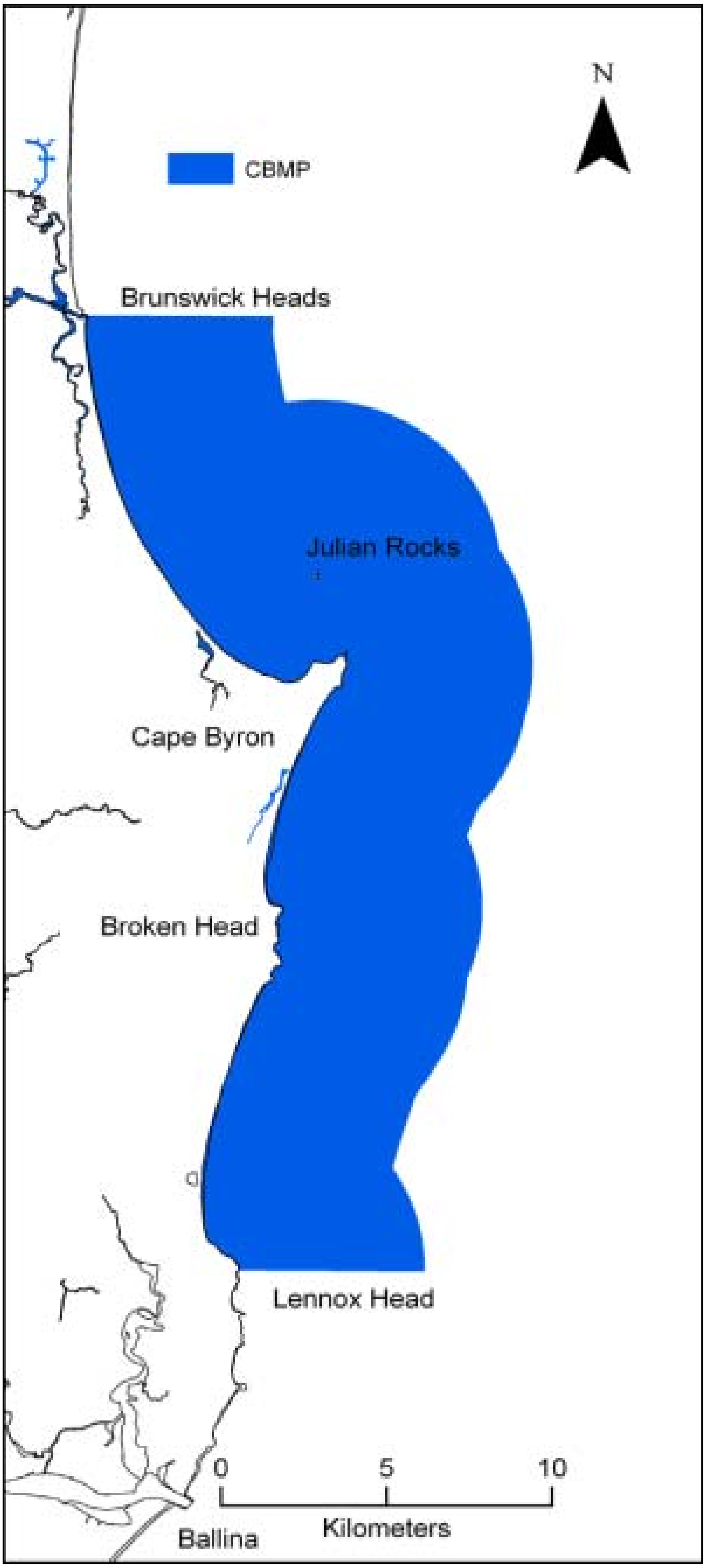

Figure 1.1 Cape Byron Marine Park (CBMP), New South Wales

1.3 MARINE HABITAT MAPPING

The preparation and presentation of habitat maps requires the collection and analysis of information on the nature and distribution of seafloor features and characteristics, followed by the presentation of this information as a map, using an agreed and standardised system of ‘classification’ of habitat types.

Broad scale information relating to features and characteristics of the sea floor can be collected using remote optical methods (such as aerial or satellite photography) or by various acoustic techniques such as single or multi-beam and sidescan sonar.

Optical methods, such as use of images from satellites or aerial photography are only effective in water to the depth of penetration of sufficient light. In the waters of the CBMP, the depth of light penetration is seldom more than 10m and mapping nearshore reefs using aerial photography has been limited to waters of less than 10m deep. For greater depths, or where the water is more turbid, acoustic techniques are more appropriate as sound propagates in water regardless of optical clarity. A number of acoustic techniques are available that provide different coverages and types of information about the seafloor. These techniques are all regularly used as part of marine habitat mapping.

Single beam sonar systems acquire depths along a line below the vessel and can be used to infer some information about the seafloor or biota at discrete points along the vessel track. Although successive vessel tracks can be built up into a grid of soundings, the coverage tends to be sparse compared to that which is obtained with ‘swath’ systems such as multibeam and sidescan sonar.

Swath systems use fan shaped beams to map a wide area of the habitat to each side of the vessel. The swath widths of these systems mean that full coverage of areas of the size of CBMP can realistically be achieved. Multibeam systems provide accurate and high resolution depths together with records of ‘backscatter’ that can be used to predict the nature of the habitat. Although yielding little information about depth, the most rapid and cost efficient full coverage assessment of habitat can be obtained by sidescan sonar. The information obtained from the very wide swaths (up to 400m) of sidescan sonar is analogous to a black and white aerial photo and despite being relatively qualitative in nature, has proved to be sensitive in the characterisation of marine habitats (Bickers, 2003).

Habitats characterised by acoustic techniques require field validation by finer scale techniques which is normally achieved either by using video or still cameras, or by collection of samples. This can, but does not necessarily, involve the use of divers. More commonly cameras can be towed or dropped from a vessel whilst the images are viewed and recorded on board with reference to positioning from a Global Positioning System (GPS). Samples can also be taken using grabs or coring equipment.

To produce a map of habitats from the survey data, a system of classification has to be applied. A classification system requires boundaries to be drawn around areas of similar structure, substratum or community. Typically in a survey of this type the acoustic records are used to determine the boundaries and extent of acoustic types. Information from towed video and/or grabs, cores and diver records is then used to characterise the habitat and biota of these discrete acoustic types, which are assigned to one of the habitats represented in the classification scheme. A suitable colour scheme is then used to represent the different habitat classes on maps at various scales. These maps provide a fundamental tool in the management of marine protected areas.

Maps produced using these techniques are subject to positional inaccuracies. The accuracy of the final map is dependant on a range of parameters including navigational system precision and processing time, atmospheric effects and weather, and difficulties in predicting the position of a towed body and the area covered by its sensors. The positional accuracy of the maps is also typically lower than the resolution of the data that was used to produce them. Horizontal positional accuracies of better than 25m are expected from surveys of this type.

2. CAPE BYRON MARINE PARKS SURVEY

2.1 INTRODUCTION

The NSW Marine Parks Authority contracted the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC) to map the CBMP using techniques and equipment used in Western Australia in the successful mapping of large areas of habitat such as in the Recherche Archipelago, Cockburn Sound and Houtman Abrolhos. Specifically, the objective of this survey was to:

"Provide a broad scale benthic habitat map of the CBMP based on information to be obtained using a combination of; sidescan sonar to provide full cover of the CBMP, and towed video cameras to provide validation".

2.2 SURVEY TECHNIQUES

Sound propagates well in water and the use of marine hydroacoustics is widely accepted as the preferred method to map the seafloor on a broad scale. Although a range of hydroacoustic techniques are available for this purpose, sidescan sonar remains a widely used method for the rapid and cost effective mapping of large areas of marine habitat. It is especially useful for rapid evaluations of the habitat when time, weather windows and resources are limited. Sidescan sonar makes use of sound signals to obtain an acoustic image over a wide swath (up to 400m) of the habitat. Subsequent adjacent and overlapping swaths can then be used to build up an image of the habitat that looks similar and is analogous to an aerial photograph. While the sidescan records allow the extent and boundaries of reefs and areas of sediment to be determined, they require validation. This validation can be provided by a towed video system which allows biological information to be obtained for the areas mapped using the sidescan. A Global Positioning System (GPS) is used while surveys are underway to ensure the records obtained are positioned as accurately as possible.

2.2.1 Sidescan Sonar

An Edgetech 272 sidescan sonar operating at a frequency of 100kHz was used in this survey (Figure 2.1). It is capable of producing a swath width of up to 400m in water 20m or deeper. Sidescan sonars utilise two sensors (transducers) each ensonifying a 'swath' of seafloor each side of a towed torpedo shaped 'fish'.

Figure 2.1 Edgetech 272 sidescan sonar 'fish' used in CBMP survey

As the fish is towed through the water these transducers periodically produce a pulse of sound in a thin fan shaped beam (Figure 2.2a). The returns recorded from this 'ping' are built up into an image of the habitat related to the texture, slope and hardness of the substrate. An example of an unprocessed 'raw' sidescan image is shown in Figure 2.2b. This shows a central dark line that represents the position of the centre of the towed body known as the 'nadir'. This is an artefact of the outgoing transmit pulse. On each side of this is the signal that is recorded from the two transducers. The lighter part near the nadir represents the water column beneath the fish, the width of which can be interpreted as the height the fish is off the seabed. Beyond this, the outer parts represent the texture of the different types of habitat as labelled. Flat sand provides a weaker return than coarse sediment and is displayed in a lighter colour. The rugged features of reefs provide characteristic harder and more varied returns with shadowed areas caused by the relief. Sand ripples can be seen as changes in the altitude of the fish along the nadir, examples of this can be seen later in this report in Figure 2.11e and 2.11f. As with all sidescan sonars a strip of data directly beneath the fish is not surveyed (Figure 2.2a). During processing the water column is removed and the data from each transducer is stretched to meet in the centre. Geometric and radiometric corrections that assume a flat seabed are also applied at this time to remove distortions due to the angle of incidence of the acoustic wave. The vessel follows survey lines that allow the swaths recorded from the sidescan to be built up into a 'mosaic' of the habitat of the required coverage.

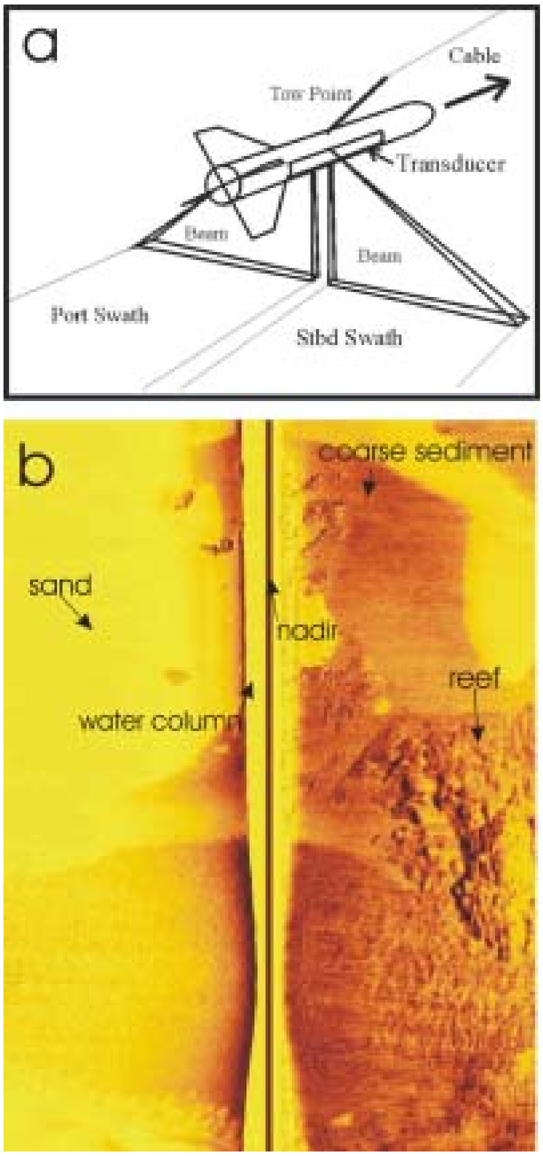

Figure 2.2 a) Sidescan sonar swath coverage b) Example sidescan image

During the surveys, analogue signals from a standard Edgtech 260TH surface unit were routed to a SonarWiz digital acquisition system and software from Chesapeake Technologies which was used to record the sonar data (Figure 2.3).

Positioning information from a GPS was recorded together with depth from the vessels echo sounder into industry standard XTF sidescan records. Although the raw sidescan images contain a great deal of information about the composition and communities of the habitat, further processing is necessary if the images are to be spatially correct and geo-referenced. To provide a map that is correct in geographical space, raw sidescan images were processed and combined into a mosaic using SonarWeb software to produce composite images of all or groups of the tracks at between 1 and 5m per pixel resolution. The positional accuracy of this image is dependant on sea condition, GPS position accuracy, sonar range and a variety of parameters and is likely to be poorer than the resultant resolution of the image. High image resolution is however still required for accurate recognition of characteristics of the seabed.

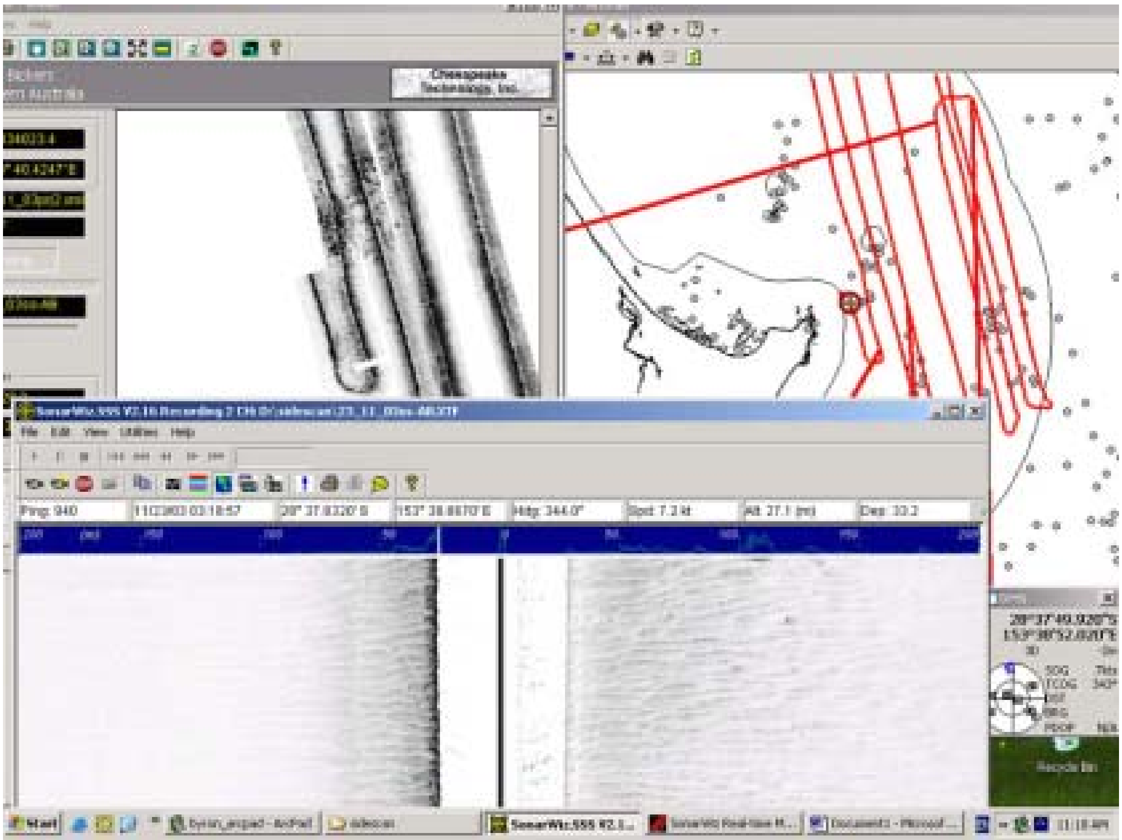

Figure 2.3 View of computer screen showing results of sidescan sonar survey

2.2.2 Towed Video

A towed video system was used for validation of the acoustic records. This consisted of a camera in a water proof housing connected to the surface by a cable of up to 100m. The camera was fitted with a wing to compensate for the drag on the cable and lights were fitted to the camera frame that could be controlled from the surface (Figure 2.4). The video was viewed live on the surface and was recorded on a Sony miniDV recorder. Software (developed at The University of Western Australia) running on a laptop computer was used to run the system and to generate a unique reference point at regular intervals (every 5s) along the video track.

The position and other information were recorded from a GPS for each one of these points. Depths from the vessels echo sounder were also recorded for each point and all the information, including the reference was permanently overlayed on the video. Files recorded on the laptop containing this information can be used to create vessel tracks in GIS systems that are referenced to points on the video.

Figure 2.4 Towed video camera with lights

2.3 DATA COLLECTION

2.3.1 Survey

The surveys were performed in two stages. The sidescan sonar survey was carried out in November 2003 on board the NSW fisheries vessel *Ngaarru* (Figure 2.5) moored in Ballina on the Richmond River.

In January 2004, 12 hours of video footage were obtained from the charter vessel *Cavanbah*, based in the Brunswick River (Figure 2.6).

Marine operations in the Cape Byron area are impeded by the lack of shelter outside of the rivers and the restrictions in terms of weather, tide and daylight on bar crossings. Unfavourable weather conditions during both surveys resulted in the full periods of vessel availability being used to obtain the required data. Any variability in data quality due to operating in these less than ideal conditions was not thought to have compromised the accuracy or integrity of the final habitat map. The full extent of the areas covered during the sidescan sonar survey, and the locations of the video transects are shown in Figure 2.7.

Figure 2.5 NSW Fisheries vessel, Ngaarru

Figure 2.6 Private charter vessel, Cavanbah

2.3.2 Sidescan Survey

The sidescan survey took place between 21st November and 1st December 2003. Surveys were hampered by southerly winds of up to 30 knots and swells to 3m. A total swath area of greater than 220 sq km was surveyed in six days and/or nights on board the NSW Fisheries vessel *Ngaarru* over almost 650km of survey lines. Survey speed was typically between 6 and 8 knots. Greater than 90% coverage was obtained within the CBMP with effort being concentrated in areas identified by NSW Marine Parks Authority as of special interest. Although the survey was confined mainly to the marine park, as the vessel returned to port in the Richmond River regularly, surveys were continued past the southern boundary of the Park.

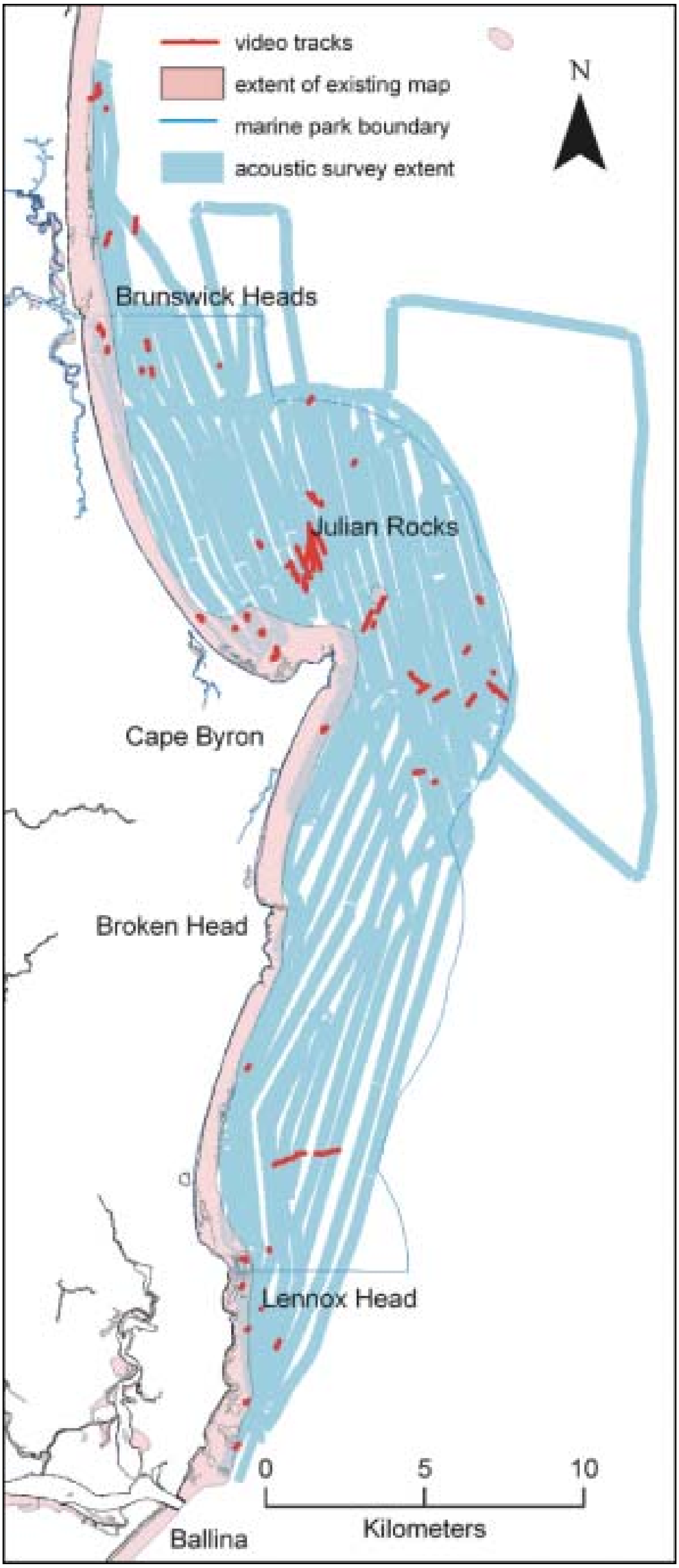

Figure 2.7 Extent of sidescan sonar survey, and locations of video transects

The reefs north of the Brunswick River entrance were also surveyed at the request of the NSW Marine Parks Authority and a single sidescan track was run over the 'Four Mile' reef approximately 9km offshore of the coast between Broken Head and the Brunswick River. The nearshore boundary of the sidescan survey was limited by depth (approximately 5m - this being the shallowest depth for safe operation of the equipment). The information obtained from the sidescan system overlapped that obtained from aerial photography.

Mosaics of the sidescan data were prepared at 1m and 5m resolution, and were segmented visually into distinct areas based on patterning and morphology. Digitisation of these boundaries into polygons was accomplished using ArcView 3.2.

2.3.3 Video Survey

Twelve hours of video validation was obtained over five days between the 5th to the 13th January 2004 on the charter vessel *Cavanbah*. Weather conditions and water quality (visibility) were generally poor throughout the survey. Northerly winds and strong currents made it difficult to control the camera system and high turbidity in the water reduced the visibility to a few meters in some areas. The lighting mounted on the camera was generally required to enable the video system to capture an image, although backscatter from suspended matter in the water often meant that artificial light could not be used.

Suitable tracks for video data collection were identified from interpreted sidescan mosaic images. The tracks typically sampled representative areas of different acoustic signatures. Geographical and ecological information was also used to select the video sites. As well as targeting transitions, boundaries, patchy areas and areas of specific interest from the mosaic, areas were sampled based on their location and depth. The final locations sampled also reflect the opportunistic nature of the survey caused by the poor weather conditions. During periods when only small weather/ tide windows were possible, only the areas to the north of the marine park were accessible. On days when the southern regions of the marine park were accessible, ample video was acquired.

2.3.4 Positioning

Positioning during the sidescan survey was provided by the GPS on the vessel *Ngaarru*. The GPS did not have differential reception capability. Positioning during the video survey was provided by a Garmin GPSII GPS with differential positioning beacon receiving the AMSA signal from Brisbane. Positions were recorded as WGS84. There are complex positioning issues associated with towing any equipment and the position of the GPS antenna recorded must be corrected for 'layback', the distance the towed body is behind the vessel, as well as any offsets in position between the antenna and tow point. This is further complicated by 'GPS latency', the time taken for the position to be processed by the GPS and to be transmitted to and recorded by the acquisition software in which time the vessel will have moved forward a distance dependant on its speed. It is also difficult to predict the behaviour of the cable in the water making it hard to estimate the horizontal distance the towed body is behind the vessel. The most efficient way to estimate the cumulative effect of all these parameters is to perform a patch test. This involves running overlapping sidescan tracks in opposite directions over a defined feature or boundary. The layback and offset applied in the sidescan acquisition software can then be adjusted to line up these features. The errors associated with these issues are hard to predict and validate. Further possible positional errors associated with the movement of the towed body in the water column must also be taken into account. Slight movements in the fish due to water and vessel movement cause movement of the acoustic beam. As data is acquired at large distances from the sidescan sonar any movement effects increases with range and can be quite large in poor weather conditions at the outer ranges of acquisition. This means that positional accuracy varies across each individual track and between tracks performed on different days in different conditions.

Positioning of a simple hand deployed towed video system as used in this survey is more difficult as the amount of cable deployed and speed of transect varies with depth and conditions. As boundaries and transitions between acoustic textures are selected for video sampling however, the positions of videos taken can be referenced to the sidescan using obvious changes in habitat seen acoustically and visually.

2.4 DATA MANAGEMENT AND INTERPRETATION

2.4.1 Processing Data

Sidescan mosaics generated at between 1 and 5m per pixel were segmented into regions of acoustically different texture by digitising polygons in ArcView 3.2. The videos were classified according to their biological and physical characteristics with reference to the unique positional identifier displayed on the screen.

Based on the video analysis and existing data, a classification system for the marine habitats of the CBMP was developed in discussion with the NSW Marine Parks Authority. Video track classifications that coincide with acoustically distinct textures on the segmented sidescan mosaic were used to classify the digitised polygons into habitat type. Where the video showed distinct, repeated changes in habitat type at particular depths that are not discernable on the sidescan record, boundaries were selected based on depth contours to allow finer delineation between habitat types. The bathymetry data set used to generate these contours was provided by the NSW Marine Parks Authority and covered the majority of the offshore reef systems in a survey of approximately 120 square km around Cape Byron. The spacing of these bathymetric sounding lines varied between 25 and 250m.

There are a number of uncertainties and errors which can be introduced by the interpretation of the data in this way. The choice of the classification scheme will have obvious ramifications on the accuracy of the final map and the positioning of boundaries based on the sidescan record is subjective and dependant on the quality and resolution of the imagery. Where depth contours have been used to create artificial boundaries, errors in classification are likely to be greater. Ultimately the final map is intended to be only one possible interpretation of all the available data.

Existing information was merged with the classifications produced using the sidescan and video survey. The classifications, boundaries and locations of all estuarine, terrestrial, island, coastal and intertidal features were retained from the existing classification system and map. In shallow subtidal areas where sidescan survey was not undertaken, the boundaries of reefs and other features mapped using aerial photography have been retained. Where mapping using aerial photography overlapped that surveyed by sidescan sonar, the acoustic boundaries have been used preferentially. There were two types of discrepancy noted during the mapping of reefs in these areas. The first is a difference in positioning between reef mapping using sidescan and aerial photography. These discrepancies were found to be of up to 20m but are few and are due partly to the fact that the original aerial photogrammetry technique used non-orthorectified images. Where these differences occur however, the boundaries taken from the sidescan sonar mosaic have been preferentially used. The shapes and areas of some reef patches also varied. This is possibly due to intermittent changes in the level of inundation by mobile sand. In these cases the boundaries taken from the more recent sidescan survey were preferentially used.

In subtidal areas deeper than those effectively covered by aerial photography, existing information was limited to that available on the Royal Australian Navy charts. Comparison of charted reef areas with the sidescan record showed clearly that the extent of offshore reef systems are underestimated on existing hydrographic charts. This may be due to reefs only being represented in areas where there is high profile relief (10m high over 150m horizontal distance) on RAN charts. These discrepancies are evident in Figure 2.18. As sidescan information was available for all subtidal areas deeper than 5m, these original boundaries were discarded and were replaced with those gained from this survey.

In previous classification systems, soft or unconsolidated sediment has been mapped by default as 'not reef'. Analysis of the sidescan sonar mosaic allowed boundaries between different types of sediment to be better determined. Where boundaries between sediment types were indistinct, bathymetric contours were used to complete polygons. These boundaries are represented as a dotted line in maps.

The final map of the area was produced as an ESRI polygon shape file with each polygon attributed with one of the agreed classifications. Maps were produced in ArcView 3.2 using the shape file after its acceptance by NSW Marine Parks Authority.

Overall horizontal accuracy of the maps is a combination of a number of issues including GPS positioning, fish positioning, acoustic beam positioning as well as accuracy of positioning and classifications of boundaries. From observation, it is estimated that the horizontal accuracy of features depicted on the maps is better than 25m.

2.5 CLASSIFICATION OF HABITAT TYPES

The sidescan sonar and video survey of the CBMP provided a substantial amount of new information as well as detail of the subtidal habitat types in the marine park.

The existing system for classification of habitat types of the CBMP (NSW Marine Parks Authority, 2003) was then able to be modified and enhanced, with a revised classification system developed for the marine habitats of the CBMP. The revisions applied mainly to the deeper parts (greater than 10m in depth) of the CBMP. The existing NSW classification system, and the proposed revised and expanding systems are presented in Table 2.1. Using the proposed revised classification system, the characteristics of the subtidal classification of the marine park are summarised in Table 2.2.

2.6 CLASSIFICATION OF REEF SYSTEMS

Distinct differences in the physical and biological characteristics of many reef systems were observed from video records. Previous classifications of reef systems in NSW relied on a broad division between offshore and inshore (or nearshore) reef systems. While assigning reefs into these categories is not strictly based on distance from the shore or depth, they do provide useful broad scale classifications of biological communities. An example of this is that the *Ecklonia* dominated inshore reef to the north of Brunswick Heads extends over 3km offshore, whereas the reefs around Julian Rocks are only 2.5km from Cape Byron and the Cape Pinnacle reef is only 1.2km from the Cape but both are classified as offshore. Inshore reefs are, however, typically located away from coastal currents in shallower areas with higher wave action and are dominated by a single species of macroalgae and support a variety of other marine invertebrates.

Inshore Reefs Classification

Boundaries of inshore reefs were determined from a combination of the sidescan record and the existing map. Classifications were made based on the video transects taken over discrete reef systems and have been described based on the dominance of one or more organisms, in this case macroalgae. The classifications chosen here also represent types of fringe habitat identified by Andrew (1999) which include *Ecklonia, Sargassum* and possibly *Phyllospora* forests. The inshore reefs have been classified into three basic types, based on the dominance of one or more organisms.

2.6.1 *Inshore Reef – Dominated by* Ecklonia

Reefs in this classification are clearly dominated by the kelp *Ecklonia radiata*. The majority of the nearshore reefs videoed were dominated by *Ecklonia radiata* as illustrated in Figure 2.8.

These ranged in depth from a few metres to over 25m. The relief varied within these reef systems. In some areas there are high profile reefs, gutters and edges but in others, the reef is inundated by sand and the *Ecklonia* appears to be growing on the seabed. Walls and edges are typically populated by sponges and invertebrates especially in the deeper areas.

2.6.2 *Inshore Reef – Dominated by macroalgae*

Reefs in this classification are dominated by a single macroalgae other than *Ecklonia*. The video record showed that the alga located here was *Sargassum* or possibly *Phyllospora comosa*. Other organisms such as filter feeders are also present. A typical image of this classification is shown in Figure 2.9.

2.6.3 *Inshore Reef – Unvalidated*

Reefs in this classification that have not been validated by video but were identified as reef from the sidescan sonar tracks. This classification comprised most of the reef along the shoreline and is easily accessible by small boat for further validation. It is likely that most areas will be able to be classified in one or other of the existing inshore reef classifications following variation.

Table 2.1 Classification of marine habitats, CBMP. Existing classification system and proposed revised classification system

Proposed Revised Classification (Bickers et al, this study)	Existing Marine Habitat Classification System (NSW Marine Parks Authority, 2003)		Example
Revised Classification	**Ecosystem Classification**	**Physiographic Unit**	
Estuary	Estuary	Estuary mature barrier group iii, c-d	Richmond and Brunswick Rivers
Beach	Beach	Beach	Main Beach, Tallow Beach, etc.
Mangrove	Mangrove		Richmond and Brunswick Rivers
Seagrass	Seagrass		Richmond River
Saltmarsh	Saltmarsh		Richmond River Flats
Seawall	Seawall		Brunswick and Richmond River entrances
Intertidal Rocky Shore	Intertidal Rocky Shore	Rocky shores/ platform	Lennox Head, Broken Head, Cape Byron
Inshore Islands and Rocks	Islands and Rocks		Cocked Hat Rocks
Offshore Islands and Rocks	Islands and Rocks		Julian Rocks
Nearshore Reef – Ecklonia	Subtidal Reef	Reef Shallow (0– 20m) – North of Ballina	Various Reefs, close to shore and in Byron Bay
Nearshore Reef – Macroalgae		Reef Shallow (0– 20m) – North of Ballina	Various Reefs, close to shore and in Byron Bay
Nearshore Reef – Unvalidated		Reef Shallow (0– 20m) – North of Ballina	Various Reefs, close to shore and in Byron Bay
Offshore Reef – 0 to 18m	Subtidal Reef	Reef Shallow (0 – 20m) – North of Ballina	Julian Rocks
Offshore Reef – 18 to 35m	Subtidal Reef	Reef Medium (20 – 40m)	Julian Rocks and Mackerel Boulder
Offshore Reef – 35 to 50m	Subtidal Reef	Reef Deep(40 – 200m)	NE of Mackerel Boulder and Cape Pinnacle reef
Offshore Reef – over 50m	Subtidal Reef	Reef Deep(40 – 200m)	Deep Reef System east of Cape Byron
Fine Sediment	Soft Sediment (0 – 20m, 20 – 60m and 60 – 200m)	Soft Sediment Shallow, Medium and Deep (0 – 20m, and 20 – 40m, North of Ballina and 40 – 200m)	Majority of marine park
Coarse Sediment – 0 to 50m	Soft Sediment (0 – 20m, 20 – 60m)	Soft Sediment Shallow and Medium (0 – 20m and 20 – 40m, North of Ballina)	Isolated areas through marine park, typically associated with sand waves or reef systems. Extensive around Julian Rocks and Mackerel Boulder
Coarse Sediment – over 50m	Soft Sediment (20 – 40m, 40 – 200m)	Soft Sediment Medium and Deep (20 – 40m, North of Ballina, 40 – 200m)	Deeper eastern area of marine park
Shells	Soft Sediment (0 – 20m, 20 – 60m)	Soft Sediment Shallow and Medium (0 – 20m, North of Ballina and 20 – 60m)	Isolated areas adjacent to nearshore reefs around Lennox Head and Brunswick Heads
Pebbles	Soft Sediment (0 – 20m, 20 – 60m)	Soft Sediment Shallow and Medium (0 – 20m, 20 – 60m)	Isolated areas between Ballina and Lennox Head

Table 2.2 Summary of physical and biological characteristics of proposed revised subtidal classification system

Section	Classification	Physical Characteristic	Biological Characteristic	Example Locations
2.6.1	Inshore Reef – *Ecklonia* Dominated	High and low profile reef	Conspicuous organism *Ecklonia radiata,* sponges and ascidians especially on walls	Reefs system in Byron Bay, Lennox Head and Brunswick Heads
2.6.2	Inshore Reef – Macroalgal Dominated	Isolated reefs	Conspicuous organism possibly *Phyllospora comosa* or *Sargassum* species	Isolated reef systems in Byron Bay
2.6.3	Inshore Reef - Unvalidated	Unvalidated, appears as reef on sidescan	Unvalidated	Various reef along coast
2.6.4	Offshore Reef – 0 to 18m	Reef, walls, sand patches, continuous reefs and large boulders	Turfing algae, coral, ascidians	Julian Rocks
2.6.5	Offshore Reef – 18 to 35m	Reef, walls, gutters, caves, etc.	Turfing and encrusting algae, sponges, hard and soft coral, filter feeders. Conspicuous yellow sponges	Julian Rocks
2.6.6	Offshore Reef – 35 to 50m	Medium profile reef with gutters to boulder fields and rubble	High invertebrate diversity, sponges, soft corals, crinoids	Cape Pinnacle and NE of Mackeral Boulder
2.6.7	Offshore Reef – over 50m	Low profile reef and rubble	Crinoids, sponges and seawhips	Deeper reefs east of Cape Byron
2.7.1	Fine Sediment	Well sorted sand	Unknown	Most areas, default classification
2.7.2	Coarse Sediment – 0 to 50m	Coarse sediment with shell	Unknown	Around Julian Rocks, trapped in sand waves along exposed beaches
2.7.3	Coarse Sediment – over 50m	Coarse sediment	Unknown, possible algal and worm colonisation, seawhips	Associated with deeper reef systems
2.7.4	Shells	Dead bivalve shells	Unknown	Isolated areas near Ballina
2.7.5	Pebbles	Round pebbles and cobble	Unknown	Associated with reefs around Lennox Head and Brunswick Heads

Figure 2.8 Inshore reefs dominated by **Ecklonia** *a, b) video stills c) sidescan image*

Figure 2.9 Inshore reef dominated by macroalgae

Offshore Reefs Classification

Mapping of the offshore reefs was performed entirely using sidescan and video obtained during this survey. Although two (Julian Rocks/Mackerel Boulder and Cape Pinnacle) of the major reef systems in this classification are formed by submarine extensions of the onshore bedrock, a further reef system east of Cape Byron has little relief and may represent an earlier resistant substratum which has been exposed (Ferland, 1990).

Boundaries between mapped classes were determined as previously described using a combination of the sidescan mosaic video validation and contours generated from a bathymetric data set. Figures 2.10 and 2.11 show examples of the sidescan record together with video stills for each type of reef described below.

2.6.4 Offshore Reef – 0 to 18m

In the CBMP this reef type is limited to the area around Julian Rocks. It encompasses steep ecological gradients in the shallower areas around the islands due to differences in exposure to both light and waves. The physical structure of this area is also quite diverse, with steep rock walls, sand patches, continuous reef and large boulders (bommies). The deeper boundary for this area was determined using an 18m bathymetric contour, the depth of which was chosen based on differences in biota recorded during video transects. A similar contour (20m) has been used in a number of previous reef classification systems used in NSW (ANZECC/TFMPA, 1998a; NSW Marine Parks Authority, 2003).

This classification differs from inshore reefs of similar depths in that habitats are not dominated by *Ecklonia radiata*. Much of the reef is bare, or colonised by small macroalgae (such as turfing algae). Features of this shallower offshore reef system exhibit characteristics described by Andrew (1999). Crustose red algae are abundant and scleratinian corals, ascidians and other invertebrates also colonise these areas. A shallow coral outcrop is shown in Figure 2.10a and bare reef at 14m is shown in Figure 2.10b. This is typical of the barrens habitat described by Andrew (1999). The sidescan image shown in Figure 2.10c shows to the right a darker textured area. This is typical of imagery of this classification.

Limited video survey work was carried out in the shallower regions of Julian Rocks as it was difficult to work close to the rocks. The area however, has been the subject of other more detailed surveys (e.g. Harriot et al., 1999).

2.6.5 Offshore Reef – 18 to 35m

From a depth of 18m, the next clear change in community structure appears at 35m. The classification between these depths covers the outer parts of the reef around Julian Rocks and most of the Mackerel Boulder. This reef is interrupted by walls, gutters, caves, overhangs and sand patches. There is a mix of sponges, encrusting algae, some hard and soft corals, and filter feeders on the reef.

Invertebrate diversity and abundance of this region is greater than in the 0 to 18m depth range. A very conspicuous feature of the landscape is an abundance of flat topped yellow sponges which do not seem to dominate waters shallower or deeper than this zone (Figure 2.10d,e,f). A typical sidescan image of this classification is shown in Figure 2.10g. The deeper edges meet areas of coarse sediment and sand ripples that surround Julian Rocks and Mackerel Boulder. This coarse sediment is represented as the darker less textured areas of Figure 2.10g. Similar coarse sediment is seen in Figure 2-10c (0 – 18m reef)

2.6.6 Offshore Reef – 35 to 50m

Both the upper and lower boundaries of this classification are formed by depth contours. Although this classification relates mainly to the Cape Pinnacle reef system, areas to the NE of Mackerel boulder also exhibit similar physical and biological characteristics. The sidescan record for the most northern part of the Mackerel Boulder reef system is shown in Figure 2.10h. An apron of darker coarse sediment surrounds the low profile and rubble reefs. Video stills (Figure 2.10i,j) show the diversity of benthic invertebrates found in the deeper areas to the north of Mackerel Boulder. The sidescan record of the Cape Pinnacle reef system also shows rubble bottoms and low profile reefs but with large sand waves, scouring and deposition of coarse material suggesting there are strong currents in the areas (Figure 2.11e, f). Although the Cape Pinnacle reef system does have pinnacle areas that rise up to less than 25m, existing bathymetric data is not sufficiently fine scale to identify these pinnacles accurately. Video data was obtained up one pinnacle from 26m to 40m and the biota did not appear to vary greatly throughout this depth range. Crinoids, sponges, soft corals, seawhips and encrusting algae dominate the benthos in these areas. The coverage and diversity of invertebrates in both areas appears to be much higher than in either of the shallower zones (Figure 2.11a,b,c,d).

2.6.7 Offshore Reef – over 50m

Along the 50m bathymetric contour both the sidescan and video information show changes in substrate and community structure. Division at this depth range is not made in any other existing NSW classification system although both the physical structure and communities of the reefs in waters deeper than 50m appear to be distinct. Reefs that fall into this category are located between 2.5 and 5km due east of Cape Byron. Sidescan and video records show the area to be of sparse rubble on coarse sediment and edges of low profile reef appearing through sand inundation. The amount and location of exposed reef and rubble is likely to vary with time as sediment moves through the area. The most conspicuous benthic organisms are feather stars (Crinoidea) which are very abundant on exposed hard surfaces (Figure 2.11g, h). Sponges, sea whips and sea pens are also present on the sand. Although no video was collected from Four Mile Reef, the sidescan data acquired there appears similar to this area. The sidescan records shown in Figure 2.11i, j are characteristic of the area showing indistinct low profile reefs and changes in sediment type. Often all that can be distinguished when videoing across these areas is a change in abundance of crinoids.

2.7 CLASSIFICATION OF UNCONSOLIDATED SEDIMENT

The majority of sediment in areas of less than 50m depth appeared to be similar throughout the marine park. This was noted to be fine and well sorted. In areas deeper than 50m, sediment appeared to be of a very different, much coarser, composition. A clear transition between these two sediment types at 50m could be noted in the areas south of Cape Byron. The transition was not as clear for the areas to the north. The extent of this coarser sediment appears to be associated with the 'Offshore Reef over 50m' classification.

Ferland (1990) in a study of sand shelf bodies of South Eastern Australia notes changes in sediment type at three depths along this part of the coast. The first at between 10 to 15m is not discernable from the sidescan data, but maps representing the second at 45 to 55m match the boundary of the 'Coarse sediment over 50m' classification well. The sand shelf body in the area studied extends south from Cape Byron to the Richmond River. This is represented well by the large area of fine sediment shown on the map known locally as 'The Desert'.

Coarse sediment associated with the influence of reefs was also noted around all the major reef systems. This was particularly extensive in the Julian Rocks/Mackerel Boulder area. Sediment in this area was particularly well distinguished from fine sediments in shallow water.

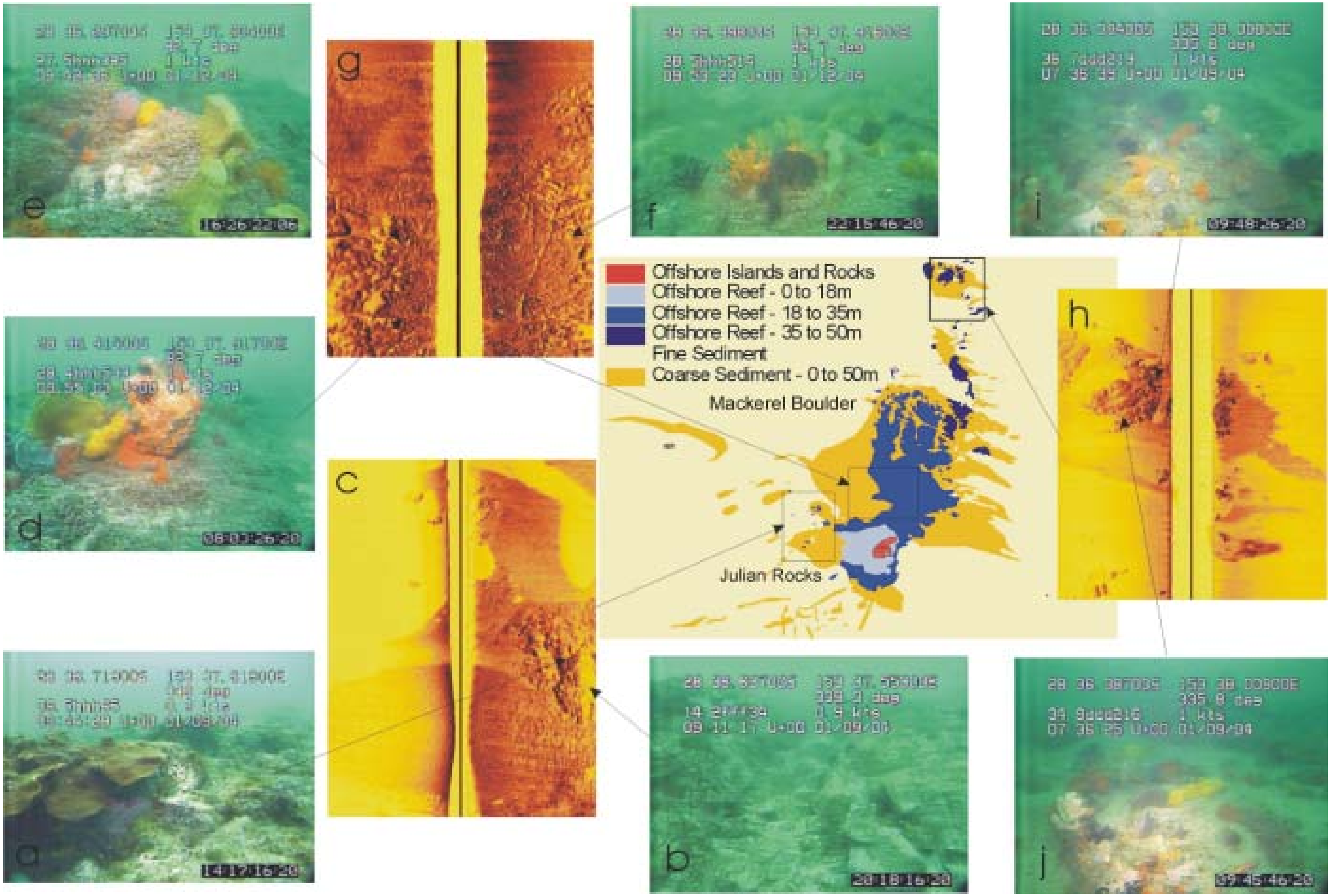

Figure 2.10 Sidescan and video still images of reef types around the Julian Rocks and Mackerel Boulder areas. Offshore reef 0 to 18m (a, b, c). Offshore reef 18 to 35m (d, e, f, g). Offshore Reef 35 to 50m (h, i, j).

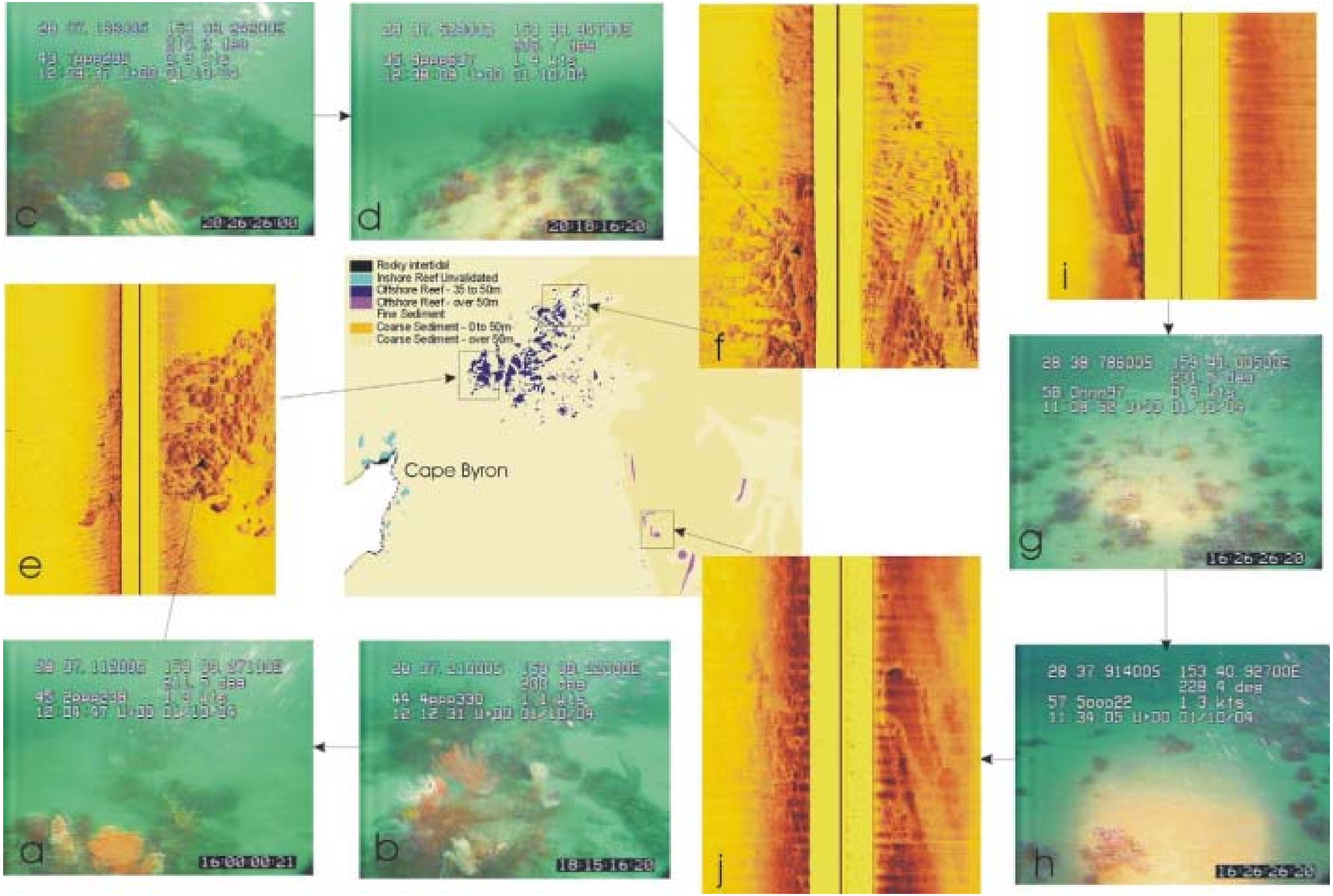

Figure 2.11 Sidescan and video still images of deeper reef types of CBMP. Offshore reef 35 - 50m (a, b, c, d, e, f). Offshore reef over 50m (g, h, i, j).

Coarser sediment is often associated with sand waves and ripples. Shells, pebbles and heavier particles accumulate within gutters. A particularly good example of this is about 1km offshore from the beaches between Cape Byron and Broken Head, and Broken Head and Lennox Head. These very defined areas of coarse sediment and sand waves were previously mapped from aerial photos as reef (Marine Parks Authority, 2001).

Defined and isolated areas of other unconsolidated sediment have also been mapped. Regions close to reefs at Lennox Head and Brunswick Head were found to be made up of pebbles and some discrete areas 1km offshore to the north of Ballina were clearly comprised of mainly bivalve shells. The boundaries of these regions were typically sharp.

It should be noted however, that it is often difficult to distinguish between rippled fine sediment and flat coarse sediment from the sidescan record. Unconsolidated sediments in the area were classified and mapped using the following scheme.

2.7.1 Fine Sediment

Fine sediment was found in the majority of the CBMP and was generally well sorted sand with little shell content. Although previously the NSW Marine Parks Authority has classified sediment into three depth ranges, there was no clear indication from the sidescan record that these boundaries were realistic. Few features could be identified on the habitat within this classification, although areas of sand waves (Figure 2.11e, f) and trawling (Figure 2.12) were noted. Lighter, smoother areas of the sidescan records (as shown in Figures 2.10 and 2.11) are mapped as fine sediment. Trawl marks, are clearly identifiable on the sidescan record. An example of these marks taken from near the edge of the marine park (3nm) south of Cape Byron, is shown in Figure 2.12.

2.7.2 Coarse Sediment – 0 to 50m depth

Many sharply defined transitions between sediment types and morphology were found in the Byron region. These were typically found in areas surrounding reefs, or associated with sand ripples. An extensive area of coarse sediment was found around Julian Rocks/Mackerel Boulder areas. The boundary between these sediment types is easily distinguished (Figure 2.10c). Coarse sediment trapped in the sand waves along the exposed beaches between Cape Byron and Ballina is also shown clearly on the sidescan record (Figure 2.13).

2.7.3 Coarse Sediment – over 50m depth

A distinctly different sediment type was found deeper than the 50m bathymetry contour. The boundary of the mapped extent of this sediment type is formed by both real and artificial boundaries. Although the boundary between sediment types to the south of Cape Byron was easily mapped from the sidescan record, the transition was more continuous to the north. No delineation could be easily made between sediment types for this area and an artificial boundary was formed using the 50m bathymetric contour shown as a dotted line on maps. Sidescan records (Figure 2.11i,j) show the changes between coarse and fine sediment and reef in this zone. Much of this sediment appeared to be colonised by an unidentified organism (Figure 2.14). A crinoid typical of the area is also shown in the upper right of the image.

2.7.4 Shells

Areas comprised mainly of dead bivalve shells are restricted to a few discrete patches 1km offshore north of Ballina. This area had very limited visibility on the day of survey and no clear still images could be obtained from the video.

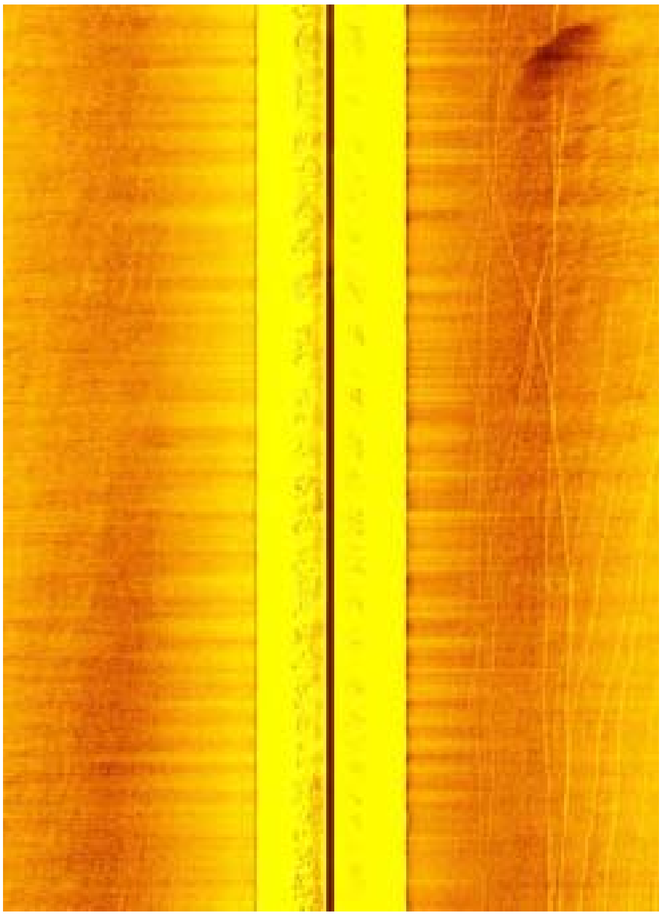

Figure 2.12 Trawl marks in fine sediment

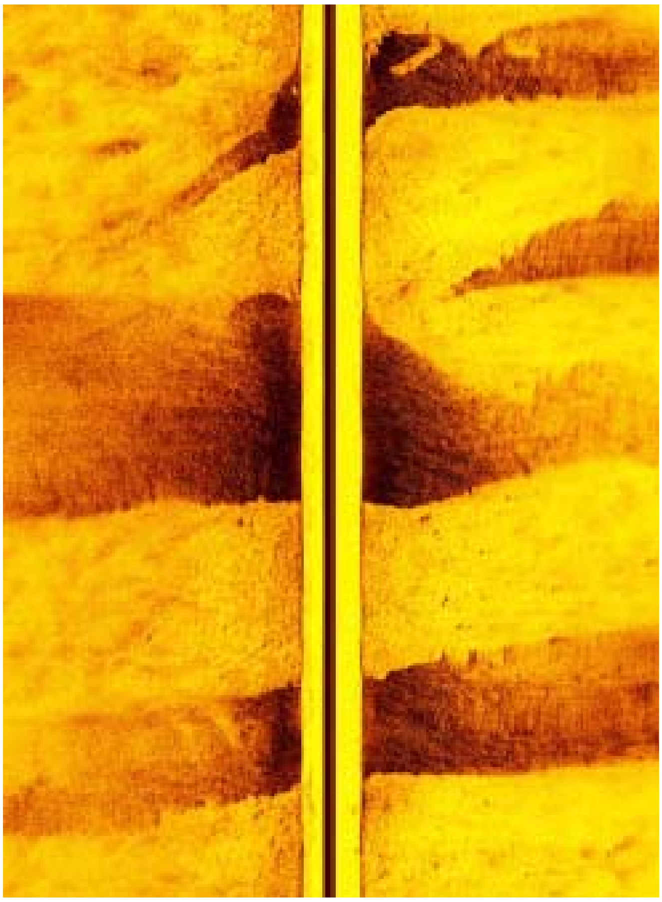

Figure 2.13 Changes in sediment type and morphology found along exposed beaches

Figure 2.14 Coarse sediment classification with unidentified benthic organism and crinoid

2.7.5 Pebbles

Small seaward areas adjacent to reefs at Lennox Head and Brunswick Heads. Also found in some areas of coarse sediment off the beaches between Cape Byron and Ballina. Pebbles were found to be normally associated with sand ripples (Figure 2.15).

Figure 2.15 Pebbles and sand waves

2.8 MAP PRESENTATION

Maps were produced as follows showing the extents of habitats in the surveyed areas of CBMP and its surrounds. Maps are presented in the WGS84 Universal Transverse Mercator projection.

Figure 2.16 Habitat map of the areas surveyed in Cape Byron Marine Park and surrounds
Figure 2.17 Habitat map of the Cape Byron Marine Park
Figure 2.18 Habitat map of the offshore reef systems within the Cape Byron Marine Park

2.9 ONLINE PRESENTATION

Copies of this report and a presentation of the supporting information is available on the following websites:

http://maps.nationalparks.nsw.gov.au/cbmp

www.coastal.crc.org.au

Figure 2.16
Habitat Map of the area surveyed in Cape Byron Marine Park and surrounds

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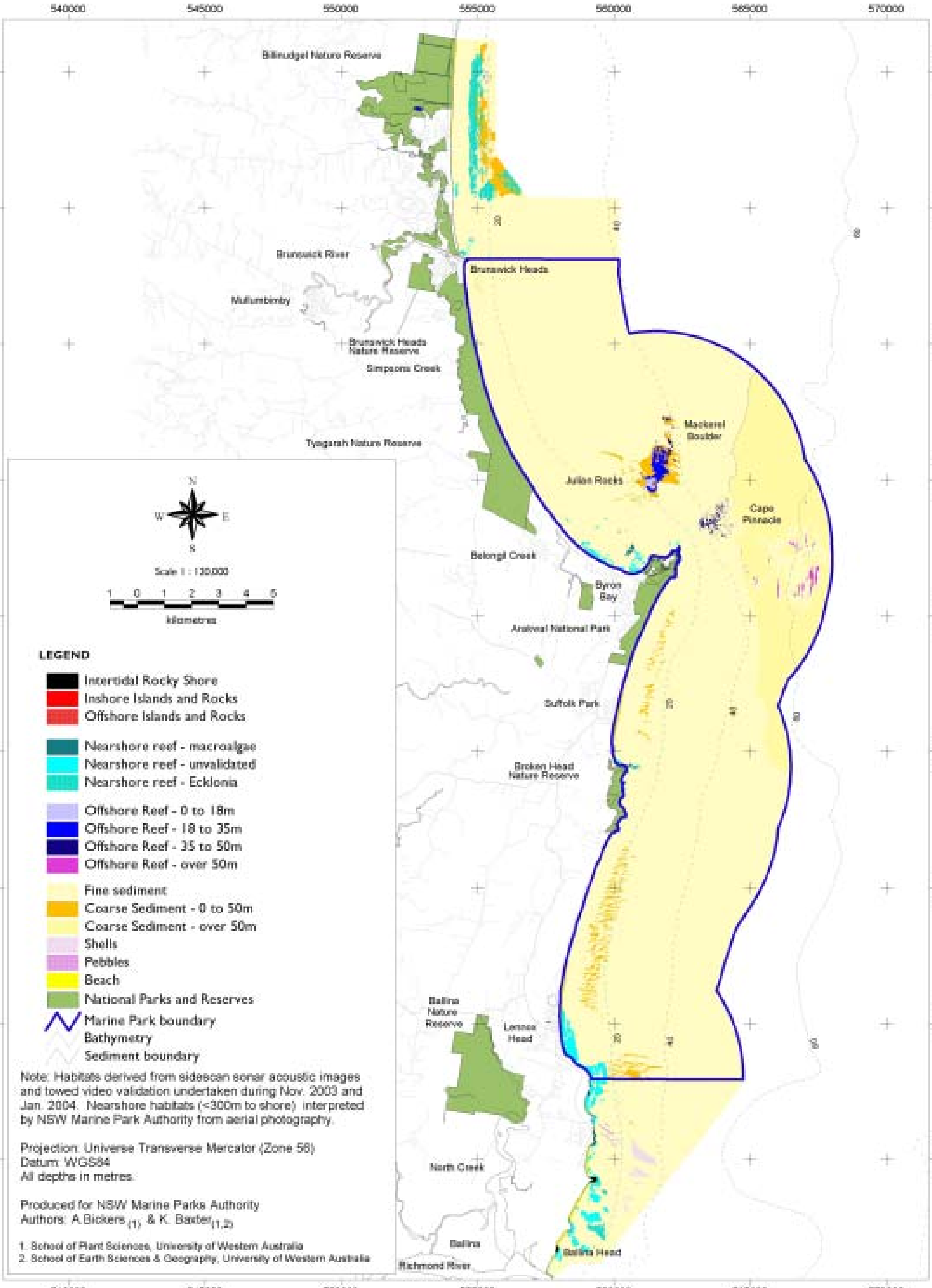
CRC for Coastal Zone Estuary & Waterway Management



Note: Habitats derived from sidescan sonar acoustic images and towed video validation undertaken during Nov. 2003 and Jan. 2004. Nearshore habitats (<300m to shore) interpreted by NSW Marine Park Authority from aerial photography.

Projection: Universe Transverse Mercator (Zone 56)
Datum: WGS84
All depths in metres.

Produced for NSW Marine Parks Authority

Authors: A.Bickers [1] & K. Baxter [1,2]

1. School of Plant Sciences, University of Western Australia
2. School of Earth Sciences & Geography, University of Western Australia

Figure 2.17
Habitat Map of the Cape Byron Marine Park

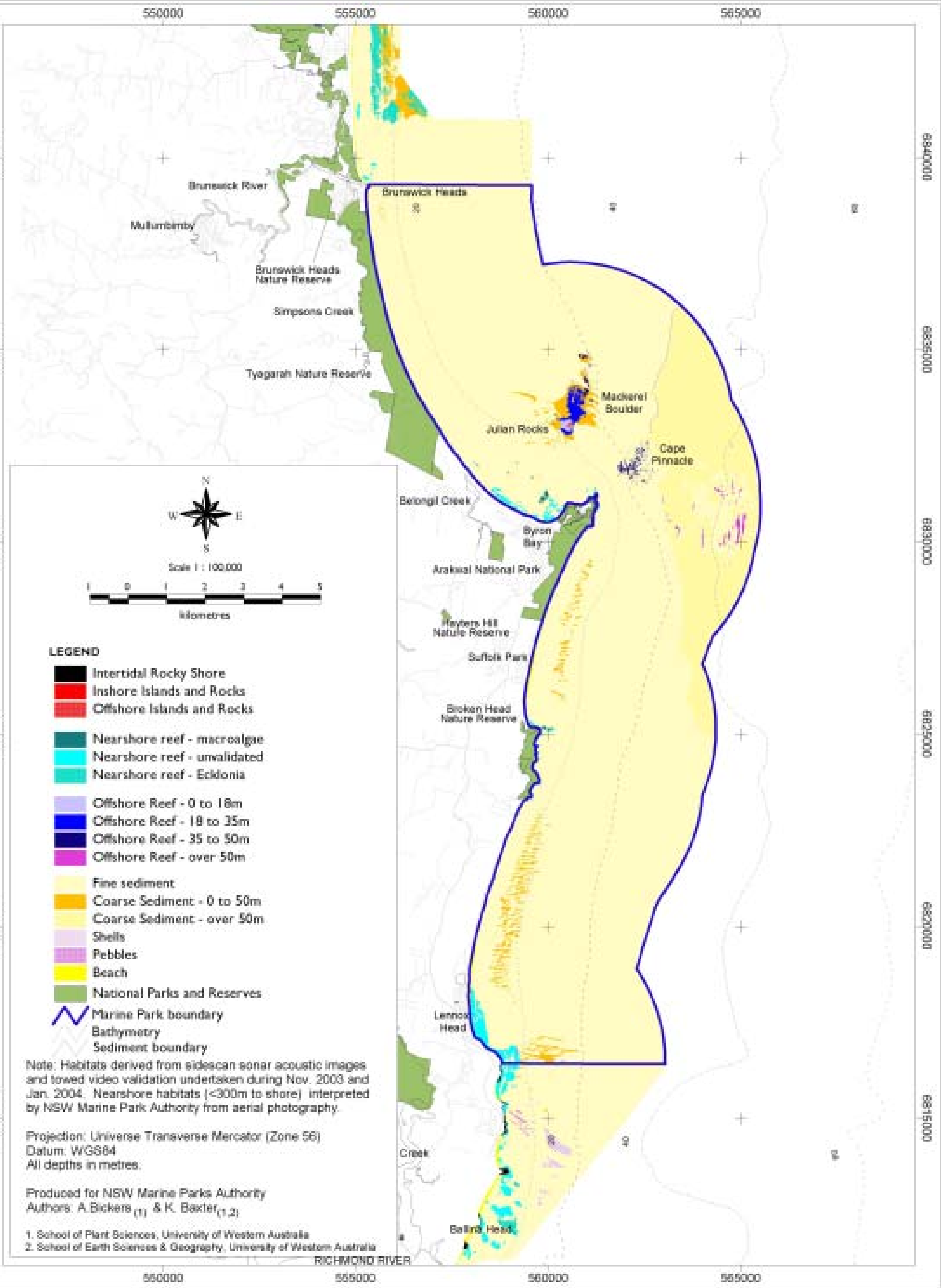
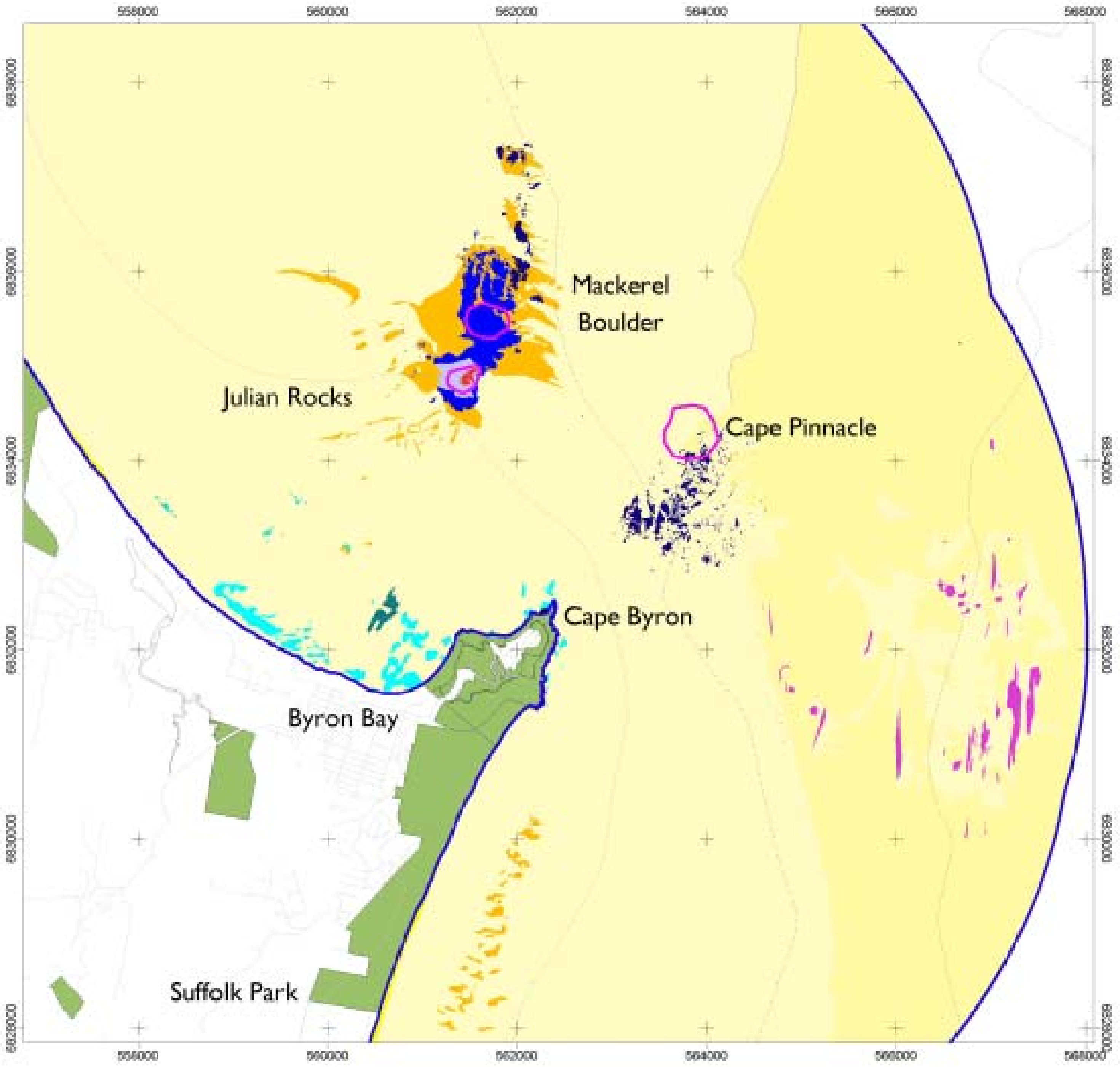


Figure 2.18
Habitat Map of the offshore reef systems within the Cape Byron Marine Park

THE UNIVERSITY OF WESTERN AUSTRALIA

CRC for Coastal Zone Estuary & Waterway Management



LEGEND

- Nearshore reef - macroalgae
- Nearshore reef - unvalidated
- Nearshore reef - Ecklonia
- Offshore Islands and Rocks
- Offshore Reef - 0 to 18m
- Offshore Reef - 18 to 35m
- Offshore Reef - 35 to 50m
- Offshore Reef - over 50m
- Fine sediment
- Coarse Sediment - 0 to 50m
- Coarse Sediment - over 50m
- Beach
- National Parks and Reserves
- Marine Park boundary
- Bathymetry
- Previously mapped extent of habitat
- Sediment boundary

Note: Habitats derived from sidescan sonar acoustic images and towed video validation undertaken during Nov. 2003 and Jan. 2004. Nearshore habitats (<300m to shore) interpreted by NSW Marine Park Authority from aerial photography.

Projection: Universe Transverse Mercator (Zone 56). Datum: WGS84
All depths in metres.

Scale 1 : 40,000
0.5 0 0.5 1 1.5
kilometres

N S E W

Produced for NSW Marine Parks Authority
Authors: A.Bickers[1] & K. Baxter[1,2]

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3. CONCLUSIONS

A sidescan sonar and video survey of the CBMP was successfully completed during the period November 2003/January 2004. Although the weather throughout the field operations was not optimal, significant enhancements to the level of information available relating to the nature and detail of the offshore benthic marine habitats of the park were made. The wide swath of the sidescan sonar provided almost full coverage of the seafloor within the CBMP and from the processed records both reef and sediment habitats in the CBMP could be successfully delineated. Validation of the acoustic records using towed video was successful in gaining a qualitative indication and description of the physical and biological structure of the acoustically distinct regions of the sidescan image. In areas where detailed interpretation of the sidescan records was not possible, depth contours from an existing bathymetric data set were also used to provide boundaries that allow further delineation of changes in community or physical structure seen on the video record.

The survey revealed a significant range of habitat types in the CBMP, these being related to location, depth and exposure to waves and currents. A revised and more detailed classification scheme was developed in discussion with NSW Marine Parks Authority to represent the physical and biological characteristics that could be determined from sidescan and video records. The revised classification scheme used in this report is a significant development on the previous classification by virtue of the improved data capture technology employed and can be further refined. Continued development of classification systems should focus on covering the full suite of potential communities on the NSW coast in order to develop a standard system for marine habitats along the NSW coast. This should ideally be an extension of compatible classifications such as those already developed in Victoria and Tasmania. Future classification systems are therefore likely to differ slightly from the one presented here. This highlights the general need for a hierarchical classification system that will deliver consistency across NSW Marine Parks and through time.

It was found that the extent and locations of offshore reef systems mapped using sidescan sonar differed greatly from those interpreted from the RAN charts. This can be seen clearly in Figure 2.18. It is suggested that errors in the extent of the Julian Rocks and Cape Pinnacle reef systems relate to differences in how a reef is defined and to the differences in survey technique. The positional error of the Cape Pinnacle reef system from previous maps cannot be explained. The major boundary between sediment types at approximately 50m depth agrees with previous investigations of the sedimentary characteristics of the Cape Byron region by Ferland (1990).

Throughout the survey many fish were seen on the videos around reefs and any type of hard substrate. Large quantities of bait fish were consistently found close to even small and isolated areas of reef. One of the very significant benefits of full coverage swath mapping of the CBMP is that important small and isolated reef habitats can be identified.

Maps classifying the habitat into a range of classes were produced from sidescan sonar mosaics processed at a pictorial resolution of up to 1 square meter per pixel resolution. The positional accuracy of the resultant habitat map was estimated to have a horizontal accuracy of 25m or less from observations of features in overlapping tracks. The benthic habitat maps that have been prepared of the CBMP provide a major contribution to the knowledge of the park, and will play a direct role in developing zoning and management plans for the CBMP.

The sound management of marine protected areas, and more generally coastal resources is inevitably dependant on the quality of available information. The benthic habitat map for the CBMP produced in this survey is of a high standard, but is of a descriptive or qualitative nature and is only intended as one of a many possible interpretations of the available data. This map can steadily be improved by detailed quantitative sampling of selected areas of the park, to enumerate the magnitude and diversity of each of the habitats and their natural resources. In addition, the benthic habitat map would be further enhanced by acquiring detailed information on bathymetry, substrate and benthos in selected areas. The recent purchase of GeoSwath equipment that simultaneously acquires both bathymetry and imagery over wide swaths by the Department of Environment and Conservation in NSW will allow the classification system and maps to be refined. Future GeoSwath bathymetry data will enable, for example, relief (such as peaks, walls and gutters) to be more accurately described. An example of an area that would benefit from further study is the deep, poorly defined low profile reef to the East of Cape Byron. Future detailed work by ROV or diver testing the boundaries between habitat classifications through analysis of flora and fauna targeted using the habitat maps would also be beneficial.

4. ACKNOWLEDGEMENTS

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The field surveys using sidescan sonar and towed video cameras were planned and undertaken by **Andy Bickers** and **Katrina Baxter** (UWA). Data analysis and habitat mapping was undertaken principally by **Andy Bickers** and **Katrina Baxter** in consultation with **Simon Banks** (NSW Department of Environment and Conservation), **Andrew Page** and **Dan Breen** (NSW Marine Parks Authority).

The report was written by **Andy Bickers** and reviewed by the NSW Marine Parks Authority prior to finalisation. Throughout the project, support and encouragement was provided by **Gary Kendrick** (UWA) and **Des Lord** (Coastal CRC) with project planning and detailed report editing and review. **Dave Cameron** (Coastal CRC) managed the contractual aspects of the project.

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5. REFERENCES

Andrew, N.A. (1999). NSW. In: *Under southern seas. The ecology of Australia's rocky shores*. Ed. Neil Andrew. University of New South Wales Press, Sydney. pp. 8–19.

ANZECC / TFMPA (1998a). *Guidelines for Establishing the National Representative System of Marine Protected Areas*. Australian and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas. Environment Australia, Canberra.

ANZECC / TFMPA (1998b). *Strategic Plan of Action for the NRSMPA*. Australian and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas. Environment Australia, Canberra.

Avery, R.P. (2000). *Byron Bay Area Assessment, Tweed-Moreton Bioregion, Northern NSW: A Review of the Current Marine Biodiversity Data Sets and An Introduction to Systematic Marine Protected Area Planning in NSW*. A NSW National Parks and Wildlife Service Report to the NSW Marine Parks Authority.

Bickers, A.N. (2003). Cost Effective Marine Habitat Mapping from Small Vessels using GIS, Sidescan Sonar and Video. In: *Coastal GIS 200*3. Eds DCD Woodroffe and RA Furness. Wollongong papers on Maritime Policy, 14.pg

Breen, D.A., Avery, R.P. and Otway N.M. (2003). Broadscale biodiversity assessments for marine protected areas in New South Wales, Australia. In: *Aquatic protected areas – what works best and how do we know?* World Congress on Aquatic Protected Areas, Cairns, Australia – August 2002. (Eds JP Beumer, A Grant, and DC Smith.), Australian Society for Fish Biology, pp. 120-131.

Ferland, M.F. (1990). *Shelf Sand Bodies in Southeastern Australia.* PhD Dept of Geography University of Sydney, August 1990.

Harriot, V.J., Banks S.B., Mau, R.L., Richardson, D. and Roberts, L.G. (1999). Ecological and conservation significance of the subtidal rocky communities of northern New South Wales. *Australia Marine and Freshwater Resource* 50:,, 299-306.

NSW Marine Parks Authority (2001). *Consultation Paper: Proposed multiple-use marine park at Byron Bay.* Marine Park Authority, Byron Bay.

NSW Marine Parks Authority (2003). *Background Resource Working Paper for the Cape Byron Marine Park*. Marine Park Authority, Sydney.

Mau, R.L. (1998). *A Preliminary Survey of the Suitability of the Byron Coastal Waters as a Marine Park*. A report prepared for the NSW Marine Parks Authority, NSW National Parks and Wildlife Service, Alstonville.

Underwood, A.J., Kingsford, M.J. and Andrew, N.L. (1991). Patterns in shallow subtidal marine assemblages along the coast of New South Wales. *Australian Journal of Ecology* 6: 231–49.