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MAPPING OF INSHORE MARINE HABITATS IN SOUTH-EASTERN TASMANIA FOR MARINE PROTECTED AREA PLANNING AND MARINE MANAGEMENT

N. Barrett, J.C. Sanderson, M. Lawler, V. Halley and A. Jordan

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Summary

A National System of Marine Protected Areas (NRSMPA) is currently being established in Australia with the collaboration of governments at the State and Federal level. In Tasmania this policy is articulated in the State Marine Protected Area Strategy (MMIC 2001) that recognises the need for a Comprehensive, Adequate and Representative (CAR) system of MPAs for State waters. The State and Commonwealth MPA implementation strategies each recognise that for MPAs to be established on a CAR basis, a thorough inventory of marine habitats is needed to ensure areas selected are appropriate.

This study presents the first such inventory for Tasmanian waters, with detailed mapping of marine habitats within the Bruny Bioregion. The study had two objectives, to map the marine habitats in the Bruny Bioregion and to use this information to identify candidate MPAs that fulfil CAR requirements. While Tasmanian waters include nine bioregions, the Bruny region was identified as a priority for mapping due to its high degree of marine endemism, high habitat diversity and the more urgent need for protection given the high population density of the region in close association with the capital city, Hobart.

Maps were produced at a scale of 1:25,000, showing the principal habitat types in shallow inshore coastal waters to the 40 m depth contour. The production of maps involved extensive field surveys of the region from small vessels equipped with colour sounders and differential GPS. Position, depth and bottom type were continuously logged in real time using a computer application developed for this task. Regular video drops were conducted to validate interpretation of sounder signals. Aerial photographs were scanned and rectified to provide more detailed information on habitats in inshore areas where water clarity allowed. For most of the coast the utility of aerial photographs was limited to a depth of ten metres. The information was collated and mapped using the GIS application ArcView, allowing detailed analysis of habitat distribution by depth and exposure.

The habitat maps were then used to suggest a number of potential MPA locations that would protect a comprehensive range of marine habitats within this bioregion. Sufficient information is also available for discussion of alternative MPA options as part of stakeholder negotiations during the implementation of the Tasmanian Marine Protected Area Strategy (2001).

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2. Introduction

The establishment of a national system of marine protected areas in Australia is a key responsibility and obligation under international and inter-governmental agreements (*Strategic Plan of Action for the National Representative System of Marine Protected Areas (NRSMPA): A Guide for Australian Governments*: ANZECC, 1998a). The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative (CAR) system of MPAs to contribute to the long term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biodiversity at all levels.

To achieve these aims, all Australian State government agencies with responsibility for marine conservation and management are participating in the ANZECC Task Force on Marine Protected Areas (TFMPA). In Tasmania, a marine protected area strategy has been developed to structure this process (Marine and Marine Industries Council 2000). In 1999, the TFMPA released a Strategic Plan of Action for the implementation of the NRSMPA. This plan recognised that the mapping of marine habitats was a primary information requirement for developing a CAR system of MPAs, given that very little information is currently available on the distribution of marine habitats throughout Australia, and particularly in Tasmania. A thorough inventory of marine habitats is essential if MPAs are intended to protect a representative range of habitats within each bioregion. A good representation of habitats should lead to an equally good representation of marine species diversity, as habitats are good surrogates for species richness (Ward *et al.*, 1999). Additionally, for the planning of individual MPAs, it is important that locations are chosen that can incorporate a range of representative habitats, and are of sufficient size with suitable habitat boundaries to minimise the loss of protected species to adjacent areas (Barrett, 1995, Kramer and Chapman, 1999).

An earlier stage in the development of the NRSMPAs recognised that an understanding of the biogeography of Australian coastal waters was an important step towards adequately protecting species within a network of MPAs. A range of physical process such as water temperature, ocean currents, wave action and nutrient levels determine the distribution of marine plants and animals, and at the scale of 100s to 1,000s of km distinct biological associations can be recognised. Classification units at this scale are termed bioregions and within Tasmanian coastal waters nine bioregions have been recognised (Edgar *et al.*, 1995). The detailed regionalisation of Tasmanian waters is primarily due to the complex oceanography of this region, interacting with substantial gradients in exposure to waves and oceanic swells. The bioregionalisation of Tasmanian coastal waters (ANZECC, 1998a) is based on the analysis of detailed biological studies of the biogeographical distribution of Tasmanian marine biota, including rocky reef biota, beach-washed shells, and beach-seine collections of coastal and estuarine fishes (Edgar *et al.*, 1995).

While detailed habitat mapping is particularly useful for planning the establishment of representative MPAs, funding restrictions meant that this process had to be prioritised. There is an existing MPA at Maria Island in the Freycinet bioregion and proposals have been developed for representative MPAs at Port Davey (Davey bioregion) and the Kent Group of islands (Twofold Shelf bioregion). In addition, preliminary mapping of potential MPAs in the Boags bioregion (Barrett and Wilcox 2001) has been completed. For this reason the Bruny bioregion was selected as the next area to be examined. This prioritisation was primarily due to the high degree of marine endemism found in this bioregion (Edgar *et al.,* 1995), the complexity of marine habitats in the area, and the urgent need for protection given the high population density of this region associated with the capital city.

The Bruny bioregion extends from the southern tip of Maria Island and Hellfire Bluff on the Tasmanian east coast, to the township of Southport on the far south east coast. The northern boundary of the Bruny bioregion is essentially determined by the average position of the interface between warm East Australian Current waters and colder sub-Antarctic waters. As this northern interface is somewhat variable in position through time, there is a degree of overlap in distinctive biota between the northern boundary of the Bruny Bioregion and the southern boundary of the adjacent Freycinet Bioregion. The southern boundary of the Bruny Bioregion is determined by a major exposure gradient, as the waters to the south of Southport are maximally exposed to the prevailing southern ocean swells. One of the distinctive features of the Bruny Bioregion is the high degree of endemism of marine species that are restricted to this region. The sheltered embayments found in this region are the southernmost refuges available in Australia for a number of cold adapted species (Edgar *et al.,* 1995, ANZECC, 1998b). A further distinctive feature is the presence of large “forests” of the giant string kelp *Macrocystis pyrifera,* a species restricted to the cool temperate waters of southern Tasmania. While *M. pyrifera* is also found in adjacent bioregions it is most abundant on moderately exposed reefs within the Bruny Bioregion.

Prior to this study, very little was known of the distribution of marine habitats within the Bruny bioregion, or more widely in Tasmanian waters. Existing studies had either focussed on assessing specific areas for marine farm development (eg. Mitchell, 1999), potential MPA locations (Barrett and Wilcox 2001), the distribution of selected seagrass beds (Rees, 1993), or had been at a very coarse scale (Edyvane *et al.,* 2000). This latter study, a broad-scale mapping of inshore Tasmanian coastal waters, was initiated by Hugh Kirkman from CSIRO as part of a larger survey of temperate Australian coastal waters. It utilised aerial photographs and Landsat images to determine the boundaries of seagrass, sand and reef habitats to maximum depths of approximately 10 m depth, the lower limit of surface visibility in most Tasmanian waters. The study included a small component of ground-truthing, sufficient to ensure broad areas of seagrass and reef were correctly identified, as they often appear identical when viewed from photographs. While limited by the availability of suitable images and the poor depth penetration of aerial photography, the work initiated by Kirkman highlighted the need for a proper inventory of coastal resources for marine planning.

This study had two primary aims. The first of these was to build on the work of Kirkman, by providing detailed information on the distribution of marine habitats within the Bruny bioregion for the identification of potential Marine Protected Areas (MPAs) that adequately represent the region. This information was obtained by mapping the principle habitat types in shallow inshore coastal waters within the bioregion to the 40 m depth contour at a scale of 1:25,000, and identifying any unique communities or habitats of limited distribution. The second aim was to use this information to identify potential MPA locations based on the CAR principles outlined in the Tasmanian Marine Protected Area Strategy (2001).

Habitat as previously been defined as “plant and animal communities as the characterising elements of the biotic environment, together with abiotic factors operating at a particular scale” (SGMHM Report 2000). As this definition indicates, combinations of biological and physical parameters of the habitat are normally required to explain where a particular species or community is found. However, physical characteristics can often be reliably used to separate representative areas at the higher levels of the hierarchy of classification (Day and Roff 2000), assuming the important physical characters are known (eg. wave energy, currents, nutrients, substrate type, turbidity, water temperature).

As detailed studies of all biotic communities are particularly difficult and time consuming in the marine environment, and also require very fine scale mapping in areas with any depth transitions, this current study has used “indicator” physical characteristics for the identification of marine habitats. In order to identify the dominant marine communities present, regular video surveying was conducted. The main physical characters used to identify key habitats were depth, substrate type and exposure to wave action. Biotic factors were included for soft sediment areas where the presence of seagrass or *Caulerpa* beds on the sediment surface provided a distinctly identifiable habitat.

While a detailed examination of biological communities has not formed part of this study, the distribution of communities with respect to major physical characteristics is relatively well known for Tasmanian waters (eg. Edgar, 1984a, Edgar *et al.*, 1995, Last, 1989, Edgar 2001) and once the main determining physical factors are known for a region, the dominant communities within habitats can be readily estimated. In Tasmania, there have been a number of studies examining marine habitat and community distributions in relation to physical determinants. Early studies by Edgar (1981, 1984b) examined the distribution of fish and algal species at a range of sites around Tasmania. This work resulted in a generalised description of the distribution of biotic communities with respect to depth and wave action for reef areas (Edgar, 1984a). In a more localised study, Sanderson (1984, 1987) looked at macroalgal community distributions on reef areas within the D’Entrecasteaux Channel in relation to depth and exposure and identified a number of distinct communities that could be defined by the dominant macroalgae present. These included *Durvillaea*, *Phyllospora*, *Macrocystis*, fucoid and seagrass-*Caulerpa* dominated communities. Additional biological studies within broad habitat categories (reef, sediment, seagrass, estuaries) add to our ability to predict communities within habitats. These studies include fishes, macroalgae and large invertebrates on reef (Edgar *et al.*, 1995), beach-seined inshore and estuarine fishes (Last, 1983), unvegetated and seagrass associated fishes (Jordan *et al.*, 1998), seagrass invertebrate communities (Moverley and Jordan, 1996) and estuarine infauna (Edgar *et al.*, 1999).

While the aim of this study is to facilitate Marine Protected Area planning, habitat mapping at the scale presented here also provides a powerful management tool for coastal planners and fisheries managers involved in coastal conservation and resource assessment and allocation. It is hoped that like the initial habitat mapping by Kirkman (see Edyvane *et al.*, 2000), the work presented here will lead to a more detailed understanding of the resources of Tasmanian coastal waters. It should also act as a Geographic Information System framework for more detailed community descriptions to be developed in the future as resources become available to conduct finer-scale biological inventories.

3. Methods

The Bruny Bioregion identified by Edgar *et al.,* (1995) extends from Hellfire Bluff to just north of Southport (see Fig. 7). However, as the area extending south of Southport to Second Lookout Point (near South-East Cape) is known to contain extensive reef systems and a significant proportion of *Macrocystis* forests, the mapping was expanded to include this additional coast. The primary physical variables determining plant and animal community distributions at the scale of the mapping presented here, have been identified as substrate type, depth and exposure to water motion (Edgar, 1984a; Last, 1989). Therefore, describing the distribution of these variables was a primary focus of the mapping process.

The first step in the mapping process was examination of aerial photographs. These often gave good resolution of boundaries between seagrass, reef and unvegetated habitats to approximately 10 m depth, but did not include information on depth and habitat structure. Extensive ground-truthing from small vessels provided substantial additional habitat information, and physical data on depth, relief and substrate type that were not available from photographs. In addition to truthing aerial photo interpretations, field observations extended habitat determinations to depths of 40 m, and to areas where there was no useable photo coverage. The 40 m depth limit was considered the lower limit that the sounder used to determine habitat types could reliably differentiate differences in bottom types and often correlated with the maximum distance it was possible to safely work from shore in a small boat. Field ground-truthing and survey work involved a series of transects perpendicular to the coast at distances no greater than 200 m apart in areas of coastal reef. Over broad areas of soft sediments, transects were conducted at greater intervals but with sufficient coverage to provide a reliable estimate of the areas bathymetry. The final maps were produced using the combined aerial photographs and field data to determine the most likely position of habitat boundaries.

To determine the correlation of physical data to the biotic component of habitat type, regular video transects were conducted perpendicular to the coast, and biotic elements and physical variables recorded. Exposure to wave action was determined from wind, fetch and swell records. Details of survey and mapping methodology is presented below.

3.1 Selection of Aerial Photographs

The aerial photography archives of the Department of Primary Industry, Water and Environment were searched to identify photographs that covered the Bruny Bioregion. Fifty-three aerial photographs were selected based on a calm water surface and suitable sun glint and camera angle conditions for determining sub-surface features through the water column. The photos varied in scale from 1:12,500 to 1:42,000 and were chosen regardless of the age of the photo or whether it was colour or black and white. The lineage of the photographs spanned a period from 1970 through to 2000. Appendix 1 lists the aerial photographs used and the location they cover.

3.2 Scanning

The selected aerial photographs were captured using the program DOSCAN on an A4 colour scanner at 300 DPI (dots per inch). The photographs were stored as 24 bit colour TIFF images.

3.3 Registering and Rectification of Aerial Photographs:

Each image was georectified using Arc Info (Environmental Systems Research Institute) (Unix based) to the LIST (Land Information Services Tasmania) coastline coverage in AGD66. To rectify, a minimum of 15-ground control points were selected for each image. The RMS (root mean square) error is an indicator of the position of each pixel relative to its location in the real world. The average RMS error calculated for the images was X 8.157 and Y10.246.

The *REGISTER* command was used within *ArcInfo* to georeference the photographs. This command adds a series of links or displacement vectors that join image locations to map coordinates. Using the links as control points, *REGISTER* applies an affine transformation to calculate the amount of scaling, rotating and translating required to align the image to map coordinates. Affine transformation does not 'rubber sheet' an image (allow for differential scaling and rotating across an image), but uniformly rotates, translates and scales the image. The aerial photographs were registered to a linear coverage constructed from datasets supplied by Land Information Services Tasmania that included the 1:25,000 Tasmania coastline (current to 2000), drainage and road networks projected in AGD66.

3.4 Capturing data from Aerial Photographs

The aerial photographs were displayed in *ArcView 3.2*. True colour images generally store data using twenty-four bits per pixel. Each pixel is composed of three eight-bit bands representing the red, green and blue colour components. Images are stored as raster data, where each cell in the image has a row and column number. The images were displayed with the coastline information overlayed over the top of the image.

In order to clearly identify certain features such as reef and sand, the colour intensity of the image was altered by selecting the image in the legend. For multiband images, a compositing process allows the creation of a true colour image by identifying the three bands used to represent the red, green and blue colour components. These three colour components can be altered using a linear scale to reduce or increase the intensity of that band.

The aerial photographs were merely used as secondary source of information to aid in determining the inner boundaries of the habitat type mainly for reef and sand habitats only and not for primary mapping of habitat boundaries.

3.5 Field Data Collection And Ground-Truthing

Habitat boundaries and attributes from 0-40 m were determined using an echo sounder and video surveys. A Garmin 135 GPS Map unit coupled with a Racal differential unit was used to collect positional and depth information. The accuracy of this unit was assessed and found to vary no more than 12 meters over a three-hour period. This unit was linked directly to a field Laptop through a COM port connection. Data was logged to file using *SeaBed Mapper 2.4*

The Visual Basic software program (*Seabed Mapper 2.4*) was specifically developed for this study and, enabled logging of field information at user defined intervals. This information included depth, substrate type (identified from a high quality sounder and video drops), differentially corrected Global Positioning System (DGPS) data, and comments on the biotic community present (identified from video drops).

A Furuno 600L colour sounder was used for habitat discrimination at 50 and 200 Khz. The 50 Khz signal gave better substrate definition in deeper waters (>30 m). The 200 Khz signal was used by preference as most of the survey work was done in shallow waters. Different substrate types were characterised by differing sounder traces based on their roughness and hardness. This signal was interpreted in the field in conjunction with camera drops, which were also used to validate signal interpretation, enabling good habitat discrimination. In shallower waters (<5 m), it was often possible to determine substrate type by using an underwater viewer. Hard substrates were indicated by strong second echoes on the sounder output, while rough substrates were characterised by long tails on these traces. This signal was interpreted in the field and logged in real time. This method allowed the exact location of habitat boundaries to be recorded.

For this survey, substrates/habitats were distinguished and noted in the field in real time rather than interpreted from post-processing of recorded sounder signals. This provided the advantage of being able to incorporate local area irregularities into the interpretation of the sounder signal on site and by the validation of signals whenever there was some doubt about the substrate below. To ensure consistency of interpretation, the operators of the equipment remained the same throughout the project.

Field data was sampled at fixed time intervals adhering to a “zigzag” pattern of transects perpendicular to the coast. These transects were run at 200 m intervals along the coast, or more frequently where habitats changed rapidly or had patchy distributions. Both *ArcPad* and a Cetrec chart plotter were employed in the field to display previous transects and help maintain a regular field-sampling regime. Habitat was broadly categorised into three main groupings. These consisted of reef, unconsolidated substrates and seagrasses (including *Caulerpa sp.*). Each of these broad categories was broken down into numerous sub-categories based on relief for reefs, dominant sediment type for unconsolidated substrates and blade density for seagrasses (see Table 1 for detailed descriptions).

The only elements of the biotic community that could be readily distinguished on the sounder were dense beds of the macroalga *Macrocystis pyrifera* and seagrass, mostly *Heterozostera tasmanica*. The remaining biotic components required video drops for identification.

Table 1. Definitions of substrate types and habitat categories used in this study-

Reef
High relief reef The term high relief was used when the apparent depth of hard substrate changed rapidly on the sounder. It usually coincided with steep underwater cliffs adjacent to or away from the coast but also includes areas of high rugosity where depth variation was greater than 4-10 m over short distances.
Medium relief reef The term medium relief referred to areas where the bottom was hard and the relief changed regularly. Changes in depth are usually from 1-4 m over short distances.
Low relief reef This definition referred to hard bottom type when there was very little change in the relief. This category occasionally overlapped with the patchy reef and hard sand categories.
Patchy reef This category commonly occurred on the seaward side of coastal reef areas. It consisted of reef elements, including boulders and rocks, intermittently outcropping from unconsolidated sediments, principally sand. In deeper water it could easily be confused with the 'hard sand' category due to the decreasing discrimination power of the sounder signal with depth. Also, 'Hard sand' type substrates such as shells and gravel were often associated with patchy reef.
Unconsolidated Substrates
Sand Sand was the most commonly encountered unconsolidated substrate in the Bruny Bioregion. Sand was common in high exposure to semi exposed environments. It represented the coarser end of a scale of sediments from silt to sand. Sand was generally characterised by a distinct second echo on the sounder trace.
Silty Sand Silty sand was common in low exposure and sheltered waters. Silty sand broadly incorporated any sediment with a significant proportion of coarse "sand" particles and fine "silt" particles. Silty sand was characterised by a less distinct second echo on the sounder trace.
Silt Silt substrate was only found in deeper sheltered bays or the backs of sheltered bays. This habitat category represented the finest unconsolidated substrate. Silt was characterised on the sounder by a lack of a second echo and often little scatter in the trace tail.

Hard sand

Hard sand referred to unconsolidated substrates containing elements that confound the sounder output causing the signal to appear either harder or rougher than would be expected from that substrate. There are several factors that lead to a substrate being classified as hard. These include large grain size, shell matter (either whole shells or shell grit) or biological material. The following list gives the physical and biological factors resulting in this hard sand category.

Physical:

Coarse sand/gravel

Compacted sand

Rippled sand

Shell or shell grit in sediment

Biological:

Burrows

Seawhips

Holothurians

Hard sand was common in and about seagrass beds indicating the possible presence of rhizoidal mats of the seagrass or associated organisms. It was also common on the seaward side of reefs indicating the presence of shells, detritus and organisms whose origin is dependent on the nearby reefs. The extensive areas of shelly substrate in high current areas in the D'Entrecasteaux Channel were characterised by a hard sand signature. On more exposed shores the sand hardened up closer to shore, due to coarser grade sands produced by the sorting action of waves.

Vegetated unconsolidated substrate

Seagrass

Over 5-10m depth, beyond the effective range of detection from aerial photographs, the division of seagrass beds into various density grade areas was dependent on interpretation of the sounder recording. As our sounder signal only sampled from an area directly under the boat, only a series of lines through the surveyed area could be mapped with certainty. Because of this, and possible unknown seasonal changes in seagrass cover, the division of the seagrass areas by density was indicative only. Seagrass areas should perhaps be regarded as a seagrass zone, where seagrass was likely to be found. The seagrass category "dense" represented areas where seagrass cover was likely to be dense. The term refers to where the substrate, usually sand, was completely obscured by seagrass.

The dominant seagrass type mapped in the Bruny Bioregion was *Heterozostera tasmanica*. Another common but minor species, *Halophila tasmanica*, often occurred in conjunction with *Heterozostera*. In some of the very shallow waters (mostly intertidal) the seagrass species *Ruppia megacarpa* was occasionally present. The habitat mapping presented here, details the extent of the larger beds of these species, however, it should be noted that seagrass was also a very common element of the biota where reef meets sand in more sheltered waters below 10m depth.

Patchy seagrass

The definition "patchy seagrass" represented areas where patch size varied from less than 1 m up to 20 m in linear extent. The patches generally consisted of dense seagrass.

Sparse seagrass This category usually applied to seagrass that occurred in waters exposed to significant swells, such as Marion Bay and Pirates Bay. Here, while the density of the shoots of the seagrass (primarily *Heterozostera tasmanica*) was low, the beds could cover extensive areas. The beds often had associated hard sand signals indicating the possibility of other biotic elements, such as shells, being present. In sparse seagrass areas, the substrate beneath the seagrass was easily visible, often consisting of more than 50% of the field of view in the camera frame.
Caulerpa While seagrasses were the dominant plant species forming distinct habitats on soft sediments, other plants were also be found, including *Caulerpa trifaria*, a green algal species that can have extensive rhizoidal networks in the sediment. This species can form extensive beds similar to those formed by seagrass. *Caulerpa* species are often found on the seaward extent of seagrass beds. In a similar manner to seagrass, *Caulerpa* species are also a common element of the biota where reef forms a boundary with sand in more sheltered waters, however this usually extends deeper, up to 15 m depth.

A submersible Benthos 4208 8x zoom colour video camera was deployed at selected sites to verify echo-sounder classifications and obtain more detailed information on habitat attributes. In addition, video transects were conducted at regular intervals on rocky reef areas perpendicular to the shore along the depth gradient. Depth, substrate and position for the video drops were recorded and the dominant species and substrate present at regular depth intervals noted for each transect. The video footage was reviewed in the laboratory, and in conjunction with the field notes, used to estimate the percentage cover of each of the major visually dominant species observed. This information was correlated against depth and exposure to determine characteristic biotic community types for combinations of each of the physical variables or habitats. A representative image was taken from a range of depths at each video transect site and archived.

Data files from the *Seabed Mapper 2.4* program were imported into *ArcView 3.2* and habitat point data used to generate shapefiles by on screen digitising of habitat boundaries. At 1:2,000 scale the points were carefully connected to form polygons of similar habitat type. The outer boundary of the polygon was generally identified in the field and with these points overlaid on aerial photographs a habitat boundary was identified and a polygon drafted. The aerial photographs were primarily used to help in determining the boundaries between sand and reef that were initially attributed from the field data. The underwater video documentation was used to help verify the habitat type and the interface between different substrates.

In some instances, reefs covered by sand and not seen in the aerial photo were picked up by the echo sounder, and these have been recorded as low reef. Likewise, low plant biomass areas observed from photographs that reflected as predominantly sand on the echo sounder have been recorded as sand, unless the plant biomass was found from video drops to be seagrass or *Caulerpa* beds.

The field data was tidally corrected and assessed for errors before initial mapping commenced. The following sections explain these processes.

3.6 Attributing substrate information

The *Seabed Mapper* program continuously logs data at a set interval and the data is only given a habitat attribute when the user specifies. Often points will be logged without a habitat attribute, especially when travelling over large areas of similar habitat. For mapping purposes in *ArcView 3.2* each cell in the substrate column should contain an attribute. Using an 'if' statement in *Excel* each of the records was attributed with the appropriate substrate based on the previous record. This relies on the assumption that every habitat boundary was accurately logged in the field.

3.7 Correcting depth measurements for tidal influence.

The ebb and flow of the tides will mean that water depth at any location will vary over the tidal cycle. Depending on the coastal region this variation can be in the order of tens of centimetres to meters over a variable six-hour period. Tide height is also affected by meteorological events differing from the average, such as strong prevailing wind, barometric pressure and floods in estuarine environments. While meteorological events do cause tide heights to vary from the predicted tide heights, the magnitude of this variation will generally not change over the course of a day. Provided the weather is close to average, there will be little variation from the predicted tide heights found in published tide tables. Due to problems in accurately quantifying these meteorological effects, they have been excluded from the method used here.

Tidal correction is based on the tidal tables produced by Flinders University (Flinders University, 2001). These are based on 160 components used to calculate the tidal cycle for standard ports. The tidal cycle can be described by a harmonic equation as above.

The following formula was applied to the data:

Depth Correction = h1+(h2-h1)*(COS(PI(*((t-t1)/(t2-t1)+1))+1)/2

Where h1 is the height of the tide preceding the depth measure being corrected

h2 is the height of the tide following the depth measure being corrected

t1 is the time of the tide preceding the depth measure being corrected

t2 is the time of the tide following the depth measure being corrected

t is the time of the depth measure being corrected.

h1, h2, and t1, t2 are obtained from published tide tables (see reference: Flinders University, 2001).

This depth correction value was applied to the field data corrected to mean sea level with the following formula:

Depth for map reference = Field Depth - Depth Correction + Chart Datum

Where: Field Depth is the depth recorded in the field at location b and time t

Depth Correction is the corresponding value from the formula above

Chart Datum is the Chart Datum value for the standard port from the tide tables (1.2m for Hobart).

3.8 Contouring

A depth coverage was generated from the field-collected data through the interpolation of *z* values. Interpolation is the procedure of predicting the values of attributes at unsampled sites from measurements made at point locations within the same area or region. This transformation is based on a data model called a Triangular Irregular Network (TIN).

Before a TIN is produced Theissen polygons must be constructed. Theissen polygons assume that the nearest single data point provides the attributes at unsampled locations (Burrough and McDonnell, 1996). Theissen polygons are used in geographical analysis for relating point data to continuous space. When there are many data points this method is quite successful in determining the characteristics of a surface.

The points were used to construct a TIN in *ArcView3.2*. A TIN is a terrain model that uses a sheet of irregularly spaced sample points to produce a continuous surface of triangles using the depth points as the corners of the triangle. This interpolation method is based on the common observation that values at points closer together in space are more likely to be similar than point further apart. Constructing the contours over this surface is based on Isometric mapping. This requires the consideration of two edges of the same triangle facet to draw polylines of equal depth (Burrough and McDonnell, 1998) (Fig. 1).

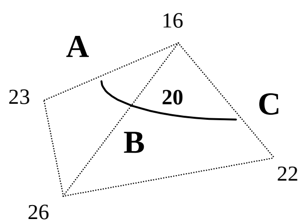

Figure 1. A contour linking points ABC constructed from a TIN.

When point A is identified, the next point is selected from the other two edges of the same triangle. In this case point B is identified because the values at the two ends of the other edge do not contain the value 20. The process continues to identify the point C. Again a line connects the three points A B C of the same value (20) define part of the isoline (Chew, 1997).

Contours in *ArcView* 3.2 were created using the extensions 3D Analyst and Spatial Analyst. by interpolating the point data into a TIN and then creating contours from that TIN. For the data in which the contours were made depth was selected as the height source and Input as Mass Points. The second theme included in the interpolation process was the coastline. which defines the base for the zero depth contour.

Once the TIN was constructed the ‘Create contours’ from the surface menu was initiated by setting the contour interval to an appropriate value with the base contour as 0 m, which will trace the coastline.

The contour coverage provides another source of information from which the habitat polygons can be verified against, especially for seagrass, which generally has constraints for the depths at which it exists.

3.9 Wave exposure index

Exposure to wave and swell action can be a major determinant of the biological community present, and yet it is often difficult to categorise this exposure for a particular section of coast. To aid this process, an exposure index was developed that responds to the major variables of wind speed and direction, fetch and exposure to oceanic swells.

Wind speed and direction data consisting of annual mean percent days (**t**), incidence of wind directions (**d**: NE, E, SE, S, SW, W, NW, N) and speed were obtained from several Tasmanian Bureau of Meteorology recording stations: Orford (1951 to 2001), Tasman (1922 to 2001), Pt Arthur (1980 to 2001), Hobart Airport (1958 to 2001), Cape Bruny (1871 to 2001), Dover (1901 to 2001) and Bull Bay (1983 to 2001). Speed data (**s**) was given for the following categories: 1–10 knots, 11–20 knots, 21–30 knots, >30 knots where the median ($\mathbf{s}_m$) was used for calculations: 5, 15, 25 and 35 knots. Averages were determined across all the weather stations in the Bruny Bioregion to give overall values for the area, thus minimising local biases.

Fetch (**f**) for the NE, E, SE, S, SW, W, NW and N directions were calculated for sections of coast varying in length from 300 m to 10 km with similar aspects with respect to compass direction. Fetch was the distance from the central area of these sections in the direction of relevant compass points to the closest coast. Where the fetch direction extended into the open ocean, fetch was given a nominal value of 99.9 km.

Habitats on coasts subject to ocean generated swell action are impacted more heavily by wave action than those subjected only to locally wind generated seas due to the higher energy state of the swell waves. To separate swell affected coasts from other coasts, swell affected coasts were set at a higher level by the addition of a constant ($\mathbf{c}_{sw}$) equivalent to greater than the maximum of wind only seastate generated coasts. Swell affected coasts were identified as those that had any direct exposure to the open ocean, not necessarily just along one of the eight compass directions. Some were designated exposed to swell action on the basis of experience. Due to time constraints wind statistics only were used. A better index may have incorporated swell statistics, however it was assumed that on the swell exposed coasts, wind speed and direction closely reflects swell state as indeed ocean swells are generated by winds.

The index was calculated by summing (for each compass direction and speed category) the product of percent time by fetch and median speed for each of the speed categories.

Swell affected shores

$$WEI_{sw} = \sum_{d=} \sum_{s=} (\boldsymbol{t} \times \boldsymbol{f} \times \boldsymbol{s}_m) + \boldsymbol{c}_{sw}$$

For no swell, wind only shores, $\mathbf{c}_{sw} = 0$

Swell affected shores were then subdivided into three categories (maximum, moderate and low swell exposure shores) and the wind only shores into two (high and low) based on their WEI_{sw} or WEI_w scores. This resulted in five exposure categories grading from sheltered, wind exposure only, low wave exposure, medium wave exposure and high wave exposure.

3.10 Habitat Area Calculation

ArcView 3.2 was used to analyse the spatial data collected in this project. The habitat polygons were categorised by depth and exposure using the *Geoprocessing Wizard* extension. The merge option was used to combine the habitat polygons with the exposure and depth contour polygons. This resulted in all habitat polygons being divided into five depth categories (0-5 m, 5-10 m, 10-20 m, 20-30 m and 30-40 m) and five exposure categories (sheltered, wind exposure only, low wave exposure, medium wave exposure and high wave exposure). This allowed area to be calculated for each habitat type in each combination of depth and exposure class.

For the purpose of analysis the Bruny Bioregion was broken down into arbitrary sub-units or sub-regions. These sub-units are broadly based on similarities in habitat distribution, exposure and other physical factors. More importantly they present a convenient sized unit for analysis and discussion. The relative proportions of each habitat type by depth range and exposure are presented for each of these sub-units.

4. Results and Habitat Descriptions

The Bruny Bioregion was subdivided into nine coastal sections, or mapping units for ease of analysis and presentation. These sections, although divided intuitively on the basis of perceived general differences in physical characteristics, are not intended to be a formal splitting of the currently accepted bioregionalisation. They simply provide manageable sized units with shared features to facilitate discussion of differences within the bioregion. An additional section of coast, which includes the Actaeon islands, Recherche Bay and Southport (the Actaeon section), has also been included for discussion. While this area is nominally in the adjacent Davey Bioregion it contains many features in common with both regions, and includes an extensive network of coastal reef and *Macrocystis* forests. The outer coast in this area is subject to the heavy swells that characterise the Davey Bioregion, while the more sheltered inner coasts are very similar to those found to the north of Southport. Including the Actaeon area, there are ten coastal sections described here. These are: Actaeon, Cloudy, Adventure, Betsey, Arthur, Peninsula, Norfolk, Frederick Henry, D'Entrecasteaux and Huon (Fig. 2).

4.1 Exposure

Coastal exposure was estimated for the Bruny Bioregion using a wave exposure index based on aspect, extent of fetch, and possible exposure to oceanic swells (see Methods section). The weighting's given to each of the compass directions in the calculation of the Wave Exposure Index for the Bruny bioregion area show the prevailing winds to be dominated by a westerly flow (Table 1). The breakdown partitioning of the coast into the wave exposure index levels 1-5 is presented in Figs. 2 and 3. Summary statistics for each of the coastal sections are given in Table 2. As the index contains a number of subjective components and weightings, the exposures in Figs. 2 and 3 are a first approximation, and in some locations the real exposure may vary by up to one level from that shown. While an attempt was made to validate the exposure model using the depth distributions of macroalgal species, exposures can change substantially over small spatial scales, and there was insufficient time during this study to collect and/or analyse biological data at this scale.

Mean calculated wave exposures per kilometre of coastline for each of the coastal sections correlates well with two factors that may be expected to vary with exposure to wave action. These are steepness of intertidal slope, and the proportion of reef and sand coastline for each of the sub-regions. Wave exposed shores tend to have greater proportions of reef substrate and have steeper shorelines.

Table 2. Weighting given for each of the compass directions used in the calculation of the wave exposure index (WEI).

NE	E	SE	S	SW	W	NW	N
8	5	6	11	19	21	16	14

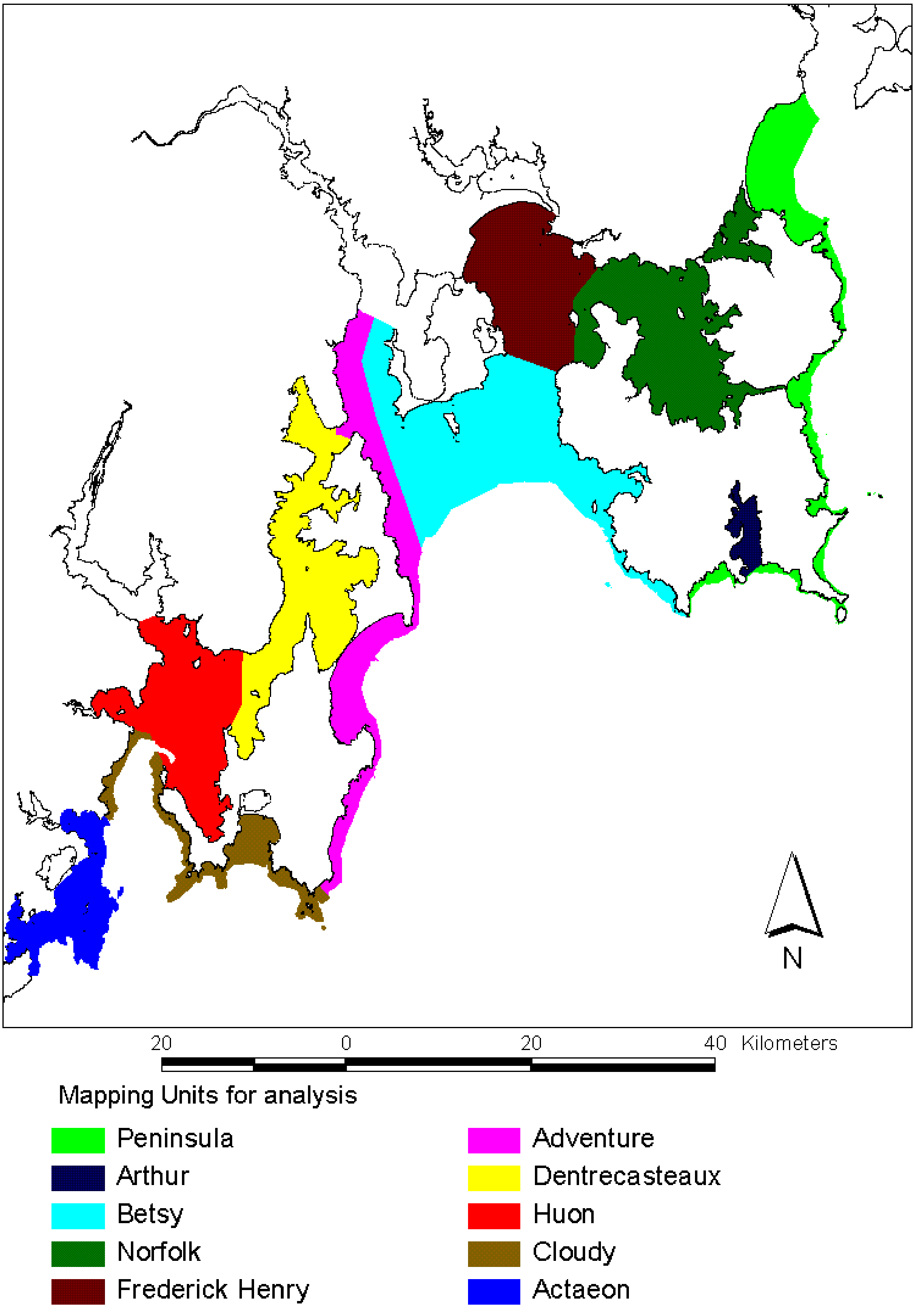

Fig. 2. Mapping units identified subjectively on exposure differences and used as a framework for mapping and discussion at the 1:25,000 scale.

Table 3. Coastal sections ordered on the basis of mean value for wave exposure per kilometre of shore. Corresponding values for percentage of coastline reef, unconsolidated sediments and percentage of varying slope for each of the coastal sections within the Bruny Bioregion are shown, based data of Sharples (2000).

SECTION	Average Exposure	%Reef	%Sand	% Flat	%Mod	%Steep	Metres length
Cloudy	4.2	89	11	13	29	57	92945
Peninsula	4.0	88	12	15	23	61	169674
Adventure	3.8	81	19	22	42	36	113072
Betsey	3.7	79	21	25	37	38	110502
Frederick Henry	3.3	53	47	52	31	18	71070
Arthur	3.1	82	18	12	61	27	38733
Actaeon	3.0	60	40	45	40	15	57909
Huon**	2.2	72	26	37	48	15	93350
Norfolk**	1.6	57	42	45	53	2	192009
D'Entrecasteaux**	1.3	56	43	55	41	4	193960
						TOTAL	1133225

* not extensively ground-truthed.
** data incomplete for reef/sand for the entire coastline, thus percentages do not add up to 100%.

As expected from the proportion of coast with rocky shores and the steepness of slope, the Cloudy, Adventure, Peninsula and Betsey sections are the most wave exposed. The Huon, Norfolk and D'Entrecasteaux Channel areas are relatively sheltered, with some areas that are very sheltered. Most of the sea state in these areas is produced by wind. The Actaeon Island section, while having a particularly exposed outer coast, also contains two relatively sheltered embayments, (Recherche and Southport) and a large coastal lagoon (Southport Lagoon). There is also a substantial component of moderately exposed reef in this area as the Actaeon Islands and the shallow reef associated with them act as a protective barrier.

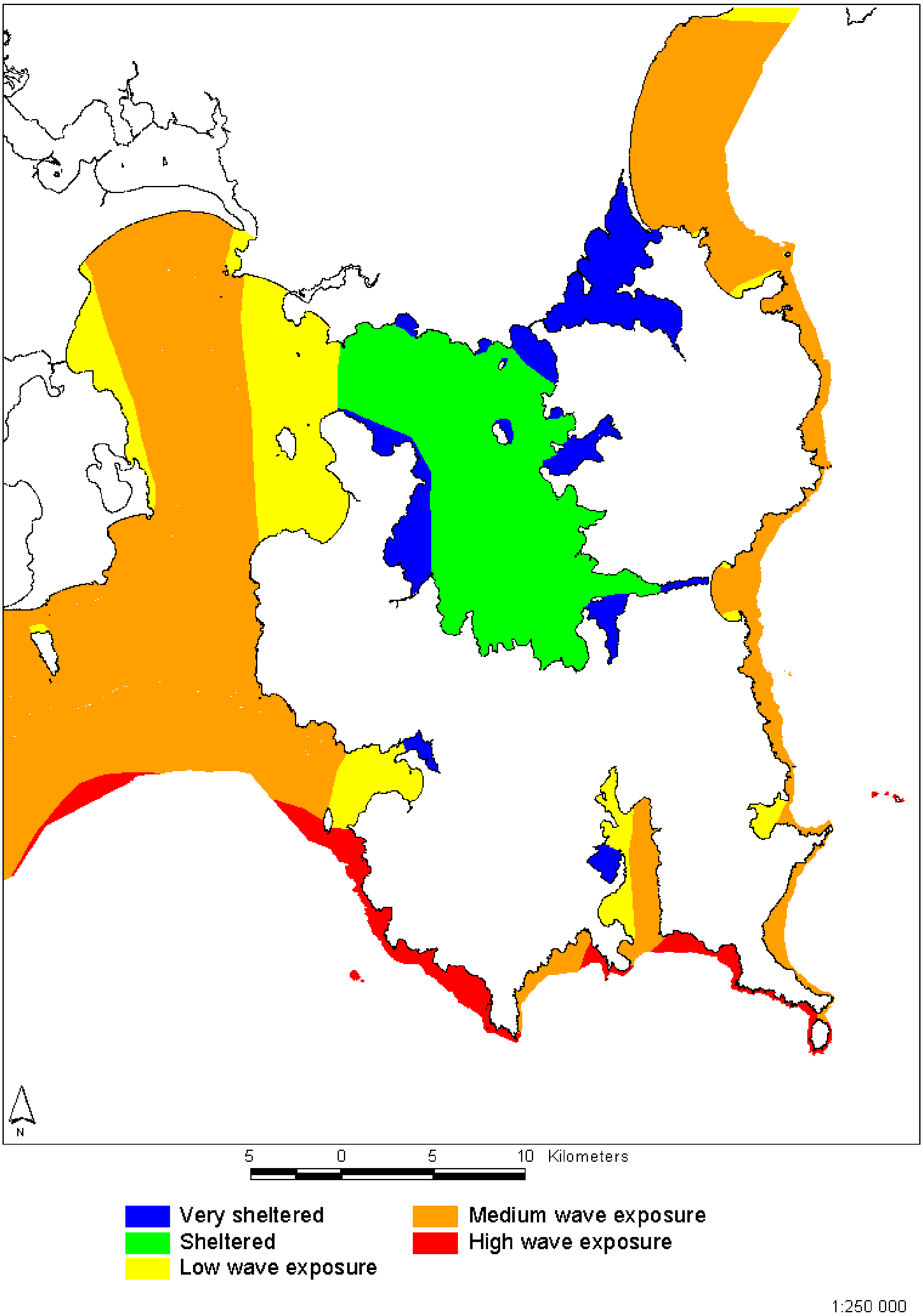

Fig. 3. Predicted exposure levels on the Tasmanian Coastline from Frederick Henry Bay to Marion Bay.

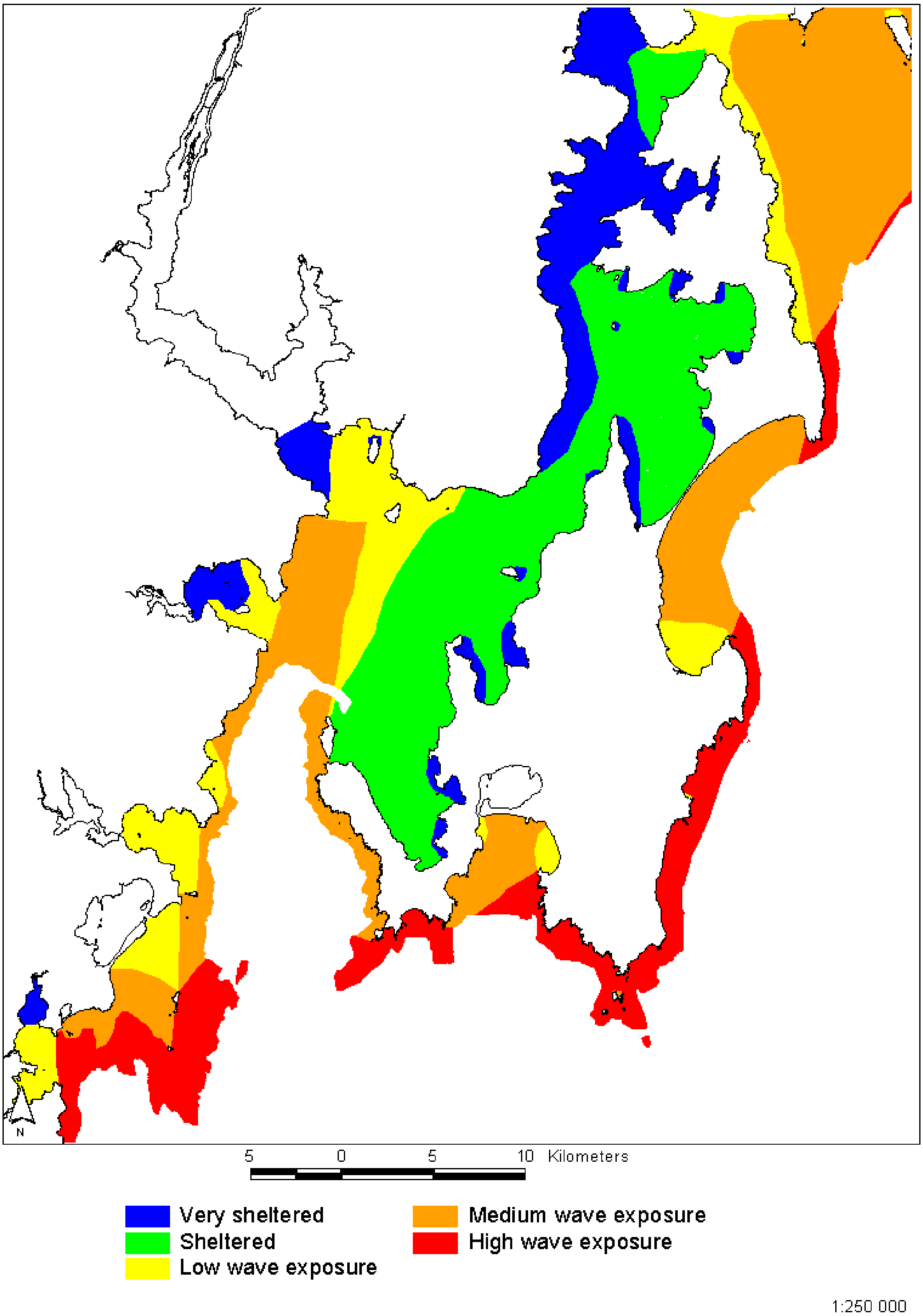

Fig. 4. Predicted exposure levels on the Tasmanian coastline from Recherche Bay to Federick Henry Bay.

4.2 Biological Communities

The biological communities examined in this survey were restricted to the major cover forming species that could be identified from video drops, namely macroalgae and large invertebrates such as sponges and seawhips. Most of these species are of widespread distribution throughout the bioregion, with their distribution and relative abundance primarily determined by depth and exposure (see Appendix 2), but with the depth response modified in areas of reduced light availability. While mostly widespread species, their relative abundance together gives a good indication of the exposure of a particular area, and the wider biological community that is likely to be present. Generally, the ecological observations are consistent with Edgar (1981, 1984), Last (1989) and Sanderson (1984, 1987). *Durvillaea* is found on the most wave exposed rocky shores, followed by *Phyllospora*, *Ecklonia*, red algae and then sponges as depth increases. As wave action decreases, the depth to which these communities occur reduces, and *Durvillaea* and *Phyllospora* are eventually replaced by brown algae of the order Fucales (Fucoides). These include *Xiphophora*, *Acrocarpia*, *Cystophora* and *Caulocystis* species. In the most sheltered waters *Sargassum* species become common. The giant kelp *Macrocystis pyrifera* often forms extensive beds in areas of moderate exposure, and can be relatively common at almost all exposures, however its relative abundance varies substantially, both seasonally and over time.

In the more sheltered sandy areas, seagrasses are the most visually dominant species found. The most common species being *Heterozostera tasmanica* and *Halophila australis*. Species of the green algal genus *Caulerpa* are often found on deeper boundaries of this habitat. A surprising find of this study was the extensive areas that *Caulerpa* beds occupy in Norfolk Bay. Throughout the Bruny Bioregion, *Caulerpa* species occupy an area almost half the size of the seagrass area. Edgar (1997) notes that this alga can form a habitat with fish and invertebrate communities similar to that of seagrass beds. In shallow waters of Blackman Bay, a large proportion of the seagrass habitat consists of the aquatic macrophyte *Ruppia megacarpa*.

The sponge-dominated communities are most abundant in areas of reef with high water motion. In sheltered waters these conditions can occur at depths greater than 10 m if there are currents present, and also in areas of high turbidity. In the D'Entrecasteaux Channel, sponges, seawhips and gorgonians can be found in relatively shallow waters, sometimes on beds of shells. More generally, similar communities are found in waters greater than 33 m, the lower limit that brown algae dominate the reef cover in this region.

The coastline in the Betsey coastal section from Iron Pot to Cape Raoul is notable for the lack of *Phyllospora commosa*, a very common alga on the southern Australian coastline. *Lessonia corrugata*, *Carpoglossum confluens*, *Ecklonia radiata* and *Pyura* spp. (ascidians) take up the niche that this normally occupies. The reasons why this has occurred are unclear but may relate to outflow from the Derwent River extending eastwards along this coast, producing the high turbidity that is characteristic of these waters, particularly when there is moderate wave action. The high turbidity restricts light availability, possibly reducing the competitive advantage of *Phyllospora* over other species. An alternative possibility is that it may be related to the fact that much of this coastline is formed of south facing cliffs, which also limits the available light.

This bioregion has particularly high abundances of two macroalgal species that are endemic to Tasmania (*Lessonia corrugata* and *Xiphophora gladiata*) and one species whose Australian distribution is restricted to the southern half of Tasmanian waters (*Macrocystis pyrifera*). The results of this survey indicated that *Lessonia* is particularly common in the region extending from northern Bruny Island to Cape Raoul, where it appears to replace *Phyllospora*. The distribution of *Macrocystis* extended throughout this bioregion, and while its distribution appears highly variable through time (see Sanderson, 1987), a number of locations appear to consistently have large beds, including Fortescue Bay, Lagoon Bay and Stewarts Bay on the Tasman Peninsula, north-east Bruny Island, and the coastline between Southport and Dover.

By overlapping these general biological descriptions with the habitat details presented in this report (substrate type, depth and exposure) and available from more detailed community descriptions from Tasmanian waters (eg. Edgar, 1984, 2000, Last, 1989), a good indication of the biological communities in south-eastern Tasmania can be obtained, including fish and invertebrates. Representative images of the biological communities associated with habitat types are presented in Appendix 3.

4.3 Bathymetry of the Bioregion

Depth was constantly recorded during field surveys of the Bruny Bioregion allowing bathymetric contours to be generated to the 40 m contour at a finer scale than those currently available from marine charts. While the fine scale contours are plotted on the detailed 1:100,000 maps in this report and the 1:25,000 scale maps (Appendix 3), an overview of the whole bioregion at 1:250,000 scale is presented in Figures 5 and 6. The bioregion is characterised by a steep outer coastline and shallow embayments and channels. Cliffs comprise much of the southern and eastern coastline of Bruny Island and the Tasman Peninsula, and this steep coastline extends underwater, with the 40 m depth contour usually being less than one kilometre from the shoreline. While the more sheltered coasts of the embayments and channels have more gradual slopes, and the waters are relatively shallow, there are several notable exceptions. In the northern D'Entrecasteaux Channel there is an area where depths in excess of 40 m are found, corresponding to the channel of the Derwent River during periods of lower sea level. A similar feature is found in the Lower D'Entrecasteaux Channel, presumably related to the channel of the combined Huon and Derwent Rivers during historical times. A deep hole located at the north-western corner of Sloping Island appears to be related to current scouring of the soft sediments found there.

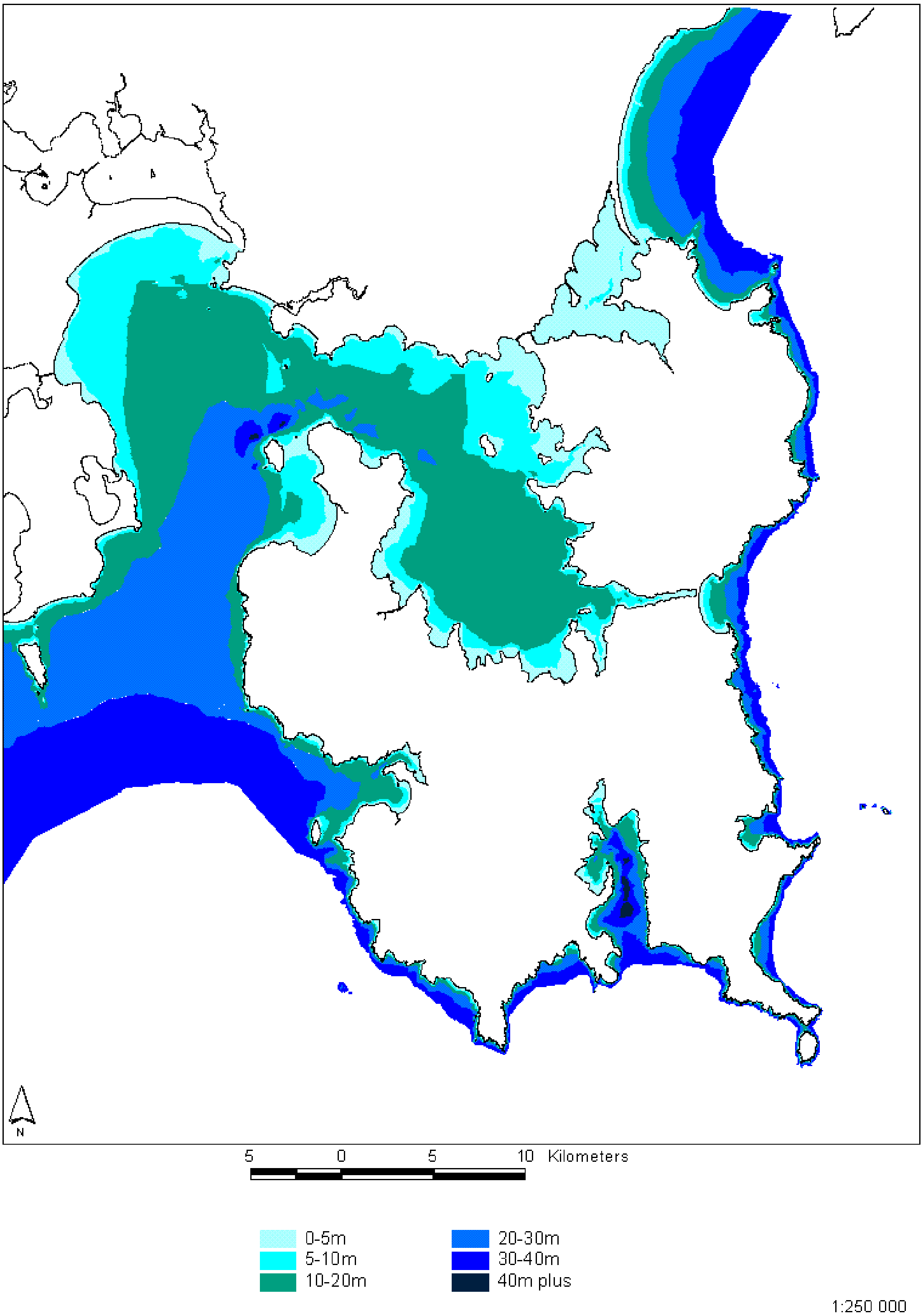

Fig. 5. Bathymetry of the Tasmanian coastline from Frederick Henry Bay to Marion Bay.

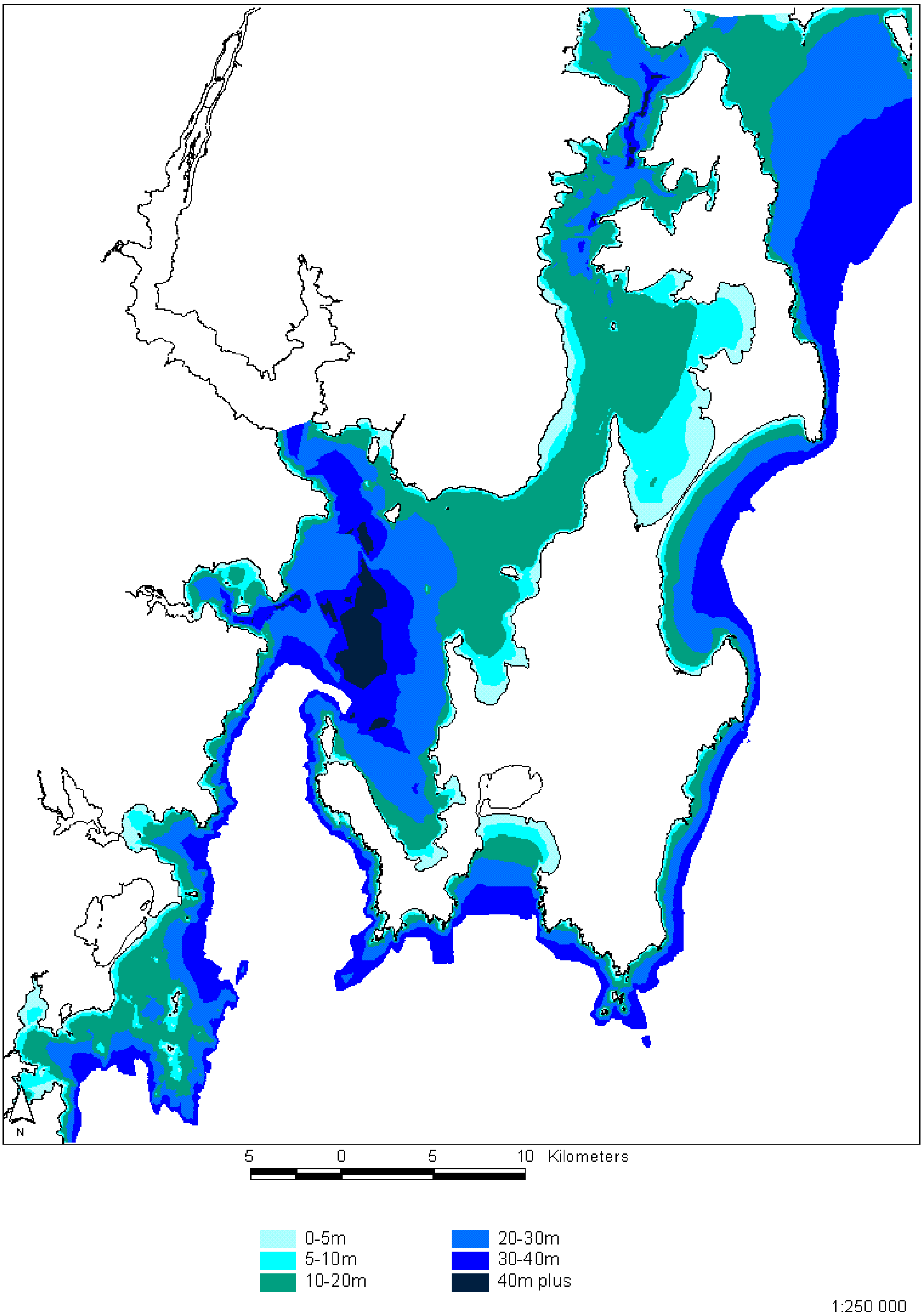

Fig. 6. Bathymetry of the Tasmanian coastline from Recherche Bay to Frederick Henry Bay.

4.4 Peninsula

The Peninsula mapping region was chosen on the basis of its dominantly easterly aspect and high cliffs (Figs. 8-11). The coastal geology is composed of alternating dolerite and sedimentary rock types, except in the vicinity of the Sisters where granite rocks outcrop.

This mapping region has four embayments with long sandy beaches and medium exposure to wave action. These are Marion Bay, North Bay, Pirates Bay and Fortescue Bay. The sediment within these bays and adjacent coastline is restricted to sand. This region is characterised by coastal reefs extending to substantial depths. It included Tasman Island and at the Hippolyte, where depths of up to 100 m are reached, and Cape Pillar, Cape Hauy, The Thumbs and The Sisters, where reefs extend to depths greater than 50 m. Along the coast to the south of Pirates Bay a number of substantial offshore reef extensions occur. One of these, located off Waterfall Bluff, extends for at least 1.5 km offshore, to depths greater than those mapped here. The combination of large areas of offshore reef, and a coastline that often rapidly plunges to 20 m before levelling out, results in a large proportion of the reef in this area being at depths below 20 m. Most of this coast is subject to medium wave exposure, with exceptions being the highly exposed coast between Cape Raoul and Tasman Island, and small pockets of low exposure at Fortescue Bay, the southern corner of Pirates Bay, and the northern shore of Cape Frederick Hendrick.

Community types:

The greater majority of the coastline in this section is subject to moderate to high exposure, and this was reflected in the dominant community types on reef that followed the typical pattern of exposed coasts with *Durvillaea*, *Phyllospora*, *Ecklonia*, red algae and sponges dominating. Sponge communities always dominate on reef below about 33 m, a depth that appears to be close to the lowest limit that most macroalgae can tolerate in Tasmanian waters. On the east facing coast *Durvillaea* rarely extended below 5 m, whereas on the south facing coast near Tasman Island, and including the Hippolyte, *Durvillaea* extended below 5 m and in places below 10 m. Due to the extensive area of reef below 30 m, sponge communities are abundant in this region, particularly in areas of high water movement due to swells and currents, such as the ends of the capes, headlands and island groups. Small pockets of mixed fucoid algae are found on reefs in the more sheltered embayments at Fortescue Bay and Pirates Bay, with areas of patchy seagrass on the sediments. In North Bay and Marion Bay at depths between 10-15 m, extensive beds of sparse seagrass are found over sand. *Macrocystis* forests also occur throughout this region on reef at depths of 5 m to 25 m and are particularly abundant in bays that provide reef habitat at suitable depths and moderate exposures, such as Fortescue Bay and Lagoon Bay.

Special Features:

- Areas of high aesthetic value to the diving community, including sponge gardens, *Macrocystis forests*, and marine cave systems.
- Large sections of sedimentary coast with rock types providing a mixture of patchy broken and low profile reef extending for one to two kilometres offshore throughout the 20-45 m depth range.
- Extensive areas of sparse seagrass in North Bay and Marion Bay.
- Deep (>40 m, up to 100 m depth) reef communities. Some of these areas are subject to high currents with rich sponge communities.

- Granitic coastline in the vicinity of The Sisters.

4.5 Norfolk

Norfolk Bay and Blackman Bay are particularly sheltered areas and are well protected from swell action (Figs 8, 9 and 12). This is reflected by the shallow and limited offshore extension of coastal reefs, a characteristic feature of low energy coastlines. The coastal geology of this area is characterised by a mix of sedimentary rocks and dolerite, with the underlying bedrock on the northern side of Blackman Bay and the southern side of Norfolk Bay being of sedimentary origin. The remaining shores are dolerite with the exception of a small basalt intrusion adjacent to Prices Bay in Norfolk Bay. In Norfolk Bay most of the dolerite shores extend to sand at 5–10 m depth, whereas most of the sedimentary shores extend no deeper than 2 m. The majority of Norfolk Bay is less than 20 m deep, and much of the substrate within the bay is silt and silty sand due to the low wave energy coastline.

Blackman Bay, was once essentially a large coastal lagoon with an opening into Marion Bay. However, with the opening of the Dunalley Canal, it now forms an enlarged water body connecting Marion Bay and Frederick Henry Bay. This bay is generally very shallow (less than 5 m) with the exception of deeper channels created by strong tidal currents that now flow between Frederick Henry Bay and Marion Bay. Much of the substrate is sand grading to sandy silts, and these are generally covered by seagrass.

Community types:

The shallow waters of Blackman Bay in conjunction with the tidal currents and sandy substrate make Blackman Bay a suitable prime area for seagrass. Extensive *Heterozostera* beds cover much of the bay in subtidal waters, while the aquatic macrophyte, *Ruppia megacarpa* is notably abundant in the intertidal zone, particularly on sediments in the western arm of the bay. *Ruppia* is notable as this species is usually associated with more estuarine conditions than those found in Blackman Bay. Reefs within the bay are restricted to the shoreline and are particularly shallow, mostly less than 2 m. The macroalgal species are primarily composed of mixed fucoids, with *Sargassum* spp, *Cystophora* spp. and *Caulocystis* dominating. The macroalgae includes the brown algae *Cystoseira trinoides*, and Blackman Bay is the only area in Tasmania where this alga has been recorded. It is not clear whether this is a relict population or whether it has been introduced, as the species also occurs in Western Australia and South Australia, however it is highly unusual for any macroalgae to have such a localised and fragmented distribution.

Norfolk Bay is unusual in that it contains extensive beds of *Caulerpa* species between depths of 10–15 m in areas where there is minimal water currents and a soft substrate. The dominant species appears to be *Caulerpa trifaria*, and while this species is commonly found on the sandy outer fringes of reefs, the extent of this *Caulerpa* bed is unusual in Tasmania. Seagrass beds occur throughout the bay, however unlike Blackman Bay, much of the bay is deeper than seagrass habitat in southern Tasmania, and the significant beds are restricted to the coastal fringes and shallow embayments. While isolated patches of reef extend to depths of 10 m, most of the rocky shoreline extends to depths of only 2 m, and is dominated by macroalgal species such as *Sargassum* spp, *Cystophora* spp, and *Caulocystis* spp.

Special Features:

- Blackman Bay has the only Tasmanian population of *Cystoseira trinoides.*

- Presence of *Ruppia megacarpa* beds in Blackman Bay
- Large extensive and unique *Caulerpa* beds in Norfolk Bay
- Large and particularly sheltered embayments with extensive seagrass beds

4.6 Betsey

The Betsey coastal section was divided on the basis of being predominantly a large exposed embayment (Storm Bay) with outcropping reefs in 20-50 m of water (Figs. 11 and 14). There are extensive areas of gravel/shells and rippled sand patches within this section, presumably produced by the action of the swells that are prevalent in the area. While the majority of the rocky coast faces southwest, direct exposure to the prevailing southwest swell only occurs on the southern-most coast, with the remainder protected by the blocking action of Bruny Island. The geology of this area is predominantly a mixture of sedimentary and dolerite rock types. North of Wedge Island, sedimentary rock types often extend to 500 m offshore, while the extent of dolerite reefs is particularly limited. South of Wedge Island the reverse is true, with dolerite reefs extending to substantially greater distances offshore than sandstone reefs, and presumably the large offshore reef located 2.5 km SE of Shipstern Bluff is of doleritic origin. Coastal reefs extend to depths of 40 m or more at Cape Raoul, but are generally limited to 20 to 30 m, with linear offshore extensions averaging 200 m. This section of coast is subject to moderate levels of exposure between Betsey Island and Wedge Island, high exposure between Wedge Island and Cape Raoul, and low exposure within the bay at Nubeena and northward along South Arm from Fort Direction. With a mixture of reef, sand and gravel/shells, this section contains a mix of habitat types at various exposures.

Community types:

An unusual feature of this coastal section is the virtual absence of a *Phyllospora* cover below *Durvillaea* on reef. Virtually no *Phyllospora* was found over the entire coastline. In exposed waters such as those in the Betsey coastal section, *Phyllospora* is usually the dominant macroalgal species on reefs from depths of 3 to 5 m where it replaces *Durvillaea,* down to 10 to 15 m where it is gradually replaced by *Ecklonia.* The absence of *Phyllospora* from this area may be related to the low water clarity of this area, a feature presumably related to the outflow of nutrients and sediments from the adjacent Derwent Estuary, however this anomaly requires further investigation to determine its actual cause. On the moderately exposed reefs in this region *Durvillaea* extended to approximately 2 m in the more exposed locations, below which *Lessonia*, *Carpoglossum* and sea tulips were common until being replaced by *Ecklonia* at 4-5 m. *Lessonia* is a Tasmanian endemic species and its centre of abundance appears to be along the north Bruny coastline, the lower reaches of the Derwent Estuary and the Betsey region. Another feature of this region was the restricted depth distribution of *Durvillaea* with respect to the degree of exposure, a compression that may be due to the low water clarity of this area and possibly competition with *Lessonia* at greater depths.

On the most exposed coasts (from Wedge Island to Cape Raoul) *Durvillaea* extended below 5 m, where it was replaced by *Lessonia* and sea tulips to 10 m, below which *Ecklonia* dominated. At depths below 30 m *Ecklonia* was replaced by invertebrate communities dominated by sponges. On the moderately exposed coast near Betsey Island *Durvillaea* extended to less than 5 m depth where it was replaced by a mix of *Lessonia*, *Ecklonia* and mixed algae including *Carpoglossum*. Below 10 m *Ecklonia* dominates and becomes sparse below 20 m where it is replaced by sponge dominated communities.

Wedge Bay, a large embayment within this region, provides substantial shelter from swell and wave action particularly in the vicinity of the Nubeena township. At the most sheltered locations, sizeable beds of *Heterozostera* seagrass are found over sand. The sheltered shallow reef areas within this embayment are dominated by mixed fucoid communities, particularly *Caulocystis*, *Zonaria* and *Cystophora* spp. At the time of the survey within this area, *Macrocystis* was common in the shallow reef areas close to the town of Nubeena, indicating that this location has at least some exposure to swell action.

Special Features:

- Offshore deep (20 to 40+ m depth) reefs outcropping from sand and from coarser sediments of gravel and shells.
- Increased abundance of *Carpoglossum confluens*, sea tulips and *Lessonia* in the upper subtidal inshore reef areas. *Lessonia corrugata,* a Tasmanian endemic species is particularly abundant in this coastal section.
- Notable absence of *Phyllospora* as a dominant community species.

4.7 Arthur

Port Arthur was identified as a distinct mapping section due to the diverse range of habitats found in the one small area, a character that clearly differentiated it from the adjacent highly exposed coastline (Fig. 10). The geology of this area is dominated by dolerite and sedimentary formations with most of the reefs on the eastern shore of the port composed of dolerite, and those of the western shore composed of sedimentary rock types. The depth of the port extends to 50 m in the middle of the embayment, with silty sand found at these depths and extending into the shallow waters of Long Bay. One notable feature is the large extent of gravel/cobble bottom off the cliffs south of Isle of the dead and off West Arthur Head. Some hard shelly patches are located in areas of 10-20 m depth in the upper reaches of Port Arthur itself. Exposure varies greatly within this area, from medium exposure along most of the eastern shore, through low exposure to very sheltered on the western shore. There is little offshore extension of reef in this area, although reefs do extend to depths of more than 20 m along parts of the eastern shore.

Community Types:

Within the embayment there is a decrease in wave exposure from south to north and a corresponding change in macroalgal communities. The headlands at Budget Head and West Arthur Head at the southern end of the port are highly exposed to swells, and have communities dominated by *Durvillaea*, *Phyllospora*, *Ecklonia*, red algae and sponges, in addition to extensive areas of sea tulips. At the substantially more sheltered northern end of Port Arthur, *Lessonia* is common and intergrades with some mixed fucoid in the shallows, while *Ecklonia* is dominant in deeper (2-8 m) waters. As the bay is relatively shallow, an extensive red algal and sponge community is not found. *Macrocystis* is common throughout Port Arthur on reefs in moderately exposed areas at depths between 5 to 15 m and forms dense stands at Garden Point and Stinking Bay. Dense beds of seagrass are found in Stewarts Bay and areas of patchy seagrass are located at the head of all the other bays.

Special Features:

- High variation in habitat types with good representation of a variety of most within a relatively small area.

- Large cobble/gravel beds on the eastern side of the Port.

4.8 Frederick Henry

Frederick Henry Bay was mapped as a coastal section on the basis of a moderate to low exposure to the action of swells (Figs. 12 and 13). The coastal geology is dominated by headlands composed of dolerite and sedimentary rock types alternating with extensive sections of sandy beaches. The bay is relatively shallow and is mostly less than 25 m deep, with few reefs extending below 15 m depth. The majority of reefs have very little offshore extension, often reaching the sand edge at less than 50 m from the coast. During the survey of offshore areas within the bay some 'harder' traces on the sounder could not be adequately field-truthed using the camera because of the low visibility but may have consisted of small areas of patchy reef and some sponges.

The substrate sediments within the bay are well sorted, with this degree of sorting relating to the shallowness of the bay, the mostly unconsolidated substrate, and moderate exposure to wave action. Shell and gravel (shown as 'Hard sand' on the maps of this section) areas were common in the bay, although a full determination of the distribution of sediment types within the bay was hindered by generally poor visibility that limited calibration of sounder outputs with video drops. Poor water clarity is a characteristic feature of this bay, where even small swells resuspended substantial amounts of sediments within the water column, and where plankton densities appear to be high. Presumably the fine sediments are derived from the outflow of the Derwent River and to a lesser extent the Coal River valley, and that these rivers enhance nutrient levels within the bay. Silt and silty sand were found in deeper waters at the entrance to Norfolk Bay, and in a deep channel to the northwest of Sloping Island. This channel is an unusual feature of the bay and extends to depths greater than 40 m.

Community types:

On the reef margins in the more swell exposed areas of the bay *Lessonia* was the dominant macroalgae in the upper subtidal zone (0-3 m) with *Ecklonia*, mixed browns such as *Acrocarpia,* and red algae below. *Sargassum* and *Cystophora* species were increasingly common on reef on the less exposed shorelines. Due to the low water clarity of this region most macroalgae are replaced by sponges at depths of 10- 15 m, and on reefs adjacent to Primrose Sands urchin barrens extend below depths of 5-7 m. Outcropping rocky areas within the bay have limited associated algal communities due to the abrasive action of the sand and swells, in combination with low light levels. While this coastline is exposed to swells, *Durvillaea,* which is characteristically found on exposed coasts, was largely absent. A combination of aspect and gently sloping shores limits the wave energy reaching the shoreline, allowing *Durvillaea* to be replaced by *Lessonia.* In some of the more sheltered locations such as Sloping Main beach and to the east of Sloping Island, *Heterozostera* seagrass beds of varying density are found on sandy substrates.

Special Features:

- Frequent high sediment load in the water column, and generally low water clarity.
- Well sorted unconsolidated sediments consisting of gravel, cobbles and shell fragments in some areas.
- Shoreline predominantly composed of sandy beaches.

4.9 Adventure

This coastal section is characterised by the continuous stretch of exposed east facing coastline (Figs. 16 and 17). The geology of the region is dominated by dolerite with occasional sedimentary outcrops, forming a coastline with a steep to cliffy aspect. There is a large sandy embayment in the centre of this section (Adventure Bay) and smaller indentations of the coastline further north of this at Trumpeter Bay, Variety Bay and Bull Bay. Reef systems within this region are limited in their offshore extent, with few extending beyond 20 m depth. Two notable exceptions are found at Fluted Cliffs where isolated reefs extend to depths in excess of 40 m. Isolated offshore reefs were found to occur in the 30 to 40 m depth range in Adventure Bay and off North Bruny, and gravel patches (shown as hard sand in Figs 16 and 17) are common feature offshore throughout this region. There is a gradient in wave exposure along this coastline which decreases towards the north as coastal aspect changes from southeasterly to northeasterly. The coastline to the south of Adventure Bay is moderately to highly exposed, while much of northern Bruny Island, and the coastline extending northwards to Taroona, is subject to medium to low exposure to swells. While still partially exposed, the southernmost corner of Adventure Bay is sufficiently sheltered for small seagrass beds to develop. The sediments of this area are primarily sand, with a similar degree of exposure to the reef habitats, although beaches are not found on the most exposed coast.

One notable feature of this area is a large extensive shelly ‘shoulder’ located on the north eastern corner of Bruny Island. This shoulder supports a large population of urchins that is commercially fished by divers. The urchins are presumably sustained by strong currents flowing into and out of the D’Entrecasteaux Channel, carrying drift algae that the urchins feed on.

Community types:

Related to the gradual decrease in wave exposure from south to north, is a subtle change in communities present. The dominant species on reefs in the southern zone are those indicative of high exposure to wave action, including *Durvillaea*, *Phyllospora*, *Ecklonia*, red algae and sponges, with *Durvillaea* extending to below 5 m. In the northern zone the maximum depth of *Durvillaea* decreases to approximately 2 m at Bull Bay. Along the North Bruny coastline, and the coastline towards Taroona, *Lessonia* communities become common, with *Lessonia* partially to completely replacing *Phyllospora*. Within embayments, mixed fucoid species (including *Sargassum* and *Cystophora* species) are common in the shallow waters, replaced by *Ecklonia* at depth. *Macrocystis* forms extensive beds along the moderate to low exposure north-eastern coast of Bruny Island, and more generally occurs commonly throughout this entire region. On the soft-sediments, small *Heterozostera* seagrass beds are found in the most sheltered waters within Adventure Bay in the 1 to 10 m depth range.

Special Features:

- Large persistent *Macrocystis* beds in the northern section on reefs in depths of 5 to 20 m
- Large extensive shelly ‘shoulder’ off the north eastern corner of Bruny Island
- Gravel patches offshore
- Extensive sand areas between 15 m and 40 m depth

4.10 D'Entrecasteaux

The D'Entrecasteaux Channel was chosen as a coastal mapping section as it is a continuous sheltered water body, protected from oceanic swells by Bruny Island (Figs. 15-18). The coastal rock types within the Channel are mostly dolerite and sedimentary. Where sedimentary, they form small cliffs in the intertidal and backshore areas, but usually slope gradually underwater. An unusual feature of this coastal section is the presence of basalt shores, particularly along the western shore of North West Bay and the shoreline between Gordon and Kettering. Most reefs within the Channel are associated with the shoreline and few extend more than 20-50 m offshore, with the majority reaching the sand edge at depths of 5 m or less. Some exceptions can be found on the ends of points extending from the eastern shore of Bruny Island. Here, at locations such as Roberts Point, depths of 25 m are reached. Isolated low-flat sandstone reefs outcrop offshore from Ventenant Point towards Zuidpool Rock in depths of 15-20 m.

While the Channel is not subject to swell action, it contains a high diversity of habitats. There are numerous bays, each subject to differing environmental conditions. For example, North West Bay is largely protected from wind, but has moderate currents, and this is reflected in relatively coarse inshore sediments grading to silty sand at depths of 20 –30 m. Barnes Bay is relatively deep and is sheltered from most winds with low currents resulting in a substrate that is mostly silt. Simpson Bay is a broad expanse of water and is a reasonably shallow (>12 m) sandy bay. The strong currents that flow through this bay have resulted in the distribution of coarse sediments throughout much of the bay, except for a small area of silty sand in the southern part of bay that is protected from prevailing westerly winds. Little Taylors Bay similarly has coarser sediments probably as a result of currents and a shallow basin. On the western side of the Channel there are a number of smaller embayments such as Kettering and Oyster Cove. These bays are protected from the prevailing winds and are generally sandy with isolated seagrass patches.

In the lower end of the Channel in the Gordon area, the channel is relatively narrow and particularly shallow. The region between Green Island and Arch Rock is no deeper than 15m, with most of the seabed between 10 and 15 m. This restriction increases current flow resulting in a well sorted sediment covered by large shell fragments. These shelly areas are also found adjacent to Alonnah and at other high current areas within the Channel.

Community types:

At the northern and southern end of the Channel the coastal reefs are subject to some swells and the algal communities here are dominated by *Phyllospora* in the upper subtidal with *Ecklonia* and mixed fucoids extending into deeper waters. Most of the Channel is protected from swells and reefs in these more sheltered waters have macroalgal communities dominated by mixed fucoids (*Caulocystis, Cystophora* spp.) in the shallows (1-2 m depth), grading to *Sargassum* spp. at 10 m.

Adjacent to the lower margins of rocky reefs there is usually a sandy to shelly strip, sometimes with seagrass but usually with *Caulerpa* spp., which extends into the sand or silt. Silt deposition on the reefs often limits algal growth, particularly on the deeper reefs in areas with limited water motion. In areas where there is moderate to strong current flow and where reefs extend below 5 m, sponges become an increasingly dominant community type. These sponge communities are commonly found on the ends of points along the eastern shore of North Bruny.

On shelly substrates in high current areas, seawhip and sponge communities can be found in quite shallow waters, often less than 10 m depth. A particularly notable area is found approximately 100 m north west of Simpsons Point, where a reef outcrops from the surrounding substrate of shelly sand. This reef contains a complex community of sponges, seawhips and red and green algae. At the reef margins very dense communities of seawhips occur, all within depths of less than 10 m. Similar seawhip and seafan aggregations can be found along the reef margin extending southwards along the eastern shore of Simpsons Point. The offshore reefs outcropping in 15-20 m in the vicinity of Ventenant Point have very little cover associated with them, and presumably this is due to low light levels and low current flows.

While seagrass is not a common community type within the Channel, the greatest coverage occurred on the shallow sandflats between Gordon and Middleton, with more isolated patches occurring along the remaining western shore of the Channel and North West Bay.

Special Features:

- Large areas of shelly-sandy substrate exposed to high current in waters less than 10 m depth.
- Sponge and seawhip invertebrate communities on shelly substrate in depths from 6-15 m in high current areas.
- Reef outcrop in high current waters adjacent to Simpsons Point with a diverse and fragile invertebrate community.
- A broad range of sheltered habitats including shallow and relatively deep reefs and sediments.

4.11 Cloudy

The Cloudy coastal section was distinguished on the basis of its exposure to high wave action and the extensive reef systems that run to the south of the major promontories (Figs. 17 and 18). The geology is dominated by dolerite coast, reefs and offshore islands. The coastline is dominated by steeply sloping to cliffy shores and one main bay at Cloudy Bay where a large sandy beach is located. On the western side of this region, between Partridge Island and Quartz Rock there are large areas of patchy reef, intermingled with a gravelly substrate. Reef habitats extend to 60-70 m depth at some locations due to the highly exposed nature of this coastline. To the east of Cloudy Bay another extensive section of reef is located around The Friars island group and reef there also extends into depths > 40 m.

Community types:

There are no significant sheltered water communities in this section of coastline, and those present are typical of those expected on a highly exposed coast. The macroalgal communities on reef are dominated by *Durvillaea* to 10 m, with *Phyllospora* extending from 5 to 15 m and *Ecklonia* from 10 to 30 m Sponges and other invertebrates dominate the benthic community below 30 m. Cover of the larger brown algae is not high in many areas, presumably due to the very high exposure to wave action, however, a higher cover of red algae and encrusting corallines is evident. South and westerly aspects had the least cover of the larger brown algae. In deeper areas subject to currents (particularly off headlands), profuse sponge, seawhip and gorgonian fan communities are found. *Macrocystis* is common in the upper reaches of small bays and in the vicinity of Partridge Island where some protection from swells is available. The sedimentary substrates are composed entirely of exposed sand which extends from the shoreline in Cloudy Bay. Although not included in this mapping, seagrass beds are located in the sheltered, shallow waters within Cloudy Lagoon.

Special Features:

- Extensive deeper water (20-40 m depth) reef areas with associated communities of encrusting corallines and red algae.
- Extensive sponge and seawhip gardens in deep waters.
- Very deep (>40 m) rocky reef communities.

4.12 Huon

The Huon coastal section was chosen to incorporate the southern waters of the D'Entrecasteaux Channel where exposure grades from moderate in the south, to the more sheltered waters of the mid-Channel region (Fig 19). The geology of this area is dominated by dolerite, which forms most of the promontory's, islands and rocky offshore outcrops. A notable exception is Ventenant Point which is of sedimentary origin, and sediments form localised outcrops throughout the region. The dolerite reefs tend to extend into deeper waters than the sedimentary reefs. In the northern section of this coastline the maximum depth of dolerite reefs reaches approximately 15 m in areas such as Butts Reef, Zuidpool Rock, Arch Rock and southern Huon Island (all influenced by the Huon River tannins). In the more oceanic southern section, reefs extend to depths of 40 m in places between Southport and Dover. This section of coast has a particularly notable component of reef, with some areas extending to one kilometre from the shoreline, and it is moderately exposed in contrast with the low to sheltered reefs found in the northern section. In most areas sand usually extends to depths of 20 m, grading to silty sand between 20 and 30 m and to silt at depths beyond 30 m. There is an extensive region of deep water (>30 m) to the east and south of Huon Island related to valley of the Huon River during glacial periods of lower sea levels. This deep region is predominantly composed of fine silt.

Community types:

The section of reef between Southport and Dover is moderately exposed and has a macroalgal community dominated by *Durvillaea* to between 2-5 m, with *Phllospora* below to 10 m where it is replaced by *Ecklonia*. Invertebrate communities replace *Ecklonia* below 25 m. *Macrocystis* forms dense forests along much of this section of coast in depths of 5 to 20 m. On the low exposure south facing coasts in the vicinity of the Huon River, such as Butts Reef, southern Huon Island and Arch Rock, *Durvillaea* is found in the upper subtidal, with *Phyllospora* to 3-5 m and *Ecklonia* dominating at depths beyond this. *Macrocystis* is common between 5-8 m in areas subject to some current. Red algae are common at most depths and dominant at depths beyond 10 m, particularly along the northern coastline. In the more sheltered waters, mixed fucoid communities are present with *Acrocarpia* and *Cystophora* being dominant species and *Xiphophora* relatively common. In very sheltered waters such as Great Taylors Bay, *Sargassum* species become dominant. At the edges of reefs, there is commonly a sandy-shelly strip, where *Heterozostera* and *Caulerpa* species are often found. In areas where there are moderate currents, such as adjacent to Arch Rock, there is a substantial cover of large shell fragments overlying the sandy substrate and in these areas seawhips, seafans and sponges are common. The heavily tannin stained waters discharging from the Huon River lead to substantial modification of the communities that are found on the reefs, particularly on reefs closest to the mouth of the Huon river, and to the east, where the bulk of the tannin water flows. The tannin limits light penetration, reducing the maximum depth to which algae can grow and compressing the succession of algal species through the depth gradient to substantially less than that found in clear water. In this unusual community, few brown algae are found at depths greater than 7-10 m where they are replaced by red algae as the dominant cover. Beyond 15 m, red algae become less common and filter-feeding invertebrates become the dominant cover-forming community. This community is highly distinctive of the region, with the only similar assemblage of species being found in Bathurst Channel at Port Davey. Butts Reef appears to have the best representation of this assemblage due to its greater maximum depth than other reefs in the strongly tannin influenced zone.

Special Features:

- Tannin stained waters due to the outflow of the Huon River with unique community compositions, including compression of algal succession, high red algal diversity and shallow water invertebrate dominated communities.
- Deep silt holes and channels (to 50 m) in the drowned river valleys of the Derwent and Huon rivers.
- Dense *Macrocystis* forests on reef between Southport and Dover.

4.13 Actaeon

The Actaeon coastal section is characterised by the presence of an extensive offshore reef system, exposed to heavy swells (Fig. 20). This reef area accounts for 27% of all reef mapped during this study. This coastal section also has two substantial embayments at Recherche Bay and Southport that are moderately sheltered, in additional to a large coastal lagoon (Southport Lagoon). Within the embayments the substrate is composed of a mix of sand and patches of fringing reef, with some areas of silty sand in the most protected waters. There is a slight gradation in exposure to swell action from south to north along this coastline, with the southern zone being more subject to westerly swells that wrap around the southern tip of the State. While the outer coast of this area is particularly exposed, the Actaeon Islands and associated shallow reef area form a barrier that provides some protection to a substantial portion of coast and reef inside this barrier. The coastal geology is dominated by a dolerite shoreline mixed with sandy beaches, dolerite offshore islands and dolerite offshore reefs. The most notable feature of this region is the extensive coverage of reef in the vicinity of the Actaeon Islands. Much of the inshore reef in Tasmanian waters is limited to a narrow coastal fringe, making this reef system an unusual feature.

Community Types:

Reef habitats on the highly exposed outer Actaeon Islands are dominated by *Durvillaea* to depths of 10 m or more, with *Phyllospora* extending from 5 to 15 m and *Ecklonia* from 10 to 30 m. Red algae are common below 10 m and sponge communities dominate below 30 m. Inside the Actaeon Islands, exposure is moderate, with *Phyllospora* replacing *Durvillaea* at approximately 5 m. *Macrocystis* is common in the moderately exposed areas, forming extensive beds on reefs of 5-15 m depth inside the Actaeon Islands, along the coastal fringe, and well into the more sheltered waters within the embayments. At the top of the embayments *Heterozostera* seagrass beds are found, and a large bed of *Caulerpa* is located in the most protected waters of Pigsties Bay, at the north western end of Recherche Bay. Mixed fucoid communities are found on reef at the sheltered end of the bays, including *Sargassum, Cystophora* and *Caulocystis* species.

Special Features:

- Extensive area of high to moderately exposed reef including a large extent of low profile reef often subject to sand cover.
- *Caulerpa* bed in Pigsties Bay.
- Large persistent beds of *Macrocystis*.

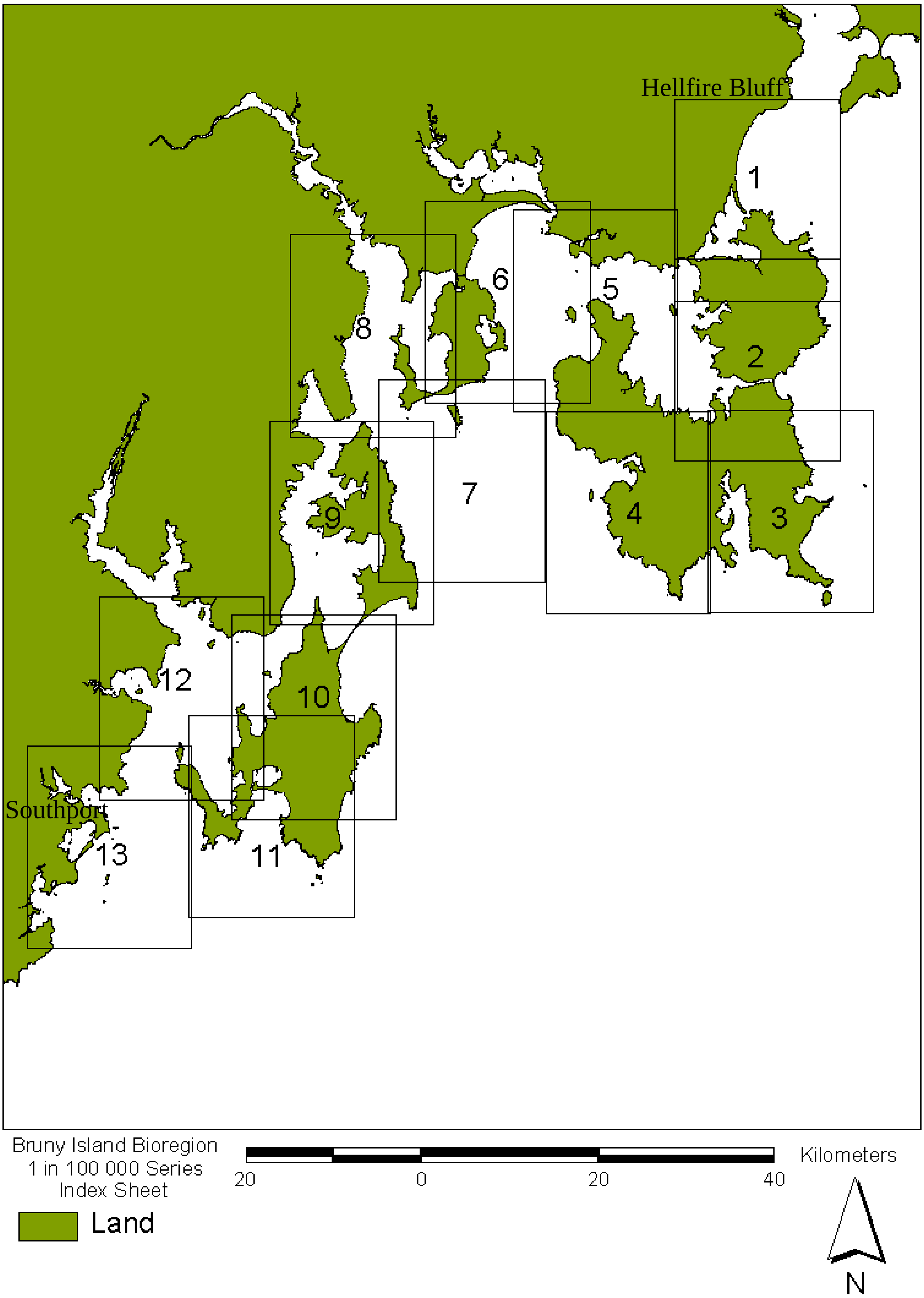

Fig. 7. Map showing location of the detailed maps within the Bruny Bioregion.

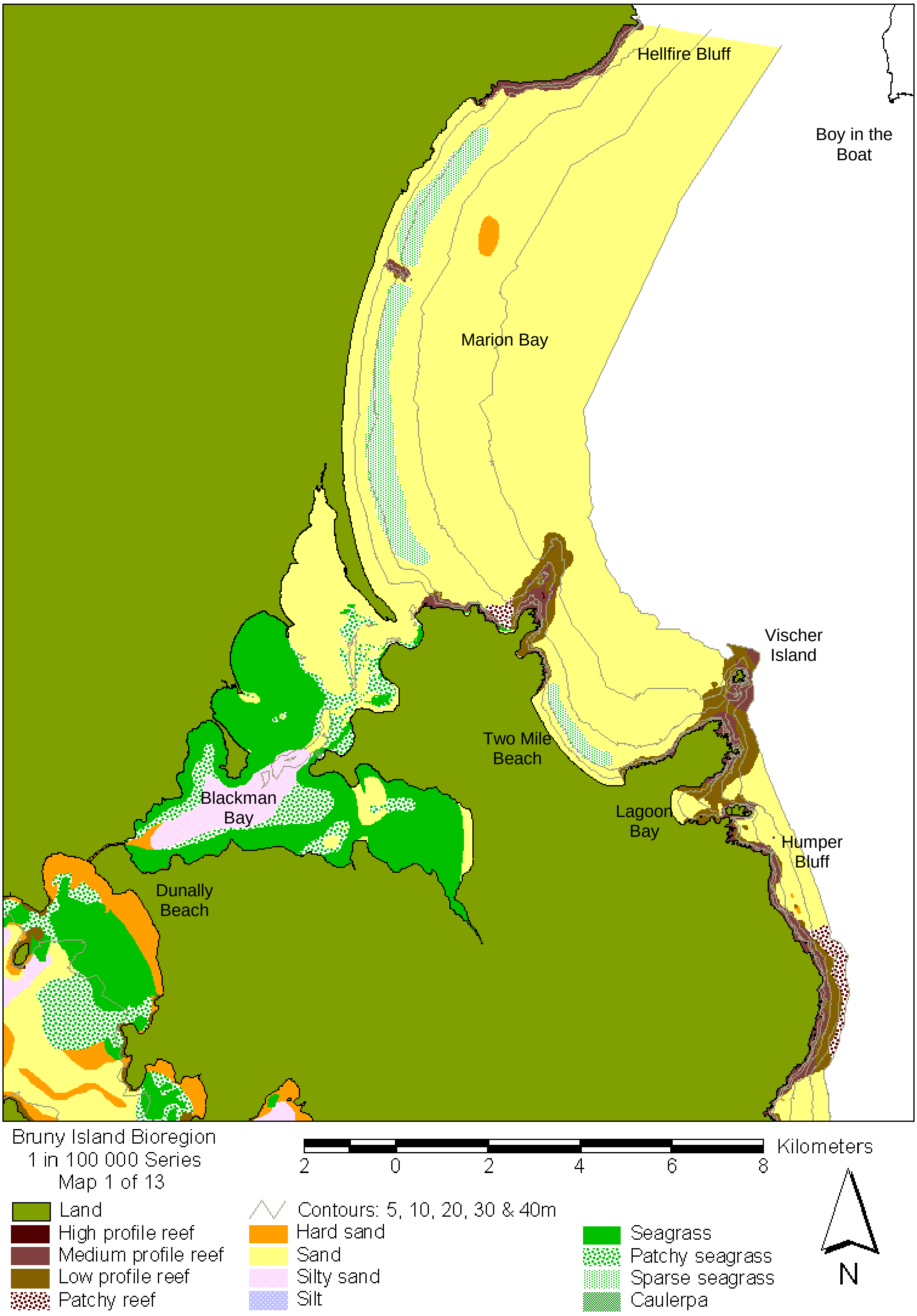

Fig. 8. Northern ends of the Peninsula and Norfolk Sections

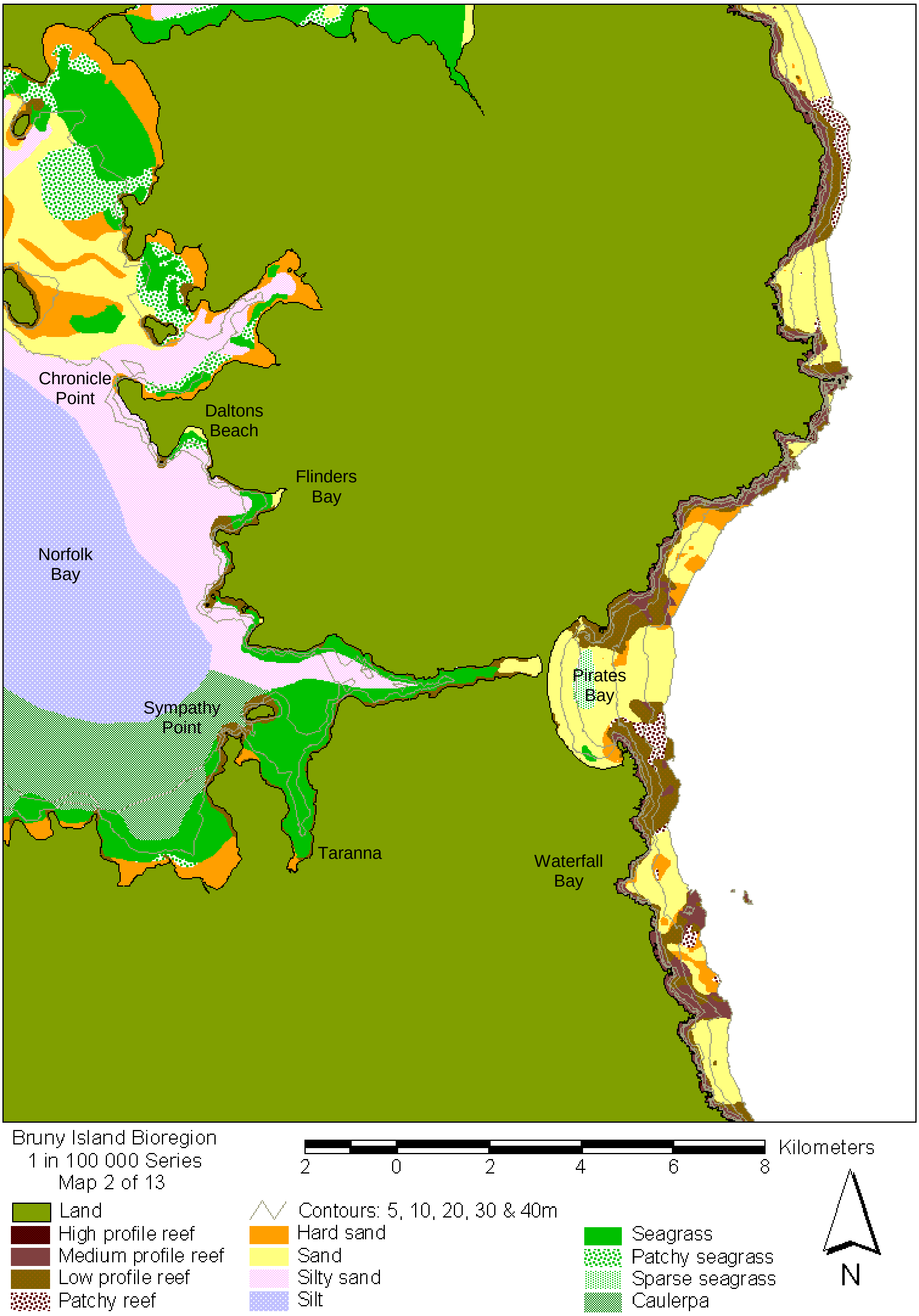

Fig. 9. Middle Peninsula and eastern Norfolk Sections.

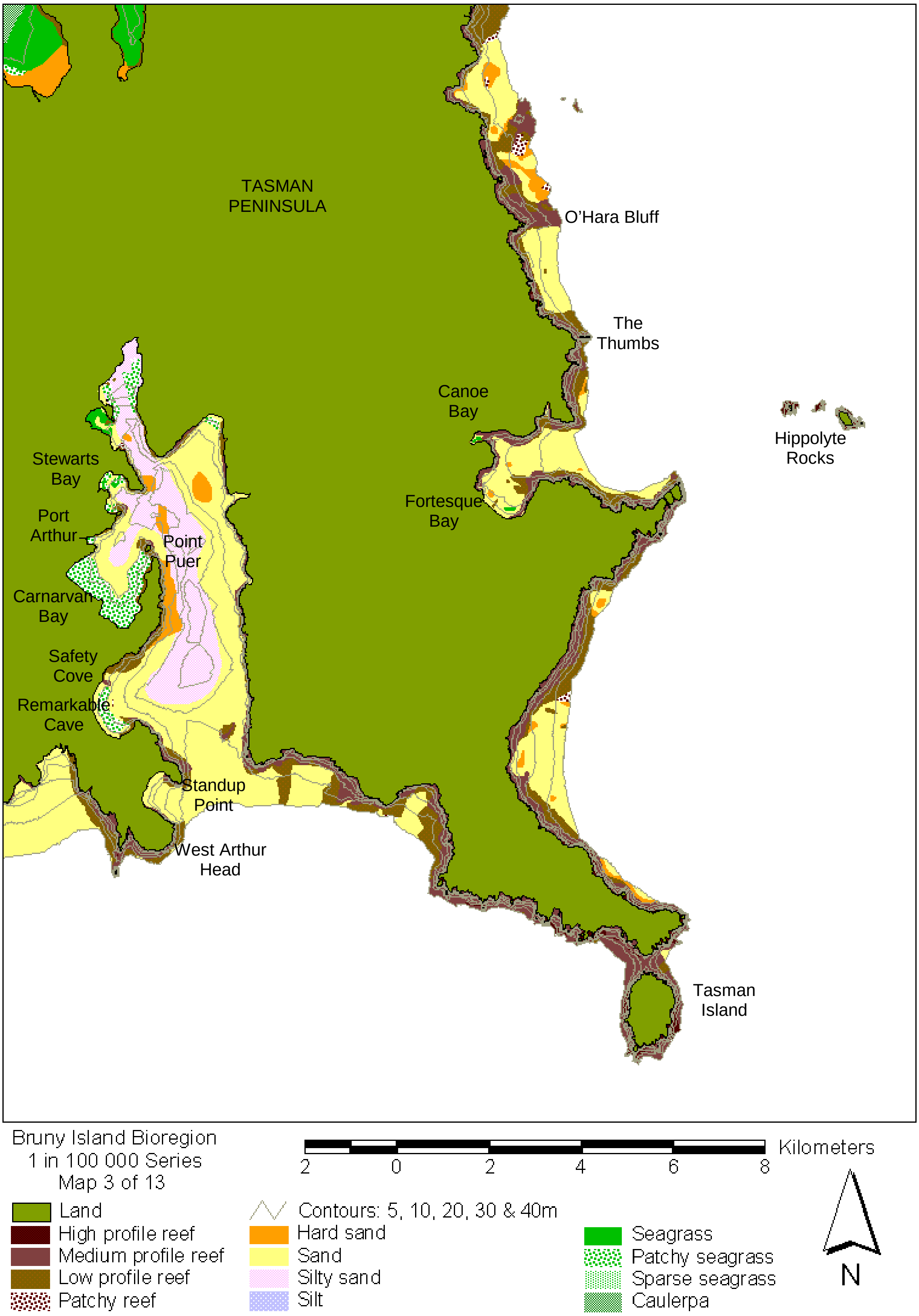

Fig. 10. Southern Peninsula and Arthur Sections.

Fig. 11. Betsey section, eastern side.

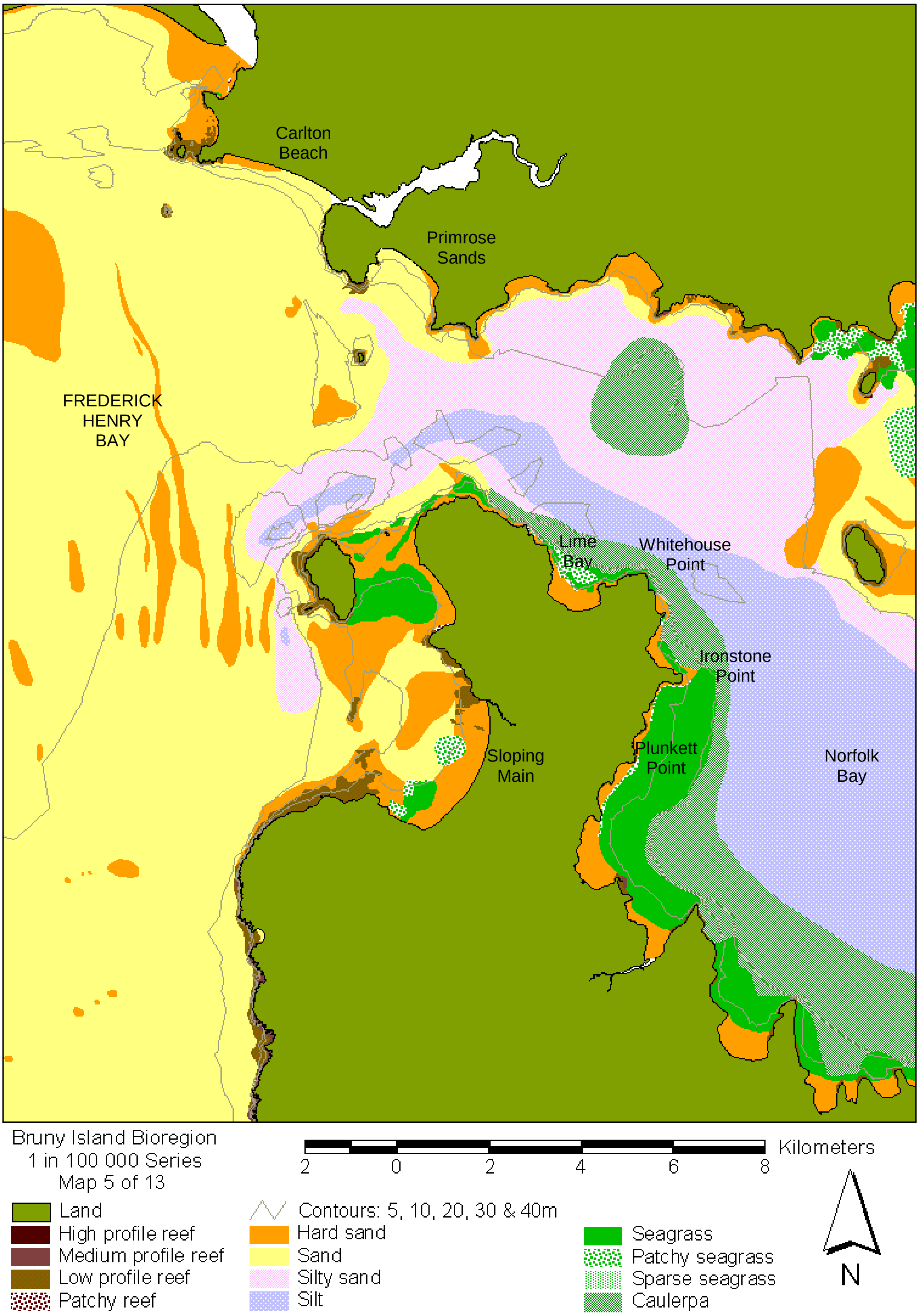

Fig. 12. East Frederick and west Norfolk sections.

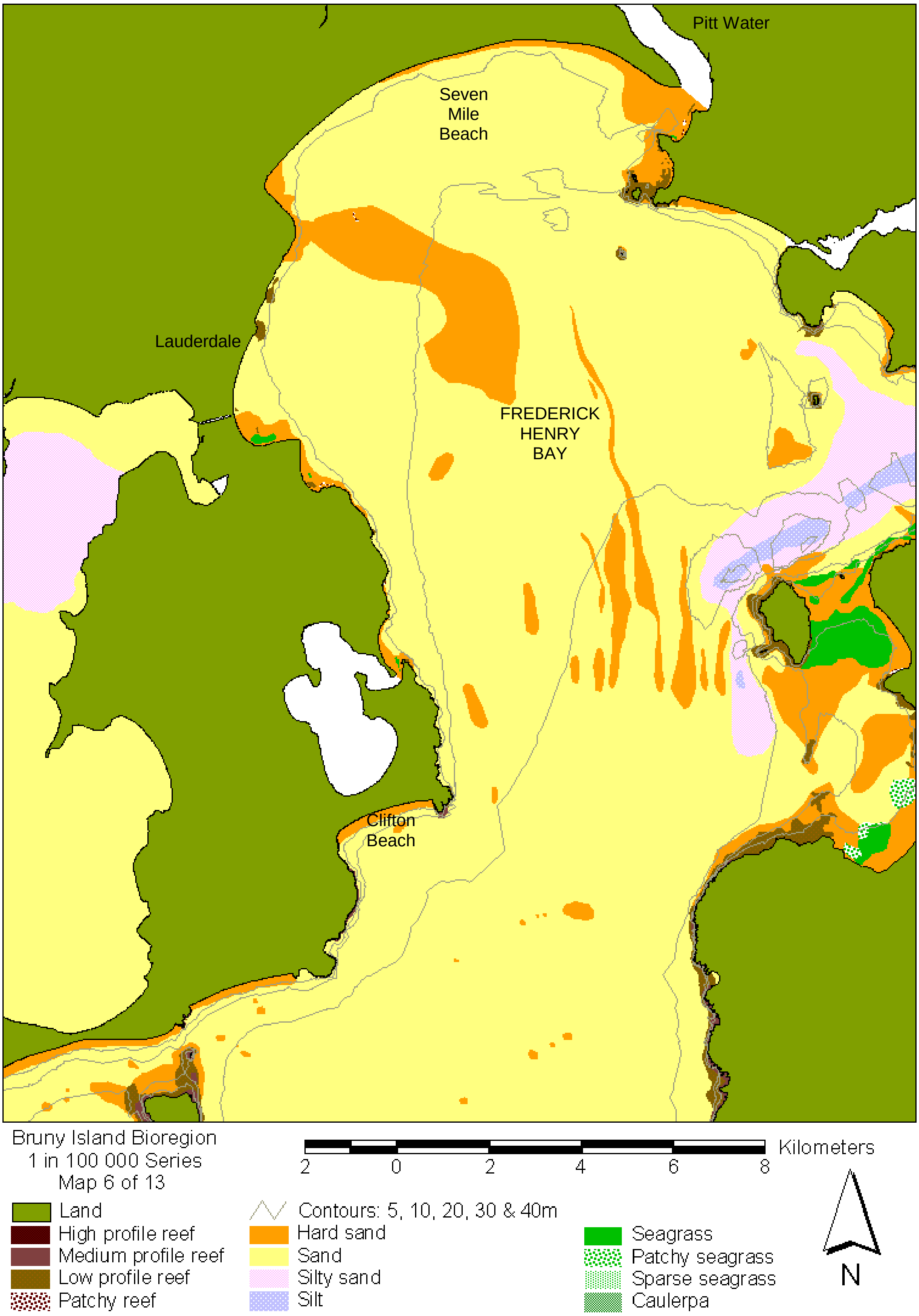

Fig. 13. Western Frederick Henry section.

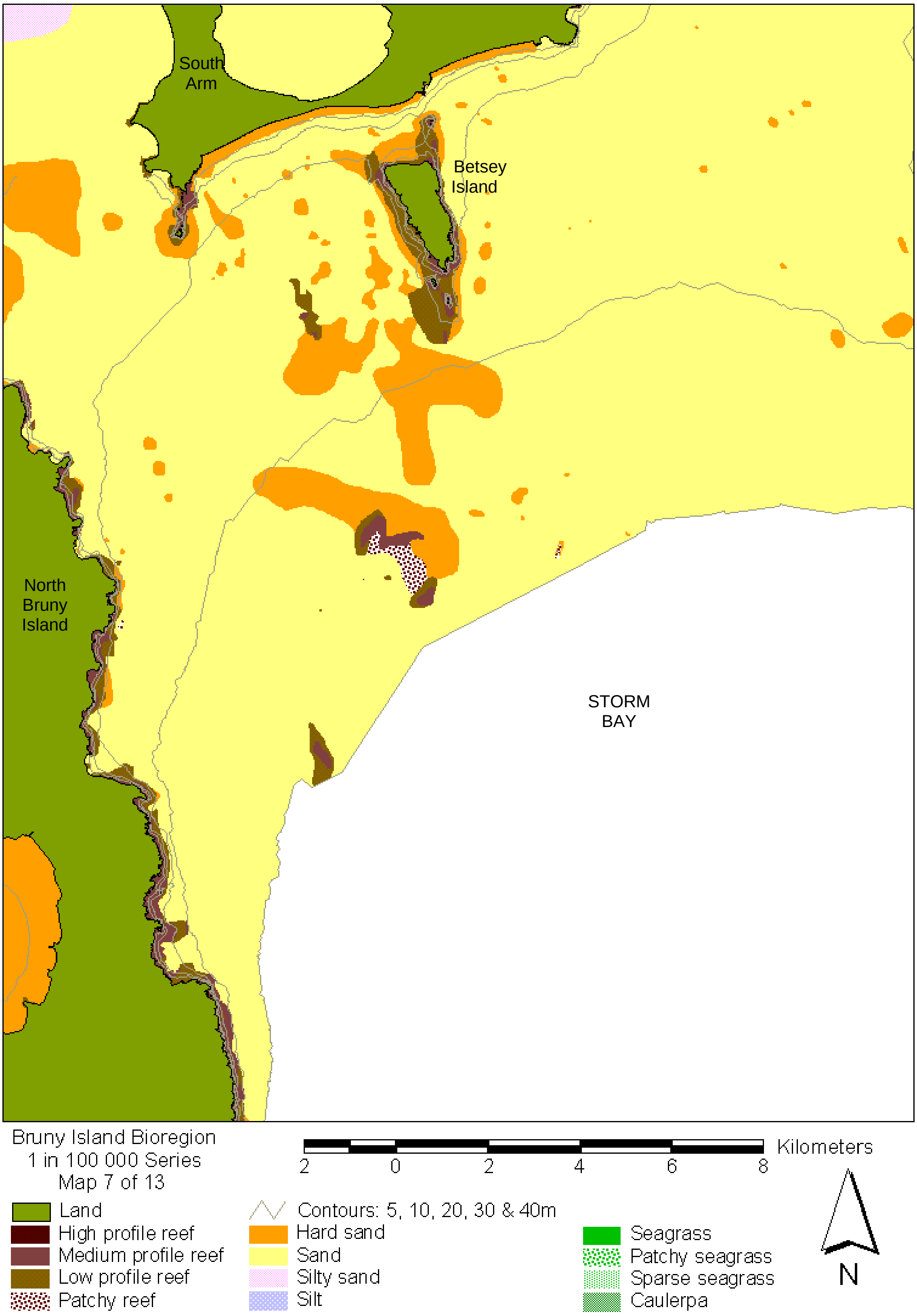

Fig. 14. Western Betsey Section.

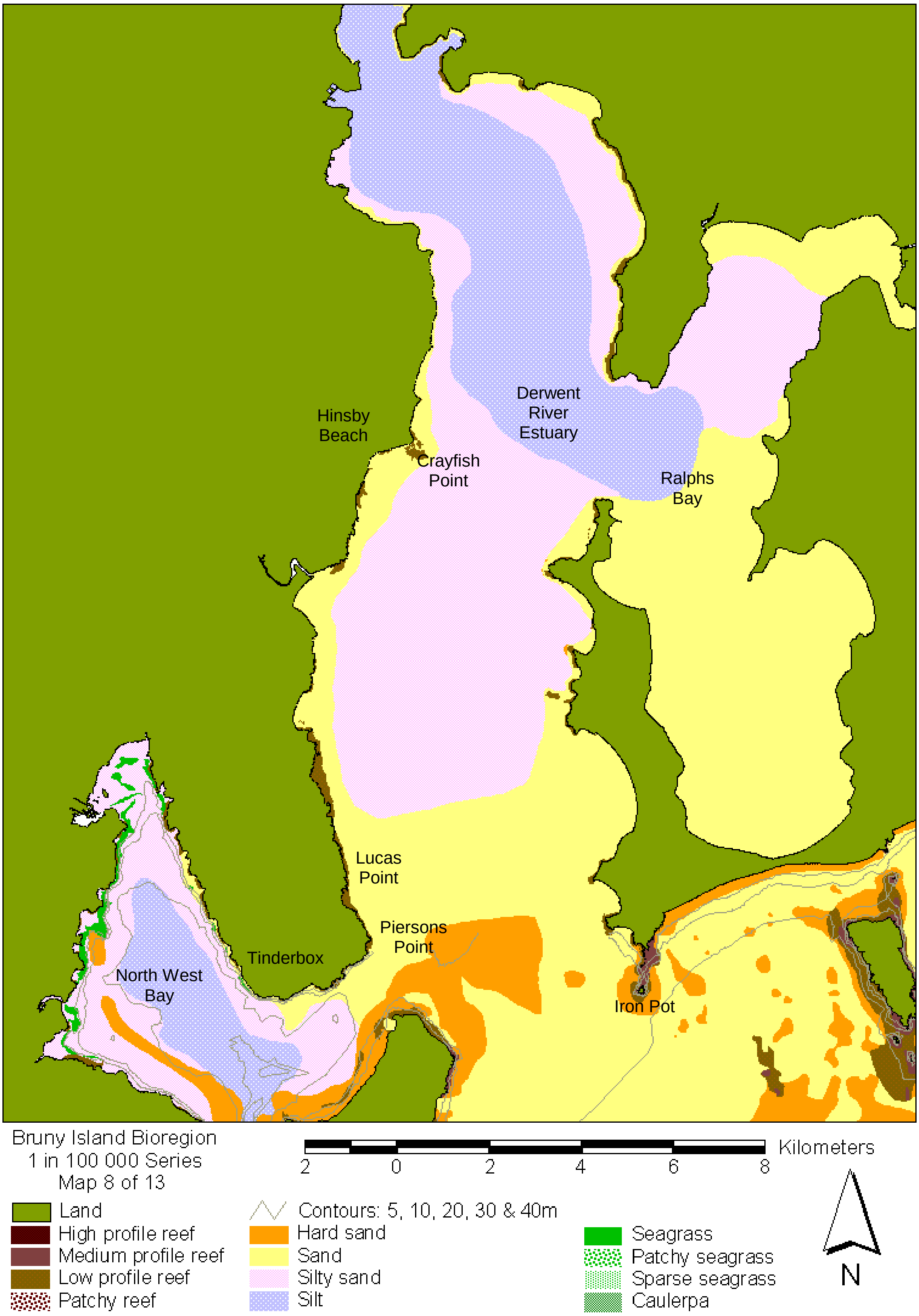

Fig. 15. Derwent River and Northern D'Entrecasteaux Channel Section.

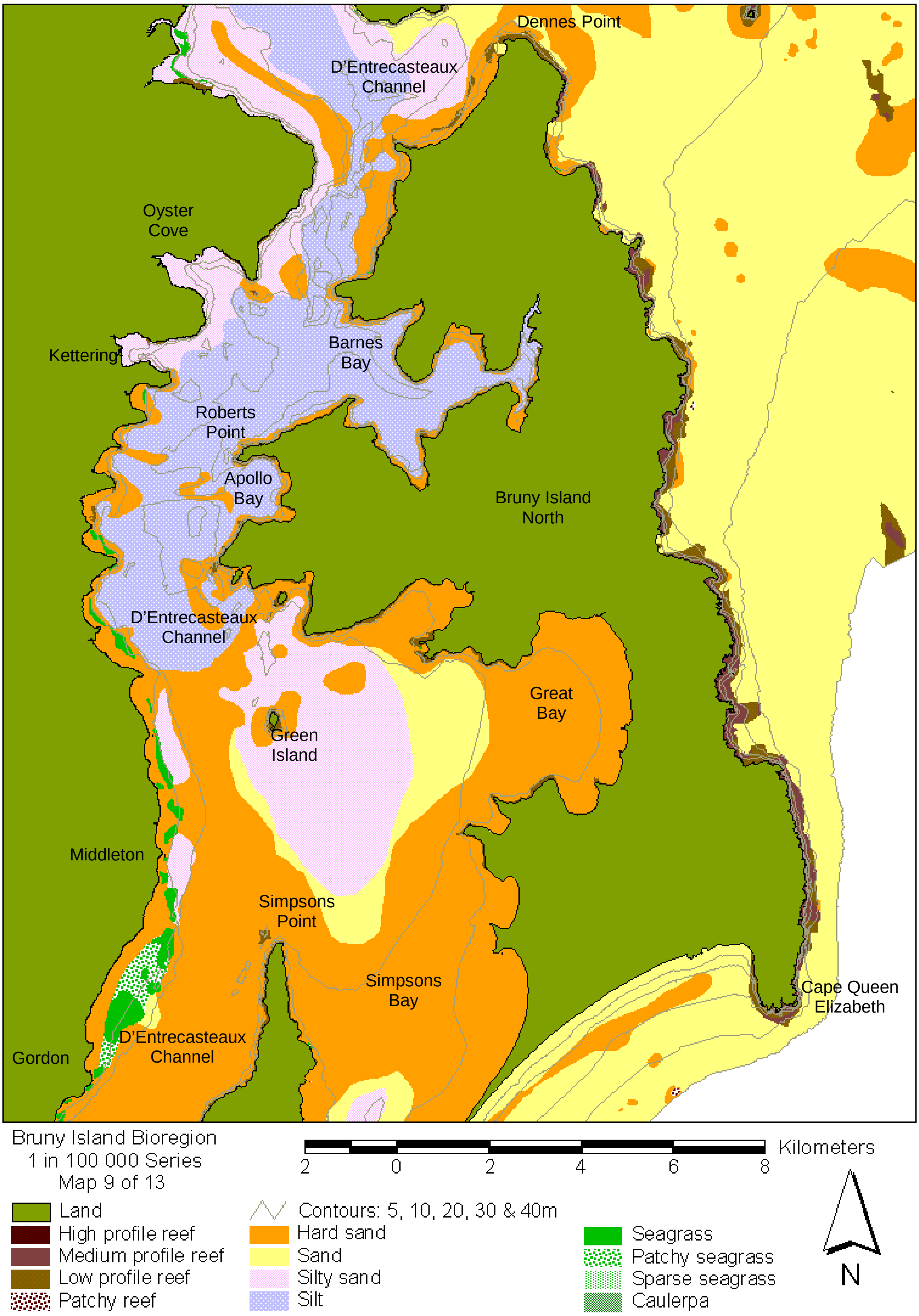

Fig. 16. D'Entrecasteaux Channel and Northern Adventure Bay Section.

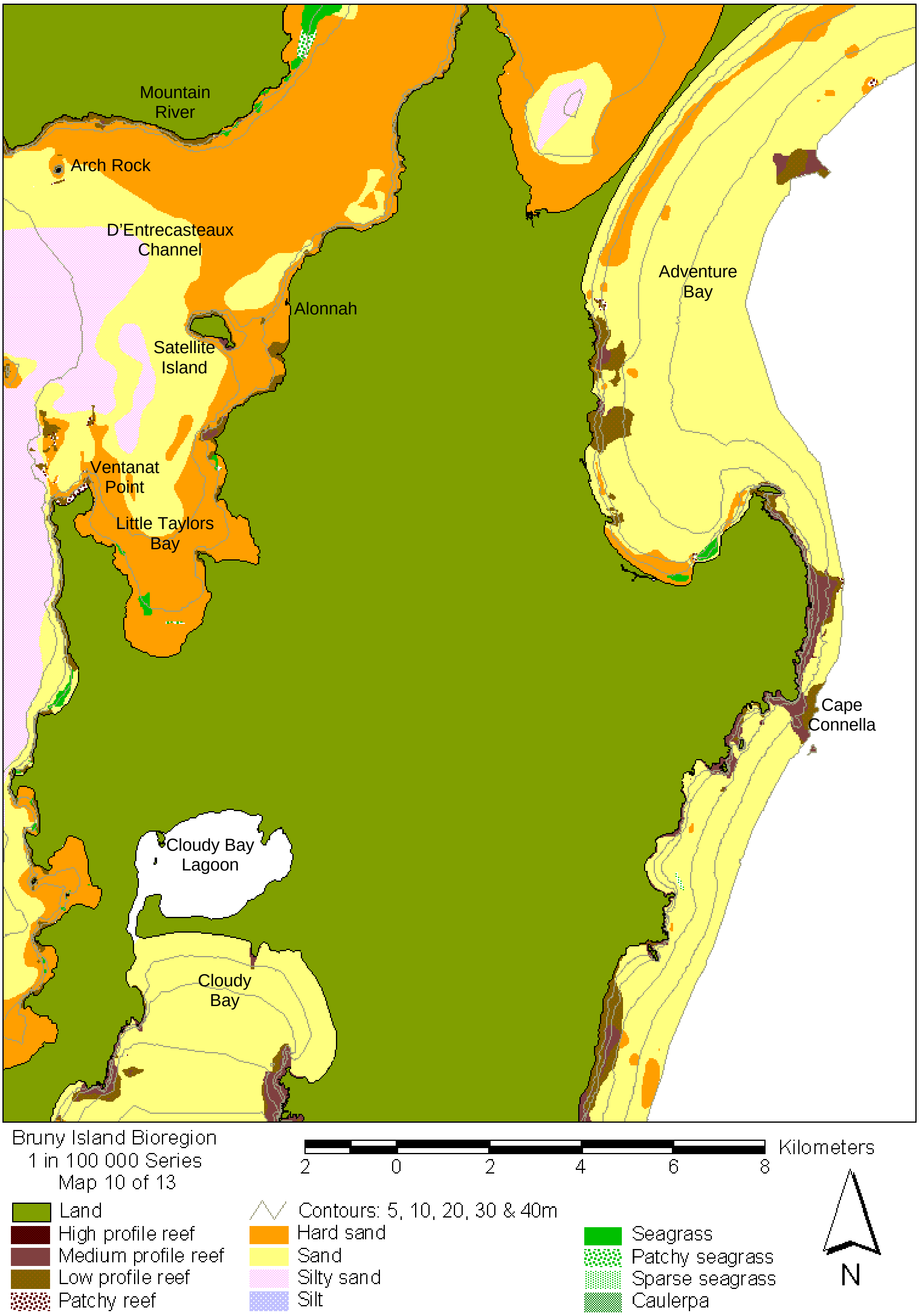

Fig. 17. Lower D'Entrecasteaux Channel and middle Adventure Bay Section

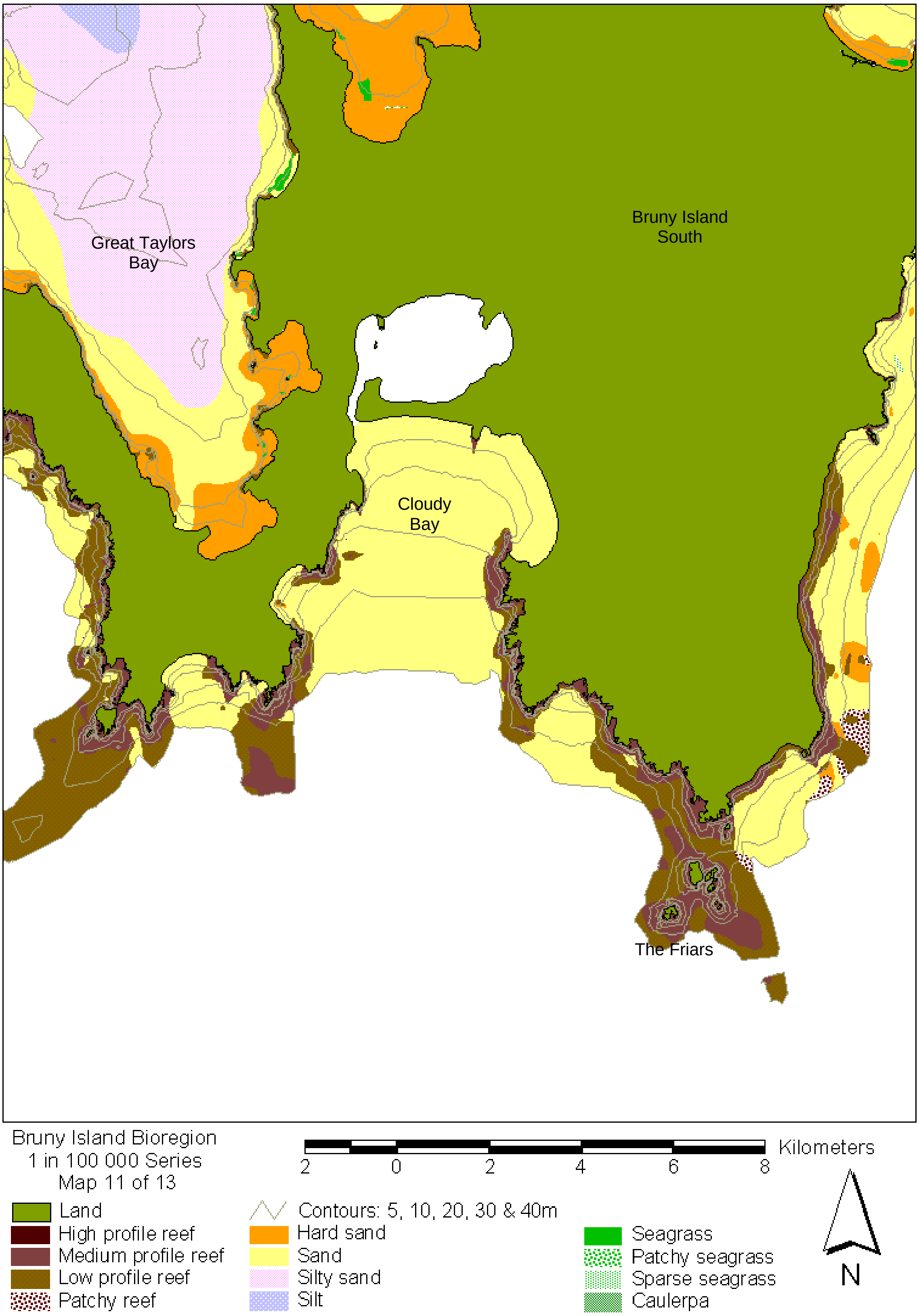

Fig. 18. Cloudy Section.

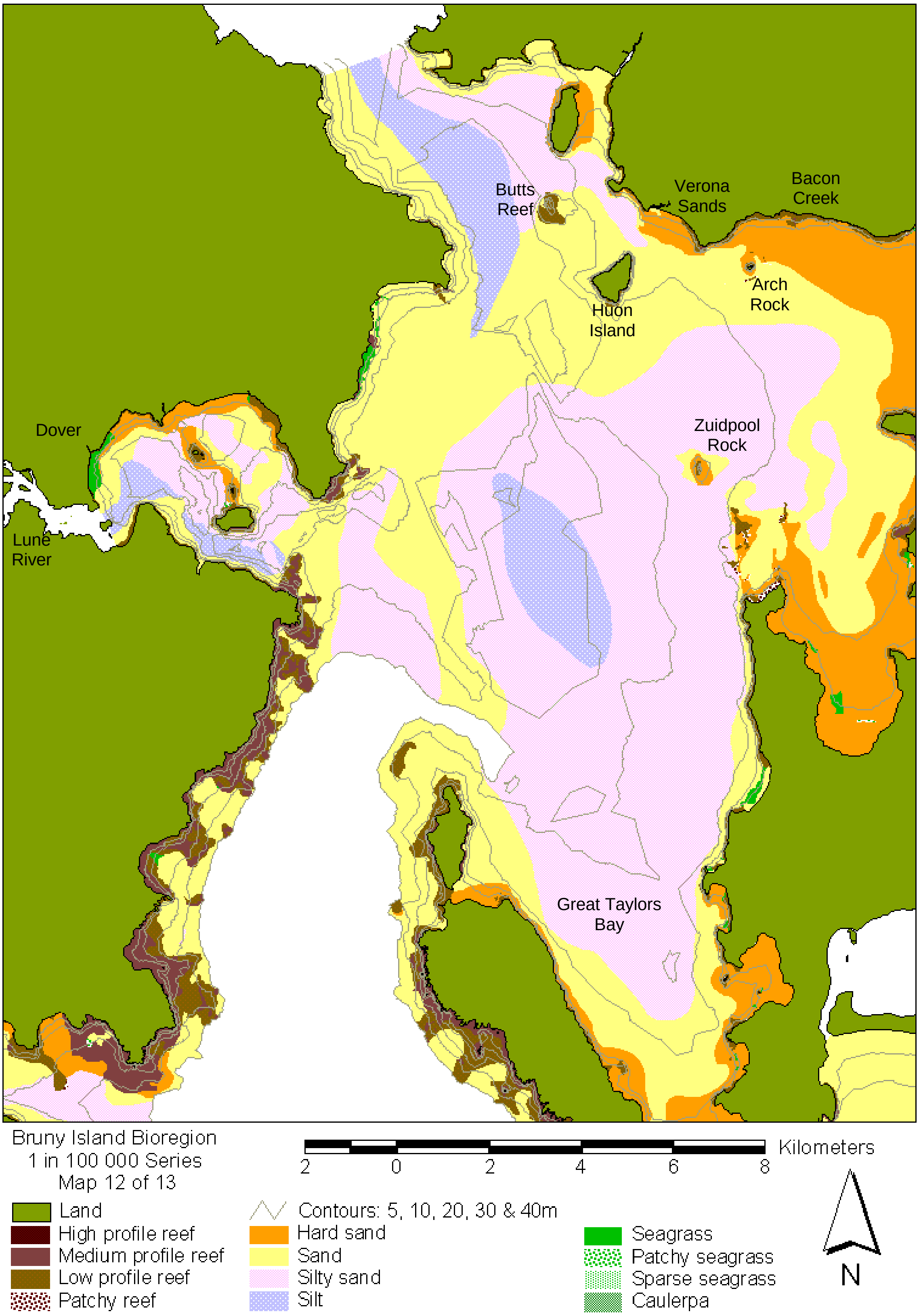

Fig. 19. Huon Section.

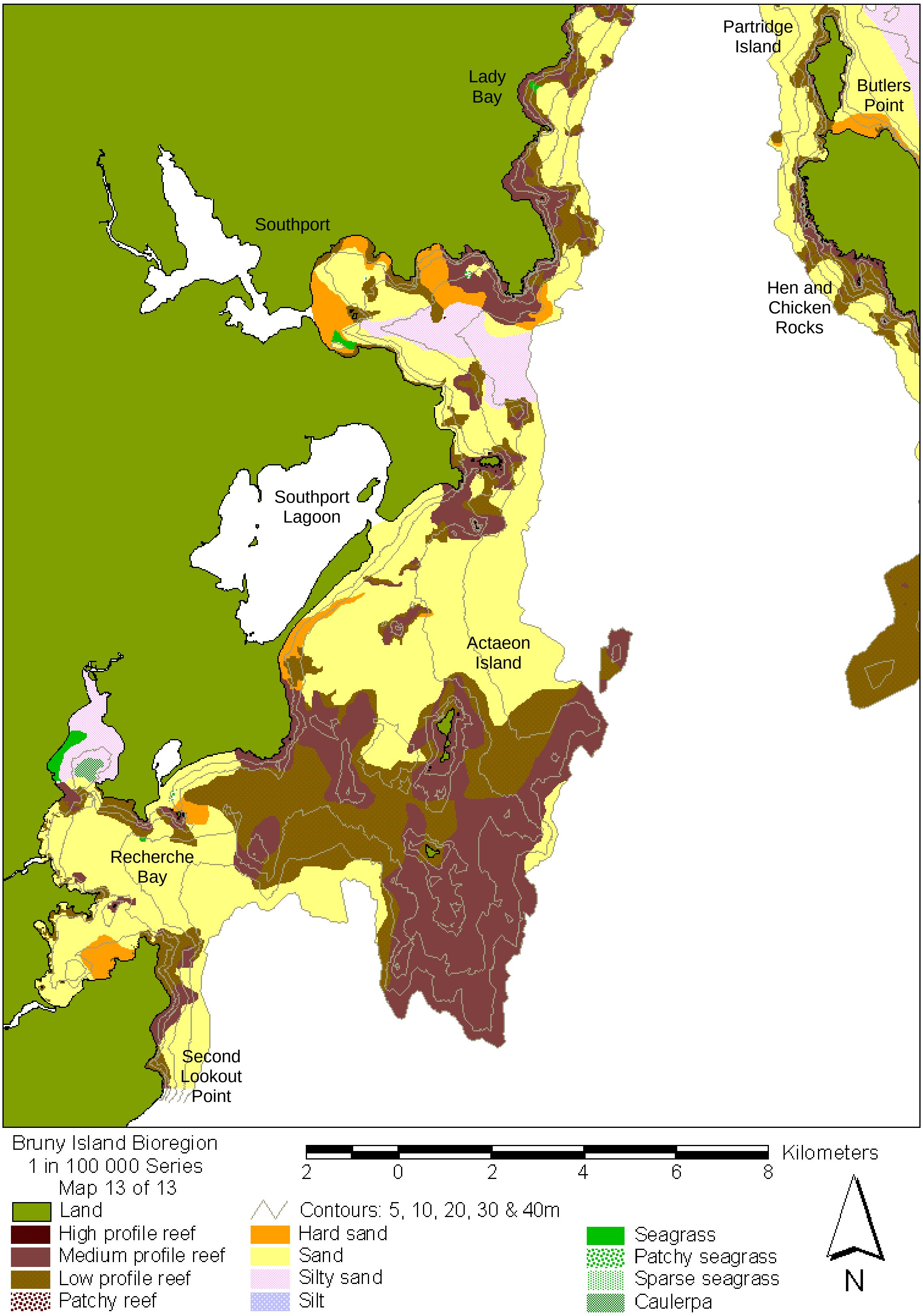

Fig. 20. Actaeon Section.

4.14 Habitat Area Calculations

The following tables summarise some of the major geographical attributes of this bioregion that have been determined from GIS analysis of the habitat mapping data. It should be noted that this summary is for coastal waters out to the 40 m depth contour only, and as a consequence is not a summary of the overall bioregion or of all State waters within the bioregion. In some locations such as the D'Entrecasteaux Channel, waters deeper than 40 m were mapped when they were surrounded by shallower regions, and some summary statistics include these outlying points.

The relative proportions of reef to sedimentary substrates within the Bruny Bioregion and adjacent Actaeon Island reef system is shown in Table 4. Not surprisingly, given that most reefs within this region are coastal fringe reefs, unconsolidated substrates comprise eight times more area than reef. Nearly one third of the reef area mapped is in the Actaeon coastal section, an area that lies immediately to the south of the nominal bioregion boundary.

Table 4. Breakdown by area (hectares) of reef and unconsolidated substrates in the Bruny Bioregion for each of the coastal sections from Mean Sea Level to the seaward 40 m depth contour. The Actaeon data is shown as an addition to the table as this area was mapped but is not included in the Bruny Bioregion.

COASTAL SECTION	REEF	UNCONSOLIDATED SUBSTRATES	TOTAL
Adventure	1609	14957	16567
Arthur	227	2031	2258
Betsey	2134	28982	31115
Cloudy	3502	4105	7607
D'Entrecasteaux	412	20420	20832
Frederick Henry	212	16460	16672
Huon	534	17705	18238
Norfolk	574	22594	23168
Peninsula	3461	10043	13504
Grand Total	**12665**	**137297**	**149961**
Actaeon	4550	4863	9413

The total reef and sand (unconsolidated substrates) have been further examined for their distribution with respect to exposure and depth (Tables 5 and 6). As a general rule, the exposed coast had substantially more reef than the sheltered coast at all depth ranges, reflecting the erosional and depositional nature of the differing exposures. In the most sheltered locations, reefs are primarily restricted to depths of less than 10 m, and even there they represent less than 8% of the substrate, with the remaining area made up of unconsolidated substrates. The limited area of reef that does extend below 10 m in sheltered locations is usually in areas of high current, such as the series of points that extend into the D'Entrecasteaux Channel from the western shore of Bruny Island. At the more exposed end of the scale, the proportion of reef habitat increases with depth, with the majority of reef being found at depths greater than 10 m. On most of the exposed coast in this region, the shoreline is either steep or is composed of cliffs, and underwater gradients are usually steep until depths of greater than 10 m are reached. At most exposures and depths, reefs made up between 5 to 8% of the substrate, reflecting the fact that most reefs within this area are restricted to a coastal fringe. These figures change, however, if the Actaeon Island area is included, as this area contains an unusually high proportion of offshore reef.

Table 5. Breakdown by area (hectares) for reef of differing wave exposure and depth ranges in the Bruny Bioregion from Mean Sea Level to the seaward 40 m depth contour. The Actaeon data is shown as an addition to the table as this area was mapped but is not included in the Bruny Bioregion.

REEF DEPTH RANGE	EXPOSURE INDEX 1	2	3	4	5	Total
0-5m	433	513	862	957	611	3377
5-10m	33	95	423	635	371	1558
10-20m	9	63	425	1288	801	2586
20-30m	0.5	0.5	108	1306	954	2370
30-40m	0.01		5	1142	1628	2775
40m plus				0.1		0.1
TOTAL	**476**	**672**	**1823**	**5329**	**4365**	**12665**

Table 6. Breakdown by area (hectares) for sand (unconsolidated substrates) for differing wave exposure and depth ranges in the Bruny Bioregion from Mean Sea Level to the seaward 40 m depth contour.

SAND DEPTH RANGE	EXPOSURE INDEX 1	2	3	4	5	Total
0-5m	6613	2927	2105	1800	84	13529
5-10m	2585	6471	3355	4199	96	16706
10-20m	4193	19447	8504	12372	443	44959
20-30m	2226	4651	5865	21302	1265	35309
30-40m	414	1765	1807	17788	3467	25240
40m plus	39	467	816	231		1553
TOTAL	**16070**	**35727**	**22453**	**57692**	**5355**	**137297**

When the distribution of reef and sand with depth is examined with the Actaeon Island area included (Tables 7 and 8), there is a substantial increase in the proportion of reef habitats within the exposure categories 4 and 5 at depths greater than ten metres.

Table 7. Breakdown by area (hectares) for reef of differing wave exposure and depth ranges in the Bruny Bioregion and adjacent Actaeon Islands mapping area, from Mean Sea Level to the seaward 40m depth contour.

REEF DEPTH RANGE	EXPOSURE INDEX 1	2	3	4	5	total
0-5m	441	514	1029	1052	705	3741
5-10m	35	96	517	810	587	2043
10-20m	9.1	62.5	633	1994	1747	4446
20-30m	0.5	0.48	205	1467	1953	3625
30-40m	0.01		9.2	1164	2187	3361
40m plus				0.07		0.07
TOTAL	486	672	2394	6487	7179	17216

Table 8. Breakdown by area (Hectares) for sand (unconsolidated substrates) for differing wave exposure and depth ranges (habitats) in the Bruny Bioregion and adjacent Actaeon Islands mapping area, from Mean Sea Level to the seaward 40 m depth contour.

SAND	EXPOSURE INDEX					
DEPTH RANGE	1	2	3	4	5	Total
0-5m	6785	2927	2553	1859	86.9	14210
5-10m	2631	6471	3804	4244	102	17252
10-20m	4193	19447	9473	12687	541	46342
20-30m	2226	4651	6329	21491	1580	36278
30-40m	414	1765	1920	18334	4155	26588
40m plus	38.9	467	817	231		1553
TOTAL	16289	35727	24895	58846	6466	142223

A breakdown of the basic substrate types into their constituents Reveals that of the reef areas, high profile and patchy reef areas appear to comprise a very low component (Tables 9 and 10). This should be interpreted with caution however, as the classification scheme was only an indication of differences, and some degree of overlap may occur between adjacent classifications, particularly with reef types. One notable feature is the difference in proportion of medium to low profile reef types between the sheltered and exposed coastal sections. Sheltered areas such as Norfolk, Huon and D'Entrecasteaux have substantially more low profile reef than medium profile reef.

For the unconsolidated substrates (Table 10), substrate type is strongly related to exposure. The most exposed locations, such as the Cloudy and Peninsula mapping units were dominated by sand and "hard sand", whereas the most sheltered locations such as D'Entrecasteaux and Norfolk had a high silt component. A notable feature is the high "hard sand" component in the D'Entrecasteaux Channel area, reflecting the extensive and high density coverage of scallop and screw shells found there, particularly in areas of high current flow.

Table 9. Breakdown by area (hectares) of the different reef types within the Bruny Bioregion for each of the mapping sections from Mean Sea Level to the seaward 40 m depth contour. The Actaeon data is shown as an addition to the table as this area was mapped but is not included in the Bruny Bioregion.

Reef	High Profile Reef	Medium Profile Reef	Low Profile Reef	Patchy Reef
Adventure	0.1	757	780	72
Arthur		94	130	3
Betsey	5	946	1109	74
Cloudy		1562	1930	9
D'Entrecasteaux		14	397	0.8
Frederick Henry		5	203	4
Huon		89	431	13
Norfolk	0.5	5	568	1
Peninsula	152	1818	1333	158
Total	**157**	**5291**	**6882**	**335**
Actaeon		2619	1930	1

Table 10. Breakdown by area (Hectares) of the different unconsolidated substrate types within the Bruny Bioregion from 0 to 40 m depth. The Actaeon data is shown as an addition to the table as this area was mapped but is not included in the Bruny Bioregion.

Unconsolidated Substrate	**Hard Sand**	**Sand**	**Silty Sand**	**Silt**
Adventure	1154	11640	2142	
Arthur	92	1095	619	
Betsey	1883	25678	1369	
Cloudy	3	4013	85	
D'Entrecasteaux	10657	2022	3490	3847
Frederick Henry	2055	13742	582	70
Huon	1329	6448	8401	1465
Norfolk	2354	2164	5088	4902
Peninsula	215	9196		
Total	**19743**	**76000**	**21775**	**10284**
Actaeon	374	3994	495	

Vegetated areas are found on unconsolidated substrates in all of the coastal sections examined (Table 11), however, the vast majority is restricted to the Norfolk section. Within this section the majority of the seagrass is found in Blackman Bay and most of the *Caulerpa* beds are found in Norfolk Bay. The low cover in other areas is primarily related to a lack of substrate at suitable depth and shelter, and in areas such as the Ralphs Bay and the D'Entrecasteaux Channel cover may be further restricted due light attenuation as a result of enhanced nutrient and sediment levels (Ralphs Bay) and tannins (D'Entrecasteaux Channel). An important point to note is that estuaries were excluded from this study for logistical reasons, and seagrass beds are known to exist in a number of these, including Pittwater, the Derwent, the Huon, Lune River, Cloudy Lagoon and Southport Lagoon.

Table 11. Breakdown by area (hectares) of the vegetated unconsolidated substrate types within the Bruny Bioregion from 0 to 40 m depth. The Actaeon data is shown as an addition to the table as this area was mapped but is not included in the Bruny Bioregion.

Vegetated unconsolidated substrates	**Seagrass**	**Patchy Seagrass**	**Sparse Seagrass**	***Caulerpa***
Adventure	19		3	
Arthur	20	206		
Betsey	51			
Cloudy	4			
D'Entrecasteaux	306	97		
Frederick Henry	11			
Huon	59	2		
Norfolk	4060	1004		3022
Peninsula	12		620	
Total	**4540**	**1309**	**623**	**3022**
Actaeon	40	6		22

5. Discussion

5.1 Providing adequate conservation in a complex bioregion

The Bruny bioregion contains a particularly complex and convoluted coastline with an abundance of islands, peninsulas and estuaries. On the outer coast, south facing shores are exposed to constant and often extremely large swells originating from gales in the southern ocean, while east facing shores are exposed to less frequent but occasionally large swells derived from easterly weather patterns in the Tasman Sea. Despite this exposure, the convoluted nature of this coastline also provides a substantial component of sheltered waters and associated habitats. A consequence of this complexity is that, unlike some other Tasmanian bioregions, it is difficult to define exactly what areas (in addition to the existing marine protected area (MPA) at Tinderbox and Ninepin Point) should be included in a MPA network to ensure it is fully compliant with the comprehensive, adequate and representative (CAR) definitions of ANZECC (1998b).

To try to represent every possible habitat combination in a legislated MPA network would lead to an overly complex and potentially unmanageable outcome. The most logical approach will be to develop a coastal habitat management strategy for this bioregion, based on the mapping presented here and in related studies (Rees, 1993; Jordan *et al.,* 2001) and the results of biological surveys (*eg.* Edgar *et al.,* 1995, Moverley and Jordan, 1996, Jordan *et al.,* 1998, Edgar *et al.,* 1999, Murphy and Lyle, 1999). This strategy, in combination with an MPA network, would ensure habitats and unusual or unique areas gain a high level of protection. Such a strategy could also be used to protect critical habitats for some of the species that are known to be endemic to this bioregion (Edgar *et al.,* 1995).

The sheltered cool-temperate waters of this bioregion provide refuge to a number of endemic fishes, invertebrates and macroalgae, giving this bioregion the highest localised level of marine endemism in Australia. Several of these species (the spotted handfish *Brachionichthys hirsutus* and the seastars *Marginaster littoralis, Patiriella vivipara* and *Smilasterias tasmaniae*) are on the Tasmanian threatened species list and protection of their critical habitats may be essential for their long term survival. In a conservation assessment of Tasmanian estuaries, Edgar *et al.,* (1999) recommended that in addition to protecting estuaries of conservation significance within MPAs, habitats with high conservation significance in estuaries also need to be given strong habitat protection if estuarine species and ecosystems are to be adequately conserved. This recognition that habitat protection can help achieve conservation goals needs to be extended to coastal and marine systems.

If a habitat protection strategy was developed, the process of selecting MPAs could focus on the more manageable task of protecting representative examples of habitats typical of the bioregion as well as unique habitats that may be particularly vulnerable to disturbance. Ideally, if MPA locations are to be nominated they should fulfil a number of selection criteria recognised by the Tasmanian Marine Protected Areas Strategy (2001). These include representativeness, size and complexity. Nominated areas should be sufficiently large, with appropriately chosen boundaries to adequately protect populations of the species they are intended to represent. For many mobile but resident reef fishes this may include the entire home reef (as many resident species rarely leave the home reef) (Barrett, 1995), or where the reef is large and continuous, sufficient coast that the proportion of the population moving across MPA boundaries is not significant. Preferably, locations should also be identified that offer the possibility of protecting a range of distinct habitats and associated species assemblages within each MPA, increasing the number of habitats and species represented (local biodiversity) while minimising the total number of MPAs needed to afford protection. Additional selection criteria include community acceptance and public access, if the maximum conservation benefits are to be obtained from these areas. The information presented here substantially aids this selection process.

Each habitat type identified and mapped in this study (see Table 12) has its own distinctive biological assemblage and community structure, and these habitat categories can be interpreted as fine-scale ecosystems for the purposes of implementing the NRSMPA under the ANZECC (1999c) guidelines. Using information currently available, the characteristic features of each of these ecosystems can be readily defined. If the range of habitats shown in Table 12 are included within a reserve system, the system will be comprehensive within the definition of ANZECC (1999c).

5.2 The Bruny Bioregion – A broad conceptual model

The biota of the Bruny Bioregion is influenced at a local scale by a wide range of physical characteristics such as ocean currents, exposure, aspect, depth, rock type and structural complexity, current strength, sediment type, nutrient levels, turbidity, salinity, temperature and seasonal and interannual variation. These factors and others structure the biotic community in such a way that no two sections of coast are identical. However, there are several features that broadly characterise the bioregion including a significant component of sheltered waterways and embayments (related to the presence of drowned river valleys), a substantial influence of sub-Antarctic water, and an extremely narrow continental shelf (Edgar *et al.,* 1995, ANZECC, 1998a). Representative features of this system therefore include a range of sheltered habitats and cool-temperate species assemblages.

At an intermediate level, freshwater discharge from the region's two large river systems, the Derwent and Huon, substantially structures the biota such that assemblages can be characterised by the influence of one, both or neither of these. Clear oceanic water influences much of the outer coast (oceanic water), including Southport to Dover, much of the outer Bruny Island coast, and the Tasman Peninsula anticlockwise from Nubeena to Maria Island. On these coasts macroalgae usually extends to at least 30 m depth. The Derwent River discharges into Storm Bay and appears to substantially influence water clarity from North Bruny Island, through Frederick Henry Bay, to Nubeena (Derwent water). The altered water clarity and associated nutrients, plankton and sediments causes a compression in species succession with depth and changes in species assemblages (such as the replacement of *Phyllospora* with *Lessonia*) relative to those at equivalent locations on clear water coasts.

Near the mouth of the Huon River the coastline is strongly influenced by tannin stained river water originating in peat soils in southwest Tasmania (Huon water). This water strongly attenuates light, resulting in a substantial compression of species succession with depth, a very high red algal species diversity, and characteristic invertebrate assemblages. This influence extends from the river to Huon Point in the south and extends eastwards past Huon Island and Arch Rock. Beyond this zone, mixing within the water column generally dilutes the magnitude of this influence. With inputs from both the Huon and Derwent Rivers, the D'Entrecasteaux Channel forms an intermediate zone with greater light penetration than the

Huon water but less than oceanic water (Channel water). There is moderate species compression with depth in this zone, resulting in a high diversity of filter feeding invertebrates in shallow waters, particularly in areas of high current flow. Continuous gradients occur between and within these “zones” and many areas show intermediate characteristics.

Of the mapping units discussed here, Actaeon, Adventure, Arthur, Cloudy, Peninsula, and the southern half of the Huon are influenced by oceanic water. The northern section of the Huon mapping unit is primarily influenced by Huon River water. The D’Entrecasteaux section is essentially all Channel water, while Betsey, Frederick Henry and the northern section of Adventure are influenced by Derwent water. The Derwent influence possibly extends to Cape Queen Elizabeth on North Bruny Island, where *Lessonia* is reported to replace *Phyllospora* (Edgar, 1984a). While riverine inputs are a strong structuring process within this region, other processes are also present. Additional features operating over the scale of this bioregion include a decrease in exposure from north to south and an increasing influence of East Australian Current waters from south to north.

The range of habitats encountered within each mapping section within the bioregion, as well as characteristic and special features is summarised in Table 12. Habitats are described on broad physical features known to have a substantial influence on the biological community present (Edgar, 1984a, Last, 1989). These include exposure, depth, substrate type (reef, sand, silt) and biotic component (in the case of seagrass, and extensive areas of *Caulerpa*). A Victorian study found rock type has a minor influence on community structure compared to factors such as depth, exposure, substratum structure and coastal region (Edmunds *et al.*, 1998). For this reason rock type (geology) was not included in the habitat characterisation of the Bruny Bioregion. Substratum structure (reef complexity) influences the availability of refuges and therefore species diversity, and in the mapping of the Bruny Bioregion this component was mapped as reef profile. Some rock types have characteristic weathering patterns and sedimentary rocks form marine cave systems more readily than other rock types, however it is important not to generalise more broadly. All rock types produce a range of structural complexity, and it is this range that structures the biotic community, not the type of rock itself.

Table 12. Summary of habitats occurring within each mapping unit (coastal section) within the Bruny Bioregion.

Mapping unit and (water system)	Broad Habitats	Characteristic features	Special Features
Actaeon (oceanic)	Exposed reef and sediments (sand) Low exposure reef and sediments Silty sand	Extensive reef formation at medium to high exposure with broad representation of depths to 40 metres. Exposed sediments, including beach. Two extensive embayments (Recherche Bay and Southport) contain sediments and some limited reef. Silty sand is found at some locations within the embayments.	Extensive reef development at medium to high exposure, with broad depth representation.
Cloudy (oceanic)	Exposed reef and sediments (sand)	Substantial reef cover, mostly at high exposure, with good representation of reef at depths greater than 20 m, and coastal reefs extending to depths greater than 60 m. Exposed sediments, including beach formations.	High component of deep reef and associated invertebrate communities.
Adventure (oceanic)	Exposed reef and sediments (sand)	Reef and sediments of medium to low exposure, with limited offshore extension of most reef areas. Occasional offshore reef patches. Gravel patches commonly found offshore.	Large *Macrocystis* forests on reef along North Bruny coast.
Betsey (Derwent)	Exposed reef and sediments (sand)	Limited cover of reef at low to high exposures, most coverage at medium to high exposure. Good coverage of sediments at all exposures. Extensive areas of gravel and shell distributed throughout region. Outcropping reefs in 20-50 m. Atypical macroalgal community with *Lessonia* replacing *Phyllospora*, compression of maximum depth of algae including *Durvillaea*.	Offshore reef patches. Atypical macroalgal community
Arthur (oceanic)	Exposed reef and sediments Sheltered sediment (sand) and reef Silty sand Seagrass	Moderate to low cover of reef at moderate to low exposures. Little reef beyond 20 m. *Macrocystis* common on northern reefs. Large cobble/gravel beds on the eastern side of the Port. Good sediment cover including beaches. Isolated sheltered reef patches with good coverage of sheltered sediments including beaches Extensive component of silty sand including deep (to 50 m), to very shallow. Moderate cover of patchy seagrass in shallow western and northern embayments.	Broad representation of habitats within small geographical area. Deep silty sand sediments in middle of bay.
Peninsula (oceanic)	Exposed reef and sediments (sand)	Moderate to high representation of reef and sediment at moderate to high exposure and some representation of low exposures. A wide depth range of all categories, particularly of reef greater than 20 m. Substantial component of deep reef and sediments, with some reef extending to 100 m. Extensive *Macrocystis* forests are found in partially sheltered bays (Fortescue and Lagoon) and coastal areas.	Deep reef systems with diverse invertebrate communities. Extensive *Macrocystis* forests.

Table 12. Continued.

Mapping unit and (water system)	**Broad Habitats**	**Characteristic features**	**Special Features**
Norfolk (Derwent)	Sheltered reef and sediments (sand) Silty sand Silt Seagrass *Caulerpa* spp.	A limited extent of sheltered to very sheltered reef, extending no deeper than 5-10 m in Norfolk Bay and 2 m in Blackman Bay. Some coverage of sand but most sediments in finer categories. An extensive coverage of silty sand, particularly at depths between 5-15 m. Extensive coverage in Norfolk Bay at depths greater than 15 m. Extensive coverage at depths from 0-10 m, particularly in Blackman Bay. Notable abundance of *Ruppia megacarpa* in shallower areas of Blackman Bay. Dense *Caulerpa* beds are found at depths of 10-15 m within Norfolk Bay.	Extensive seagrass coverage, including presence of *Ruppia*. *Caulerpa* beds. High silt component.
Frederick Henry (Derwent)	Exposed reefs and sediments (sand)	Low coverage of low to moderately exposed reef. Little offshore extension and maximum depths around 15 m. Shell and gravel patches common. Atypical algal community with substantial depth compression possibly due to high water turbidity. *Durvillaea* mostly absent and *Phyllospora* replaced by *Lessonia*. Invertebrates below 15 m. Extensive sediment coverage, including beaches.	Compression of algal depth ranges. High water turbidity. High beach component.
D'Entrecasteaux (Channel)	Sheltered reefs and sediments (sand) Shells Silty sand Silt Seagrass	Limited extent of sheltered to very sheltered reef, usually shallow (to 5 m), occasionally to 25 m on points or offshore outcrops. General compression of macroalgal assemblages due to tannins and other freshwater influences. Invertebrate communities often dominant below 7-10 m, with notable assemblages in areas of high currents. Limited extent of sand (mostly grading to silt or covered with shells). Shown as hard sand on map, extensive areas of high density shell accumulations cover a substantial area in the mid Channel. Silty sand coverage is moderate in 10-15 m in the upper and mid Channel. Silt covers an extensive are of the mid to upper Channel, particularly at depths below 15 m. Silt extends to depths of 50 m in a deep channel (drowned river valley) through this area. A limited extent of seagrass is found scattered along the western shore of the Channel and North West Bay. Abundance is possibly limited by low water clarity.	Compression of algal depth ranges. Freshwater influence from Huon and Derwent Rivers. Extensive deep silt coverage. Shelly substrates abundant. Shallow water invertebrate assemblages, notably in areas of high current. Deep water fine sediments abundant.

Table 12. Continued.

Mapping unit and (water system)	**Broad Habitats**	**Characteristic features**	**Special Features**
Huon (Huon)	Exposed reef and sediments (sand)	Moderate to high coverage of moderately exposed reef and sediments in southern (oceanic) section to depths greater than 30 m. In northern section (tannin), low to moderate coverage of low exposure reef (to 15 m) and sediments (to 30 m). Atypical algal community on reef in the northern section due to strong tannin influence from Huon River causing depth compression of algal assemblages. Invertebrate communities usually dominant below 10 m, with assemblages highly distinctive of region. Very high red algal diversity.	Tannin modified system in northern section. Strong algal depth compression. Very high red algal species diversity.
	Sheltered reef and sediments (sand)	A limited extent of sheltered reef and sediments is found in the lower Huon River region (tannin) and in Port Esperance (oceanic). Most reef is very shallow, and sand grades to silty sand beyond 15 m.	
	Shells	Shown as hard sand on map, shell dominated substrates extend into this region from the mid Channel. Arch Rock is near the western limit of this distinctive substrate.	Distinctive invertebrate assemblages extending into shallow water.
	Silty sand	An extensive area of silty sand is found in the Huon/lower Channel region, extending from 10 to 30 m in places. Also in sheltered waters of Port Esperance.	Deep water fine sediments present.
	Silt	Silt is found in deep water associated with the Huon River and drowned river valley areas (from 30 to 45+ metres). Extends to shallower waters in mid Huon estuary and in Port Esperance.	Extensive *Macrocystis* forests on reef between Southport and Dover.
	Seagrass	Seagrass is rare, possibly due to tannins, turbidity and latitude. Small patches in sheltered locations, notably Port Esperance.	

In the absence of detailed biological studies of all assemblages at all locations and depths within the bioregion, initial MPA planning for this complex bioregion requires the assumption that physical attributes mapped here can act as surrogates for biological diversity. The biological descriptions given for each mapping unit in the results section give a broad overview of the dominant macroalgal community present and an indication of the influence of exposure and depth at that scale, but this is insufficient to identify small differences. Planning at this broad habitat scale will certainly lead to some species assemblages being missed, including assemblages with unique features and threatened species. However, given a good understanding of the processes that structure communities and selecting areas of suitable size across the broad range of habitats and systems identified, MPA locations could be chosen to provide a high degree of representation (Ward *et al.*, 1999).

While sufficient information exists within existing literature (*eg.* Edgar, 1984a, Last, 1989, Jordan et al. 1998) and Tasmanian research organisations to provide a detailed characterisation of the biota of all habitat categories identified here, it is beyond the scope of this present study to do so. It is recommended that a conceptual model of this detail be developed to assess the adequacy of any formal MPA proposals to fulfil CAR principles.

Ideally, areas suggested as being suitable for MPA locations would include representatives from all the broad habitat categories listed in Table 12, including the range of characteristic features for that habitat type. They would also include areas identified as being unique or characteristic of an area. The most suitable locations are those that include a wide range of habitats within a relatively small geographical area. The following discussion suggests areas on this basis, as one of the primary aims of this study was to identify potential MPA locations within the bioregion. A detailed breakdown of the area (ha) of each habitat in each suggested coastal section is not given as specific boundaries are not identified. A GIS capability has been developed to calculate these areas at the appropriate stage of the planning process. The 1:100,000 scale maps can be used to gain an indication of the relative components included, and the 1:25,000 scale maps give finer detail (Appendix 3). The Actaeon coastal section was not included in this discussion as this area is not within the currently defined boundaries of the Bruny bioregion. Details of this area were surveyed as it includes many similar and overlapping features to the adjacent coastal sections and if the bioregional boundaries were reviewed at some stage, it is possible that this area could at least partly be included within the Bruny region.

As stated above, few locations offer the possibility of representing a significant component of the habitat diversity in the Bruny bioregion within a single MPA. This substantially limits the range of options available for selecting individual areas with broad representation of habitats and species assemblages. Where possible, areas have been suggested here that incorporate a range of habitats and are known to reflect the characteristic features of the region. Fragmentation of protected areas into special purpose zones such as “protection of highly exposed reef to 40 m” has been avoided as the possible combinations of suitable areas at that scale are too numerous to discuss here. The mapping information presented at the 1:100,000 (see Figs. 8-20) and 1:25,000 scale (see Appendix 3: CR-ROM) is sufficient to facilitate discussion of alternative proposals at this scale should they arise.

5.3 Representation of ocean influenced waters.

The range of suitable locations capable of representing a broad range of ocean influenced habitats is particularly limited in the Bruny Bioregion, with most locations containing only a small subset of habitats at the scale of an individual MPA. The notable exception is the section of coastline extending from Carnarvon Bay in Port Arthur to Remarkable Cave. This coastline includes a good representation of high exposure reef between Remarkable Cave and West Arthur Head, medium exposure reef and beach from West Arthur Head to Standup Point, low exposure reef and beach from Standup Point to Point Puer, and very sheltered reef and beach in Carnarvon Bay. An MPA at this location would give a reasonable representation of exposed coastal reef and sediments, including reef to depths of 40 m. It would also include a component of sheltered substrates and seagrass in Carnarvon Bay. Although a popular fishing location, the inclusion of part of Canarvon Bay would substantially enhance the range of habitats protected. One of the key features of this area is the presence of a *Macrocystis pyrifera* forest that often extends from Standup Point to Safety Cove. As these forests are a characteristic feature of southeastern Tasmanian waters, and provide a distinct habitat structure, the selection of representative MPA locations in exposed waters should focus on including relatively stable populations of this species.

Exposed coasts. Two alternative locations that offer protection to *Macrocystis* forests and representation of a variety of exposed habitats are Fortescue Bay and Lagoon Bay. A protected area including the northern half of Fortescue Bay and the coastline to O'Hara Bluff, and extending to one kilometre offshore in the waters outside of Fortescue Bay, would protect a range of habitats from the sheltered waters of Canoe Bay to the exposed outer coast. Fortescue Bay has one of the most stable and highest density *Macrocystis* forests in southeastern Tasmania, and is an ideal location for protecting a representative *Macrocystis* forest with its associated habitat. At The Thumbs, a small island group at the mouth of Fortescue Bay, reef extends into 50 m, giving a good representation of reef depths within this exposed habitat. While the extent of sheltered water is limited to Canoe Bay where a small seagrass bed is located, the continuous gradient from shallow sheltered to exposed and deep within this area contributes substantially to the overall high level of species diversity found within this section of coast. As well as protecting an area of high species diversity, this proposal has the additional advantage of adjoining an existing coastal National Park.

An MPA at Lagoon Bay extending from Humper Bluff south of Lagoon Bay to Two Mile Beach and including all reef around Vischer Island would protect unconsolidated sediment and reef habitats of medium to low levels of exposure. These include beaches at Lagoon Bay and Two Mile Beach, sediments and reef ranging to 40 m depth, and a number of small islands. Like Fortescue Bay, Lagoon Bay usually contains dense beds of *Macrocystis,* and the extensive area of reef between the 10 and 20 m depth contours within this bay offers the possibility of protecting an area of optimal habitat for this species.

Additional alternative exposed coast locations include:

- Adventure Bay Beach to Cape Conella (mostly highly exposed coast with little representation of reef with low exposure or shelter).

- Southport Beach to Lady Bay (good representation of low to moderately exposed reef and sediments to 40 m, including extensive *Macrocystis* forests, but no representation of sheltered habitats).

- Labillardiere Peninsula from The Hen and Chickens to Butlers Point, including Partridge Island (good representation of moderate to highly exposed reef and sediments to 40 m, grading to low exposure. Some representation of sheltered reef and sediments, with the additional advantage of being adjacent to a national park).

Sheltered coasts. While the previous suggestions canvass options for protecting as wide a range of representative habitats as possible in oceanic influenced waters, they substantially under-represent sheltered locations, particularly those with dense seagrass beds. Options here are somewhat constrained by the presence of existing marine farm (shellfish) leases, particularly in Blackman Bay, the location with the greatest extent of seagrass. Of the available coastline, the Lime Bay area, within Norfolk Bay, appears to be the most notable location. This area contains a mix of sheltered beach and sandstone platform, with offshore seagrass (*Heterozostera*) and *Caulerpa* beds. With a suitable offshore extension, an MPA at this location could include a component of silt habitat in the relatively deep waters found off Whitehouse Point. Marine farm leases two kilometres to the west of Lime Bay limit the nominal western boundary of a MPA here, although a protected zone could extend from one kilometre west of Lime Bay eastwards to Ironestone Point or to Plunkett Point. This area is bounded by National Park and offers the opportunity to integrate marine and terrestrial parks.

Alternative locations exist further to the south and east of Plunket Point where sheltered habitats without existing marine farms continue to Sympathy Point, near Taranna. These habitats are a similar mix of sheltered beach and sandstone platform with offshore seagrass and *Caulerpa* beds extending to silty sediments. An appropriate sized protected area could be located anywhere along this section of coast. The disadvantage of this area over the Lime Bay proposal is that it does not have the additional benefit of being adjacent to existing National Park.

Additional alternative sheltered coast locations include:

- Dunalley Beach to Daltons Beach (includes extensive seagrass and beach, with some fringing reef and sandy sediments. Little coverage of finer sediments or habitats below 10 m).

- Chronicle Point to Flinders Bay (includes sandy beaches, some fringing reef and small seagrass beds, and extensive coverage of silty sand to 15 m).

5.4 D'Entrecasteaux Channel (Channel water)

Currently there is some limited protection of sheltered habitats in the D'Entrecasteaux Channel provided by the Tinderbox marine reserve, where sheltered shallow reef and sediments extend one kilometre from Tinderbox Beach to the western boundary of the reserve. It is unlikely that this sheltered component could be increased as a marine farm has recently been established in close proximity to the existing reserve boundary. If the representation of Channel habitats is to be increased, this process needs to take into account the influence of extensive coastal development in North West Bay, and the abundance of marine farm leases in the D'Entrecasteaux Channel. While there may be many suitable locations, no obvious ideal location was identified by the mapping process and a suitable location may be best identified by consultation with stakeholder groups using the mapping information presented here and any existing biological data.

The long points extending into the D'Entrecasteaux Channel from the western shore of Bruny Island (*eg.* Simpsons and Roberts Points) are subject to strong currents at their extremities and extend into deeper waters than most locations, providing habitat for a range of communities not commonly found elsewhere. Away from the end of the points currents are usually reduced and typical sheltered communities are found. Protection of these locations would offer the best opportunity to incorporate representative and unusual features, although there may be conflicting interests as these areas contain undeveloped marine farm leases. A protected area at Simpsons Point would include representation of the unusual invertebrate communities found on sheltered high current substrates in the D'Entrecasteaux Channel. These are usually found on reef margins and shelly substrates although one particularly outstanding association was identified on a small reef adjacent to the tip of Simpsons Point. Ideally, a protected area would include approximately 3 km of coast on the eastern and western shores of the point. This would protect shallow reef and shelly substrates (to 15 m) in high current areas on the western shore, and similar but low current substrates on the eastern shore.

A protected area extending from the northern shore of Roberts Point to Apollo Bay would include a small component of reef (to 25 m) in strong currents, in addition to low current reef extending into Apollo Bay. This location includes an extensive component of silt that ranges from 5 m in Apollo Bay to depths greater than 30 m off Roberts Point.

5.5 Huon River waters (tannins)

The tannin stained waters associated with the outflow of the Huon River produce distinct habitats that are characteristic features of this bioregion. The Ninepin Point Marine Reserve currently includes habitats in this area ranging from low exposure reef (to 15 m) at the end of the point to more sheltered reef (5-7 m), particularly at the eastern boundary, and a mix of sandy and shelly substrates. Because of the small size of this reserve, many resident reef fishes are currently lost across the boundary to adjacent fished areas, limiting the effectiveness of the area to fulfil the conservation role intended of a representative MPA (Edgar and Barrett, 1999). By extending the boundaries of this reserve, the conservation significance would be considerably enhanced, and would better represent several of the habitats characteristic of this area. Extensions of the western boundary to the beach at Verona Sands, and the eastern boundary by a similar distance to Bacons Creek or Mountain Creek, (including Arch Rock) would improve the effectiveness of this reserve by substantially increasing the component of sheltered reef and sediments given protection. This would also increase the protection of the invertebrate assemblages below the algal zone, as Arch Rock has more deep reef (to 15 m) than Ninepin Point.

An alternative option to the extension of the Ninepin Point Reserve is to include Butts Reef as an annex to the existing reserve. Butts Reef is located three kilometres to the northwest of Ninepin Point, and is an isolated offshore reef at the mouth of the Huon River. This reef has many similar characteristics to Ninepin Point and could be effectively protected by a boundary located at some distance seaward of the outer reef boundary. Butts Reef is characterised by a low exposure reef, extending to 15 m, where it is surrounded by sandy sediments. Situated at the mouth of the Huon River it is subject to a stronger tannin influence than Ninepin Point and therefore invertebrate communities become dominant at shallower depths. Butts Reef has an extensive coverage of deep reef invertebrate assemblages. Adjacent to the western side of the reef is the deep Huon River channel filled with silty sand and sediment. These habitats could be included in a suitable offshore extension.

5.6 Derwent River waters

Derwent River water extends throughout Storm Bay and Frederick Henry Bay, and influences a wide range of habitats and species assemblages. In the absence of detailed biological surveys it is difficult to determine the extent of this influence on exposed open coasts, however the replacement of the exposed water macroalgal species *Phyllospora comosa* by *Lessonia corrugata* in much of this region may be one influence of this water. Currently there are two protected areas within this area of influence, one is a no-take marine reserve at Tinderbox, the other is a scientific reserve with some fishing allowed at Crayfish Point, Taroona. At Tinderbox the habitats currently protected include sheltered to low exposure reef and sediments, typical of those found in the Derwent estuary and D'Entrecasteaux Channel. In a similar manner to the Ninepin Point marine reserve, Tinderbox is ineffective in protecting reef populations due to its small size and fishing occurring on its western boundary. An extension of the western boundary to at least Lucas Point would provide a more effective buffer for resident reef fishes than currently exists at the western end of this reserve, in addition to including a high density *Macrocystis* forest that is currently not well represented in the existing reserve. This would also add a significant component of low exposure reef (to 15 m) and sediment to the reserve, in addition to sponge dominated assemblages on the deeper reef margins at Piersons Point.

Upgrading the protection of the Crayfish Point reserve to no-take status and extending its boundaries to Taroona Beach and the middle of Hinsby Beach would give effective protection to the resident reef fishes within this reserve, and include representation of low exposure shallow reef (to 7 m) and sandy sediments. With a suitable offshore extension this location could also include silty sand habitats within the Derwent River channel.

Sheltered locations under Derwent influence include the sheltered component of the existing Tinderbox reserve (an overlapping area with the D'Entrecasteaux Channel habitats) and Norfolk Bay (an overlapping area discussed with potential locations for sheltered oceanic locations). Potential sheltered locations exist within the Derwent estuary, although these are impacted by heavy metals, sedimentation and urban development. The entire Derwent Estuary has been recently mapped at the 1:25,000 scale (Jordan *et al.*, 2001), and this information could be used to identify potential sheltered locations within the Derwent if they were required.

5.7 Estuaries

While estuarine lagoons and some specific estuaries (eg. Pittwater) were not examined in this study due to a recent conservation assessment (Edgar *et al.*, 1999), they do form a continuous link with the marine habitats considered here. If the recommendations in that report are adopted they will lead to additional protection of sheltered habitats within this bioregion. Edgar *et al.*, (1999) recommended full protection of Southport Lagoon and protection of habitats within Cloudy Bay Lagoon and the Catamaran and D'Entrecasteaux River estuaries. If adopted these recommendations will add to the degree of protection given to habitats within this bioregion.

5.8 Additional habitats

This study was limited to coastal waters from the low tide mark to depths of 40 m. As such it has not examined deeper offshore areas, or all estuarine areas. Deep-water habitats were logistically difficult to survey and were beyond the scope of this project. Very little is known of the distribution of these habitats in Tasmanian waters, and at some stage they too should be adequately surveyed so that representative locations can be identified and protected. At present insufficient information is available for the identification of any such locations.

While coastline above the low tide mark was not examined, this area can generally be considered to be a marine influenced extension of the habitats mapped here (the littoral fringe), and should be included in any MPA proposals, at least to the most inland extension of extreme high tides or seaspray. Where possible, potential MPA locations have been suggested where they would integrate with an existing terrestrial national park or conservation reserve providing conservation links between terrestrial and marine systems.

The biota of estuarine areas in the bioregion is more strongly determined by the physical characteristics within the estuaries than bioregional processes (Edgar *et al.*, 1999). Estuaries were therefore recommended for conservation on the basis of their representativeness of estuarine "types" and their pristine status, rather than on a bioregional basis. It is likely that if adopted, these recommendations will be sufficient to provide adequate representation of Tasmanian estuaries in a MPA network. Estuaries are particularly vulnerable to anthropogenic degradation and an overall habitat management strategy of the type suggested in this report is needed to ensure the less protected areas are sufficiently conserved as well.

5.9 Conclusions

This study provides the necessary information required by planning agencies involved in the selection of MPA sites within the Bruny Bioregion. The detailed mapping presented here is an essential tool needed to determine alternative MPA options in a ecologically complex bioregion, to select appropriate boundaries and to ensure protected areas are comprehensive, adequate and representative. Suggestions for potential MPA locations were objectively derived from the mapping results in a process aimed at maximising the habitat diversity for each location. It is recognised that numerous alternative compromises exist, and the mapping presented here is intended to facilitate discussion of all possibilities.

The broad nature of these surveys meant that other than dominant macroalgae and seagrasses, unique features at the species, population or community level could not be readily detected. Where features involve obvious species or communities such as the Norfolk Bay *Caulerpa* beds or the invertebrate communities of the D'Entrecasteaux Channel they have been included. Substantial additional biological information will need to be collated, however, if the protection of small scale unique features or species distribution is to be an important component of the MPA planning process. Much of this information already exists but requires analysis within an MPA framework. As more biological information becomes available within this region, important and unique features may be identified that are not included in the present or future MPAs and will require some level of protection. This level of protection will often not require MPA status to be effective. Sufficient information now exists for the development of a habitat management strategy and this should be developed concurrently with the MPA planning process. A habitat management strategy, together with MPAs and appropriate fisheries and land use management, would provide the flexibility required to conserve marine and estuarine biodiversity within the Bruny Bioregion in the long term.

6. Acknowledgments

The authors wish to acknowledge the many people who have made significant contributions to this project. They include the Land Information Bureau of DPIWE for access to aerial photographs and coastal maps and the DPIWE GIS section for the use of computer facilities for the scanning and rectification of coastal photographs. Comments on the manuscript were kindly provided by Peter Bosworth, Doug Nichol, Colin Buxton and Karen Edyvane. Rob Driessen developed the *SeaBed Mapper* software for this project, and provided excellent technical support with the integration of software and hardware.

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Appendix 1. Catalogue of aerial photographs used.

1229-145	Actaeon Island
984-2	Arched Island
984-169	Badger Cove
1249-100	Bay of Islands
1199-162	Bellettes Bay
1229-145	Bennetts Point
1229-145	Big Lagoon Beach
1271-95	Birchs Bay
1271-94	Birchs Point
1262-69	Blackman Bay
1026-61	Blight Rocks
984-61	Boreel Head
1199-162	Breaknock Bay
984-169	Brother and Sister Rocks
1176-167	Bull Kelper Reef
1307-1	Canoe Bay
1249-100	Cape Conella
1233-97	Cape Deliverance
1233-25	Cape Deslacs
1260-30	Carnarvon Bay
1176-43	Cascades Bay
1026-59	Cemetry Bluff
1026-59	Coal Point
1026-61	Coal Point
1262-64	Connellys Bay
1245-95	Cookville
1248-04	Creeses Mistake
1186-91	Cremorne
1199-162	Daltons Beach
1271-94	Deadmans Point
1154-108	Deer Point
1262-64	Dorman Point
1262-66	Dorman Point
1199-162	Dunalley Beach
1199-108	Eagles Beach
979-99	East Partridge
984-169	Elbow Hill
1176-43	Eli Point
1123-2	Eliza Point
1271-96	Fleurtys Point
1307-1	Fortescue Bay
984-152	Fortescue Bay
1189-20	Fryingpan Point
1262-66	Fulham Beach
1199-162	Fulham Island
1262-66	Fulham Point
1150-186	Garden Island
1150-186	Garden Island Point
1150-186	Garden Island Sands
1176-43	Glenila Point
1233-72	Goats Lookout
1249-100	Grays Bluff
1262-64	Gypsy Bay
1176-43	Halfway Bluff
984-1	Haulage Bay
1176-43	Impression Bay
1233-97	Iron Pot
1271-94	Ketteing Point
1271-94	Ketteing Point
1199-162	King George Island
1154-108	Lagoon Beach
1154-108	Lime Bay
1229-145	Little Lagoon Beach
1271-94	Little Oyster Cove
1271-94	Little Peppermint Bay
1154-106	Lobster Point
1189-18	Long Bay
1260-30	Long Bay
1249-182	Long Bay Shoal
1248-04	Lory Point
1248-04	Low Point
1076-100	Mabel Bay
984-1	Mangana Bluff
1256-124	Maydena Bay
1256-124	Mays Hill
1256-124	Mays Point

1262-70	North Bay
1248-04	North Passage Point
1184-58	North West Bay
1261-207	North West Head
1176-43	Parkinsons Point
984-169	Parsons Bay
979-97/9	Partridge
1229-145	Pebbly Bight
1245-95	Penguin Island
1271-94	Percle Bay
1229-145	Pigsties Bay
979-97	Pineapples
1233-23	Pipe Clay Lagoon outer co
1248-50	Pirates Bay
1154-108	Plunkett Point
1199-108	Point du Ressac
1076-100	Point Grand
1260-30	Point Peur
1189-20	Port Arthur
1233-97	Pot Bay
1176-43	Premaydena Point
1176-43	Prices Bay
1262-64	Primrose Point
1026-58	Quiet Corner
1229-145	Quiet Cove
1268-221	Red Ochre Beach
1256-124	Roches Beach
1229-145	Rocky Bay
1233-97	RSL Corner
1189-20	Safety Cove
1189-24	Safety Cove
1154-108	Salem Point
1229-145	Shag rock
1143-9	Shallow Bottom Point
1154-106	Sloping Main Beach
1233-25	South Clifton
1092-179	Southport Bay
1268-221	Spectacle Head
1268-221	Spectacle Island
1229-145	Sterile Island
1189-20	Stewarts Bay
1189-18	Stingaree Bay
1260-30	Stinking Bay
1199-162	Strouds Point
1229-145	Sullivan Point
1262-70	Tasman Bay
1088-79	The Lufra
1268-221	Tiger Head Bay
1184-62	Tinderbox
1271-94	Trial Bay
1154-108	Turners Point
1626-69	Watsons Bay
984-139	Wedge Island
1076-100	West Cloudy Head
1143-9	Whalebone Point
1249-182	Whalebone Rock
1199-162	Wiggins Point
1271-94	Woodbridge
1262-66	Wykeholm Point
1262-66	Wykeholm Point

Appendix 2. Dominant algae in the Bruny Bioregion and their relationship with environmental variables.

For the following species descriptions, the average percent cover and the percent of observations are based data obtained from the video drops (all species except *Macrocystis*). The *Macrocystis* distribution shown is based on all observations taken from videos and notes made on Sea Mapper. Tables A and B show the number of observations for each depth and exposure category these are based on. Table C shows the combined number of observations made for *Macrocystis* distribution.

Appendix 2a. Number of observations from video drops for each depth and exposure category for reef areas.

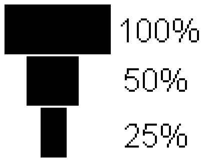
REEF	EXPOSURE INDEX				
Depth Category	1	2	3	4	5
0-2m	14	19	5	3	1
2-5m	20	26	14	18	4
5-10m	4	14	20	24	12
10-20m	4	4	21	47	35
20-30m			6	30	31
30-40m				26	34

Appendix 2b. Number of observations from video drops for each depth and exposure category for unconsolidated substrates.

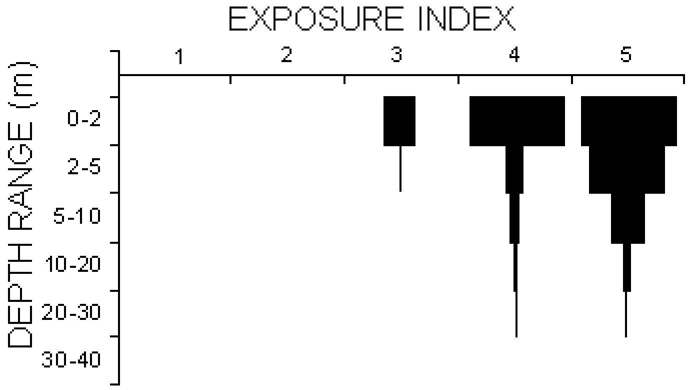
SAND	EXPOSURE INDEX				
Depth Category	1	2	3	4	5
0-2m	17	2	1	2	
2-5m	69	24	9	4	
5-10m	58	38	17	9	
10-20m	34	30	29	21	6
20-30m	3		5	14	1
30-40m	1			19	7

Appendix 2c. Number of combined observations from video drops and observations noted on Sea Mapper for each depth and exposure category for reef substrates.

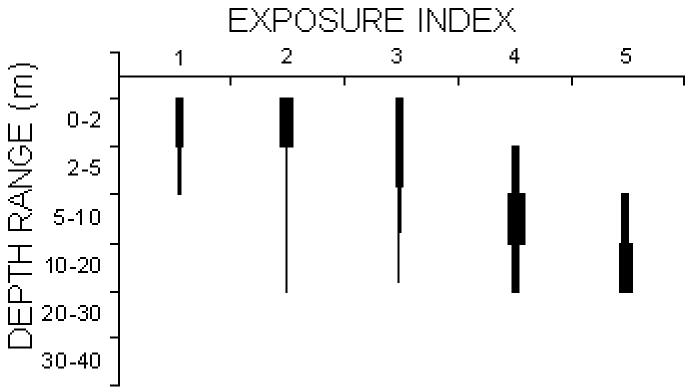
REEF	EXPOSURE INDEX				
Depth Category	1	2	3	4	5
0-2m	60	55	84	14	3
2-5m	55	101	180	43	26
5-10m	19	38	148	54	30
10-20m	8	29	99	124	86
20-30m			72	99	78
30-40m			10	115	95



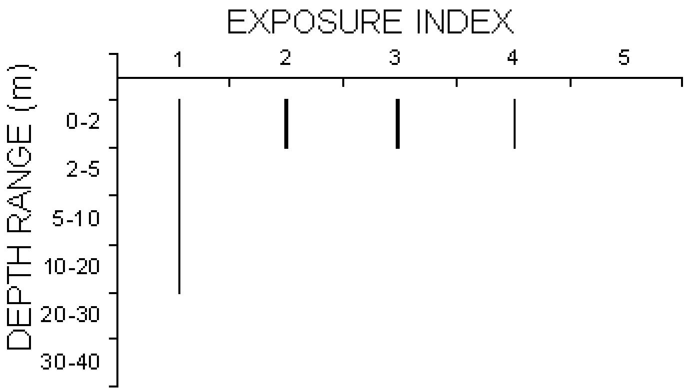
Appendix 2d. Scale for use with the following percent cover indice diagrams:



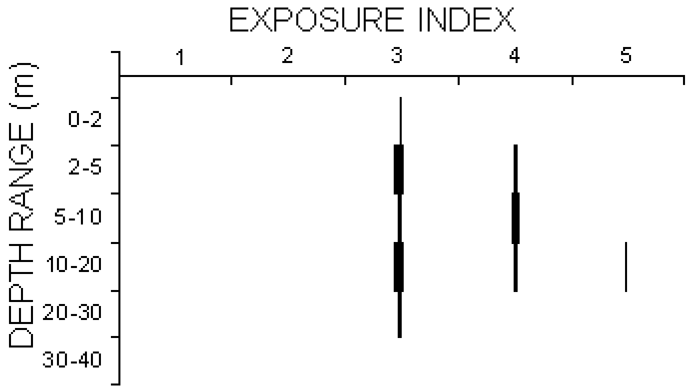
Appendix 2e. Mean percentage cover index for *Durvillaea potatorum* for depth and exposure categories on reef substrates based on video observations.



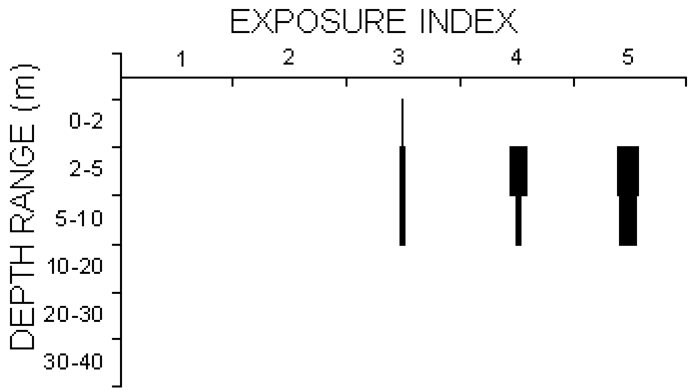
Appendix 2f. Mean percentage cover index for *Phyllospora comosa* for depth and exposure categories on reef substrates from video observations.



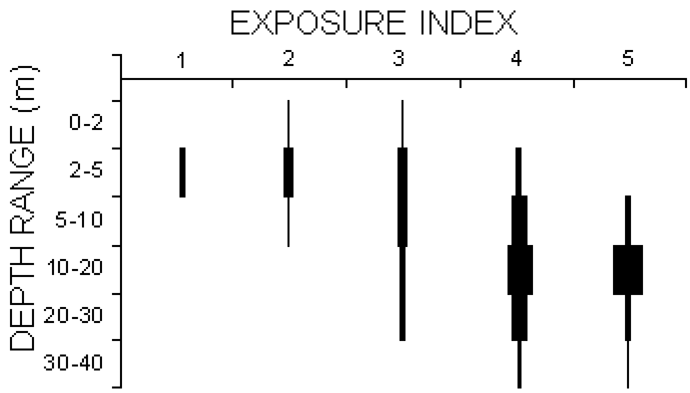
Appendix 2g. Mean percentage cover index for *Xiphophora gladiata* for depth and exposure categories on reef substrates from video observations.



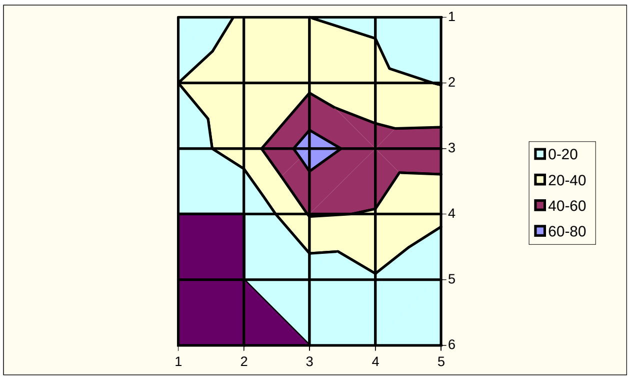
Appendix 2h. Mean percentage cover index for *Lessonia corrugata* for depth and exposure categories on reef substrates from video observations.



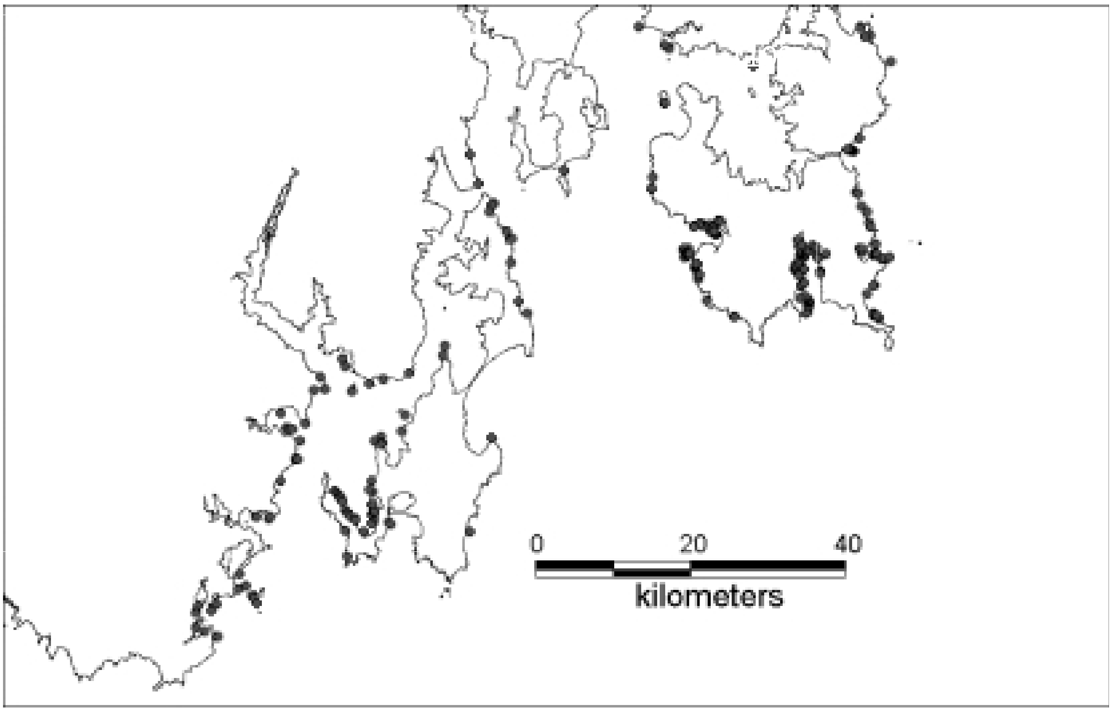
Appendix 2i. Mean percentage cover index for *Carpoglossum confluens* for depth and exposure categories on reef substrates from video observations.



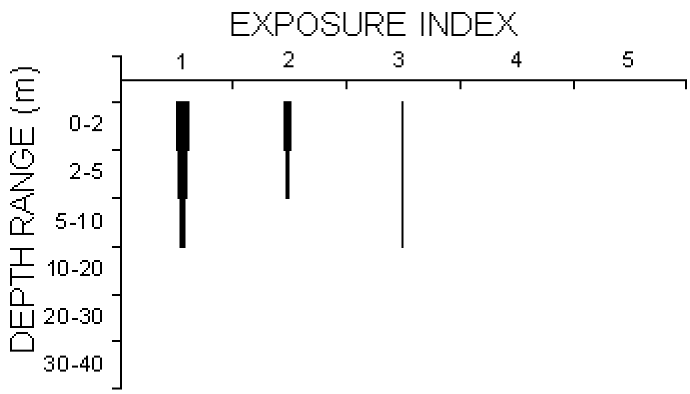
Appendix 2j. Mean percentage cover index of *Ecklonia radiata* determined from video observations on reef at the depth and exposure categories shown.



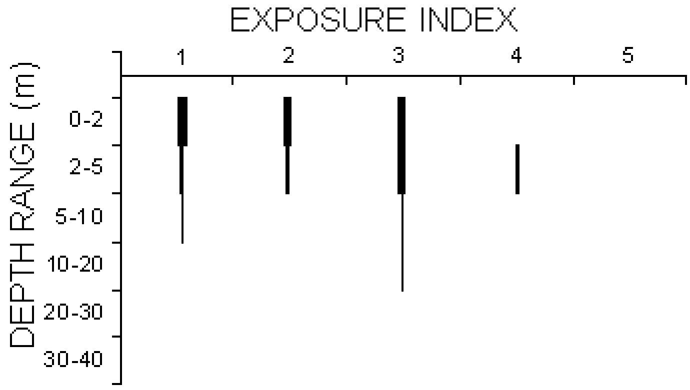
Appendix 2k. Frequency of observations of *Macrocystis pyrifera* determined from video observations and field notes at the depth and exposure categories shown. The horizontal axis is exposure categories and the vertical axis is depth (0-5 m, 5-10 m, 10-20 m, 20-30 m, 30-40 m).



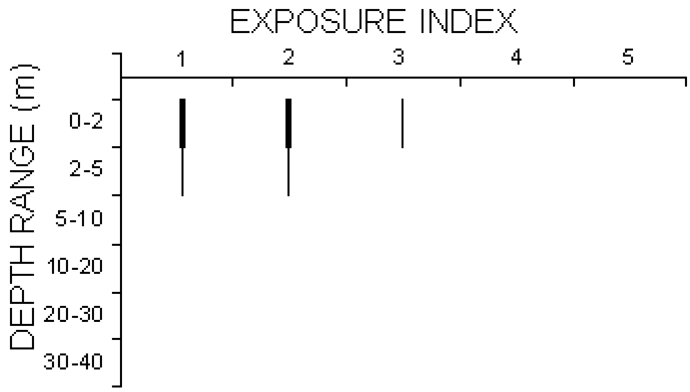
Appendix 2l. The distribution of *Macrocystis pyrifera* in the Bruny Bioregion determined from mapping records.



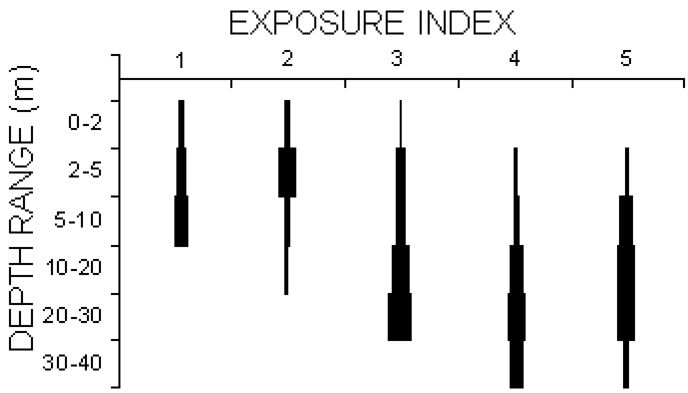
Appendix 2m. Mean percentage cover index for *Sargassum* species determined from video drops on reef at the depth and exposure categories shown.



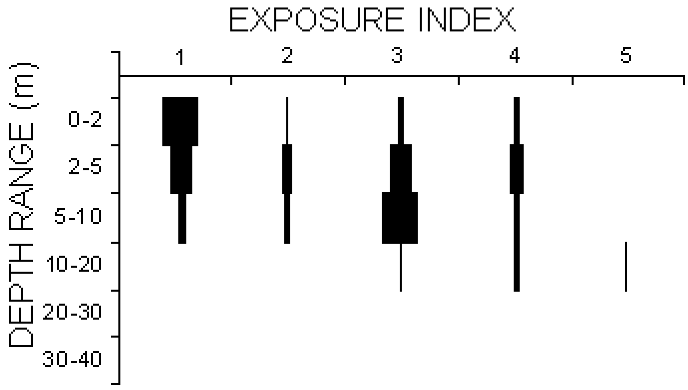
Appendix 2n. Mean percentage cover index for *Cystophora* species determined from video drops on reef at the depth and exposure categories shown.



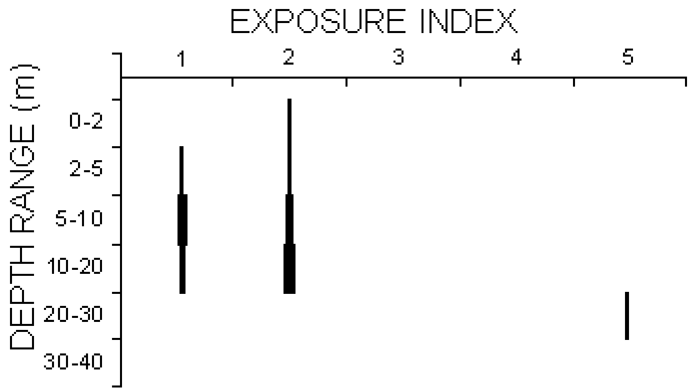
Appendix 2o. Mean percentage cover index for *Caulocystis cephalornithos* for depth and exposure categories on reef substrates from video observations.



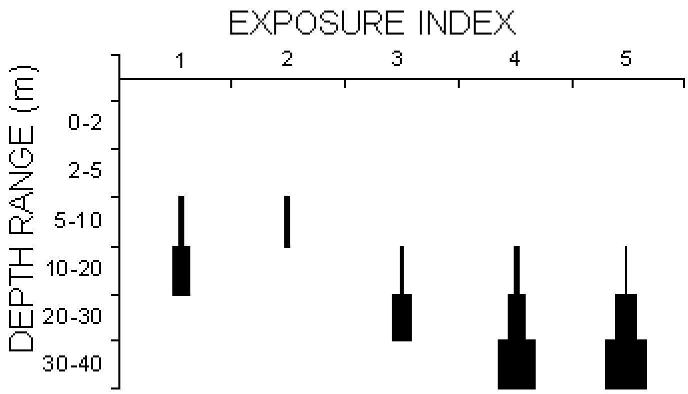
Appendix 2p. Mean percentage cover index for red algae for depth and exposure categories on reef substrates from video observations.



Appendix 2q. Mean percentage cover index for all seagrass species for depth and exposure categories on all substrates from video observations.



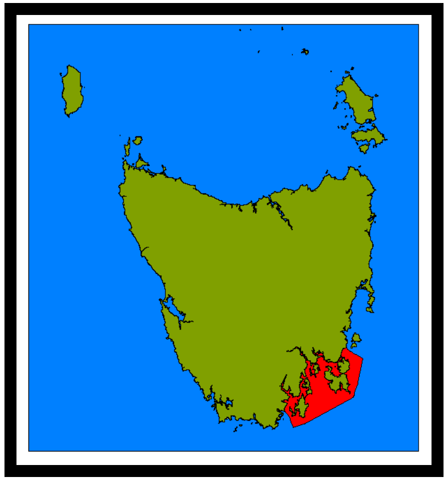
Appendix 2r. Mean percentage cover index for *Caulerpa* species for depth and exposure categories on reef and unconsolidated substrates from video observations.



Appendix 2s. Mean percentage cover index for sponges determined from video observations at the depth and exposure categories shown.

Appendix 3. 1 in 25,000 habitat maps

Appendix 3
1:25 000
Map Series



Click on map to go to introduction page

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& Fisheries Institute
University of Tasmania

Introduction:
Contained in this document are 1 in 25 000 maps of the IMCRA Bruny Bioregion. These maps were produced as part of a NHT funded project by the Tasmanian Aquaculture and Fisheries Institute. The full methodology and analysis can be found in the accompanying report *Mapping of Inshore Marine Habitats in South-Eastern Tasmania for Marine Protected Area Planning and Marine Management* (Barrett *et.al*. 2001).

The project focussed on mapping out marine habitats under three general categories; reef, unconsolidated substrate and vegetated unconsolidated substrate (Seagrasses). Each of these habitat types was divided into several more distinct categories as detailed below:

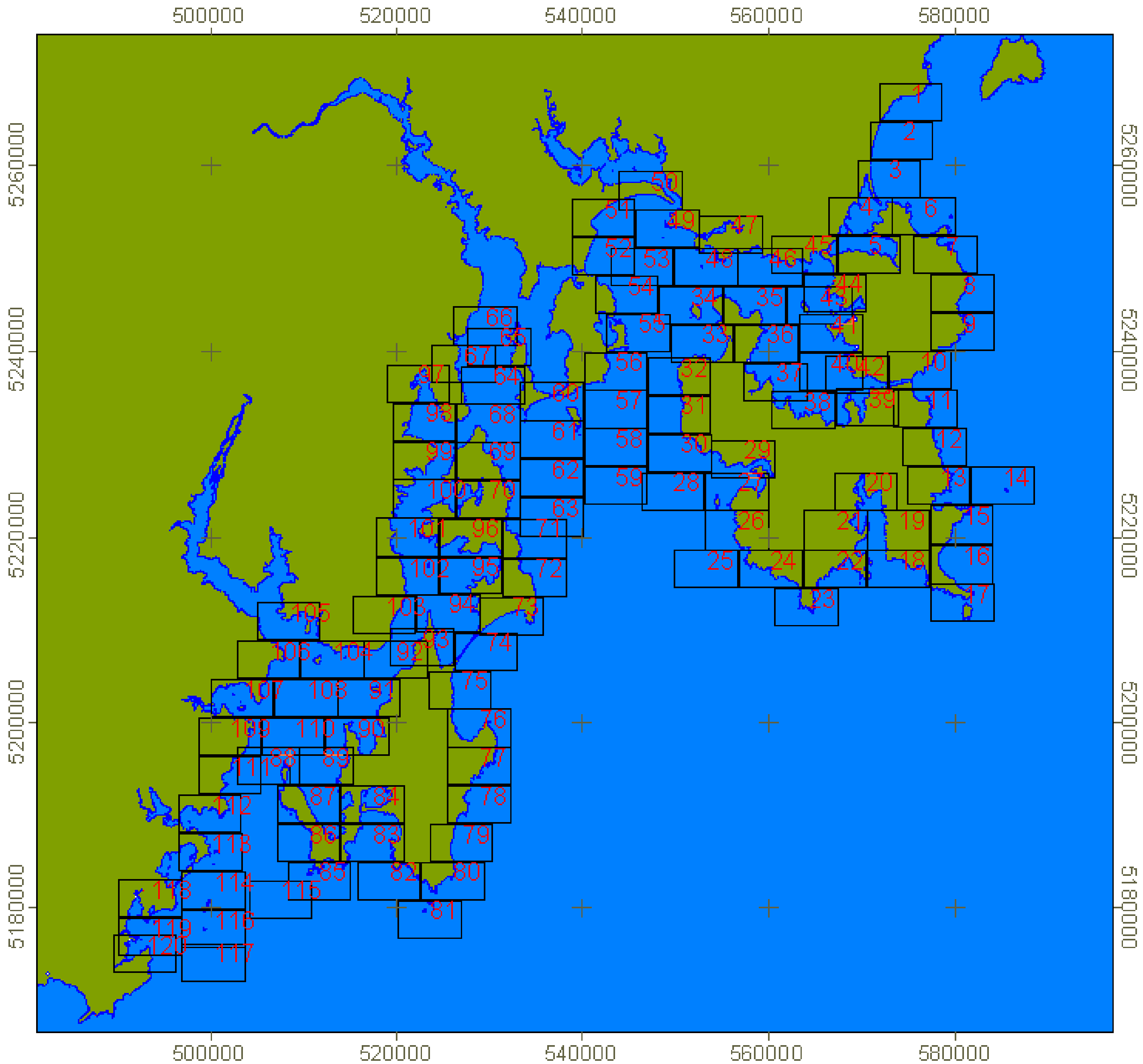
Reef	
High profile reef-	Complex reef that rises and falls greater than 4m over a short distance
Medium profile reef-	Reef that rises and falls between 1 and 4m over a short distance
Low profile reef-	Reef with less than 1m profile
Patchy reef-	Reef intermixed with sand
Unconsolidated substrate	
Sand-	Unconsolidated sediment with large grain size
Silty Sand-	Unconsolidated sediment with mix of large and fine grain
Silt-	Sediment with small grain size
Hard Sand-	Unconsolidated sediment with either very large grain size (gravel), shell or shell fragments, burrows or extensive ripples.
Vegetated unconsolidated substrate	
Seagrass-	Dense beds of *Heterozostera tasmanica* or *Halophila australis*
Patchy seagrass-	Beds of the above species with bare sand patches throughout
Sparse seagrass-	Seagrass beds with light but consistent cover
Caulerpa-	*Caulerpa trifaria* Occurs in extensive beds on soft substrates.*

*NB other Caulerpa species found associated with reef were not mapped as a separate habitat.

Whilst every effort has been made to produce up to date and accurate maps, seasonal variation and mapping error may result in some feature not being accurately represented. These maps should not to be used for navigational purposes.

Click here to go to index page

Map Index Sheet: Bruny Bioregion 1:25 000



1	Map Sheet Location
	Land
	Water

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Tasmanian Aquaculture & Fisheries Institute
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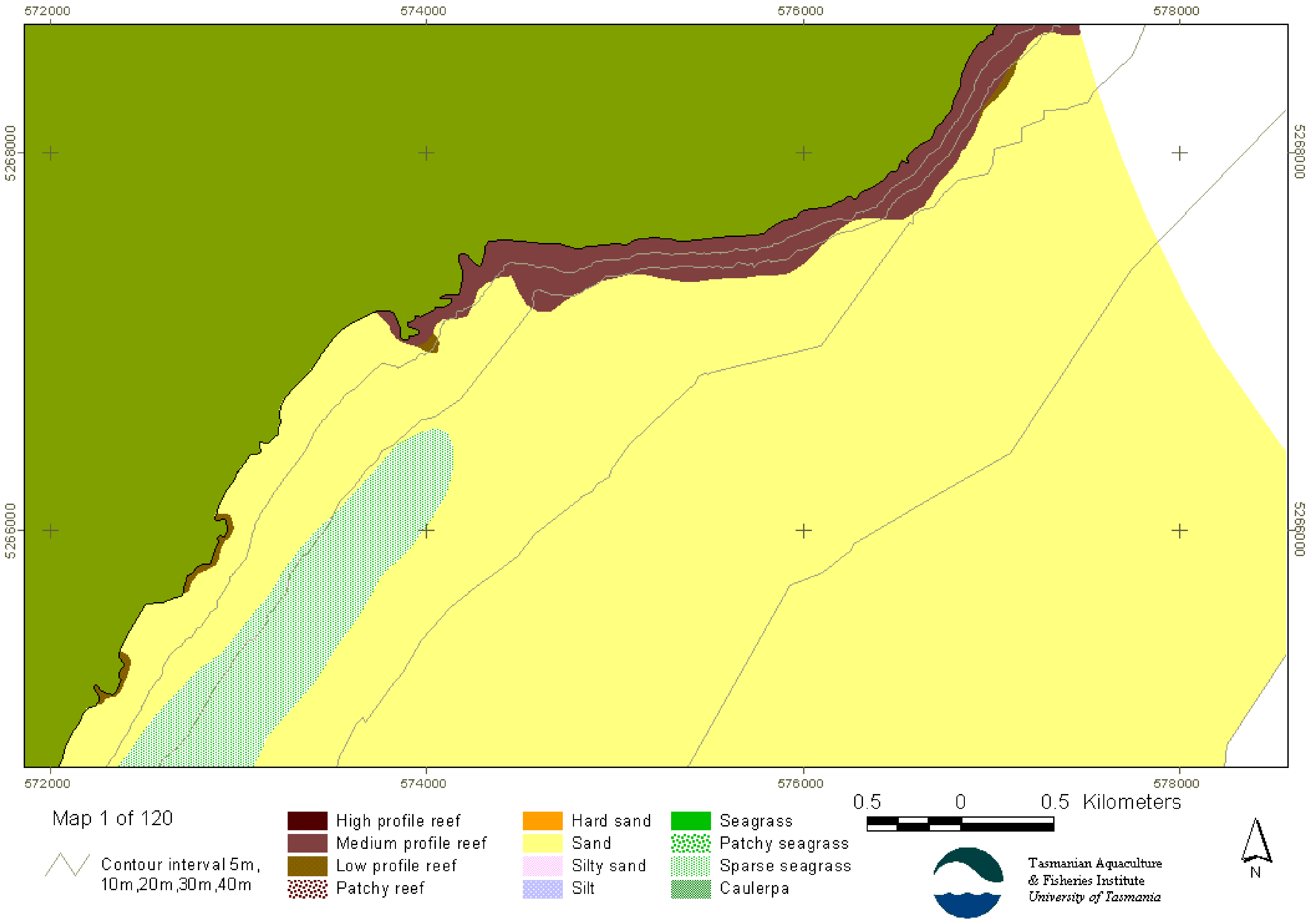
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578000
5268000
5266000
Map 1 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Contour interval 5m,
10m,20m,30m,40m
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& Fisheries Institute
University of Tasmania

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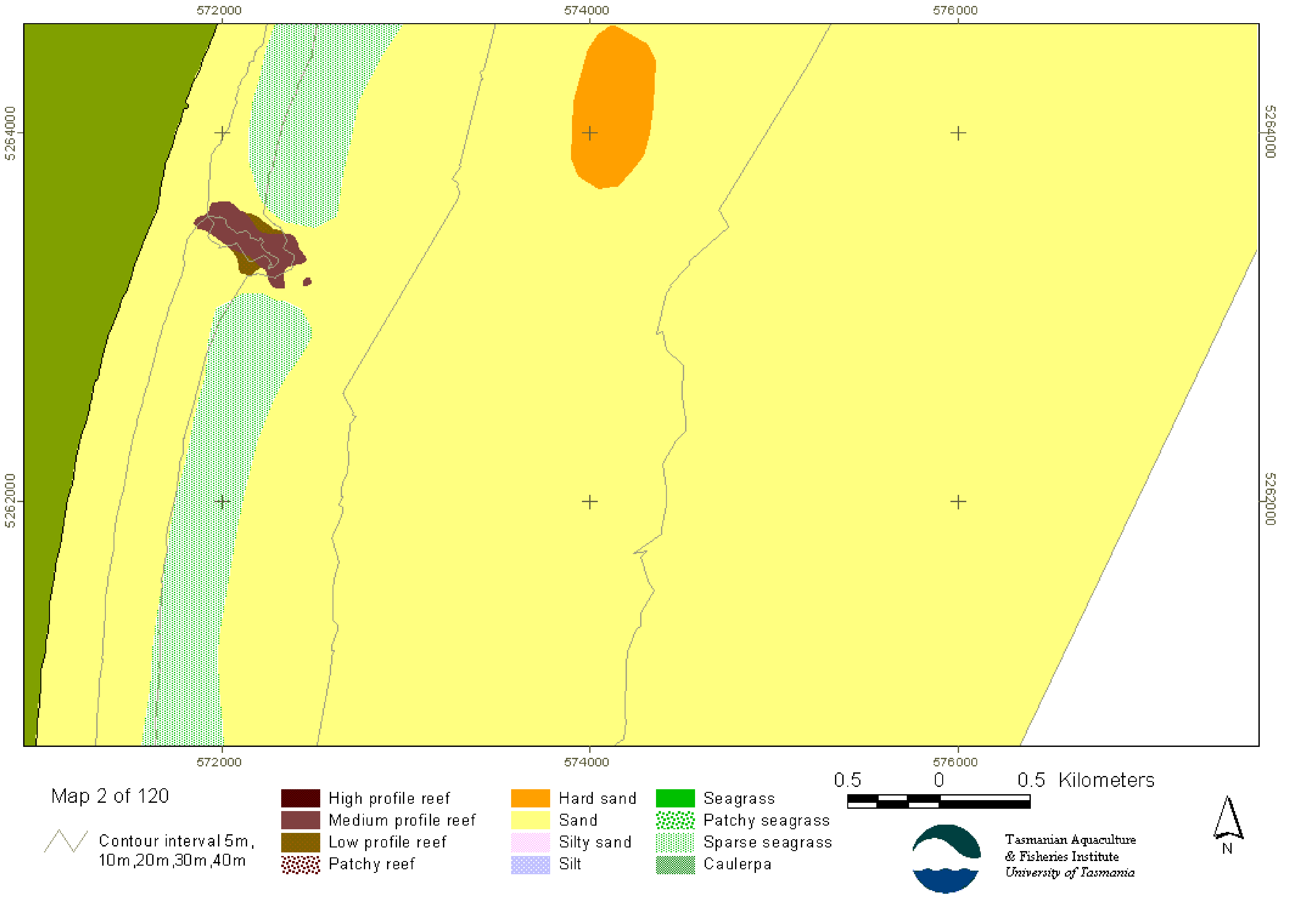
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Map 2 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
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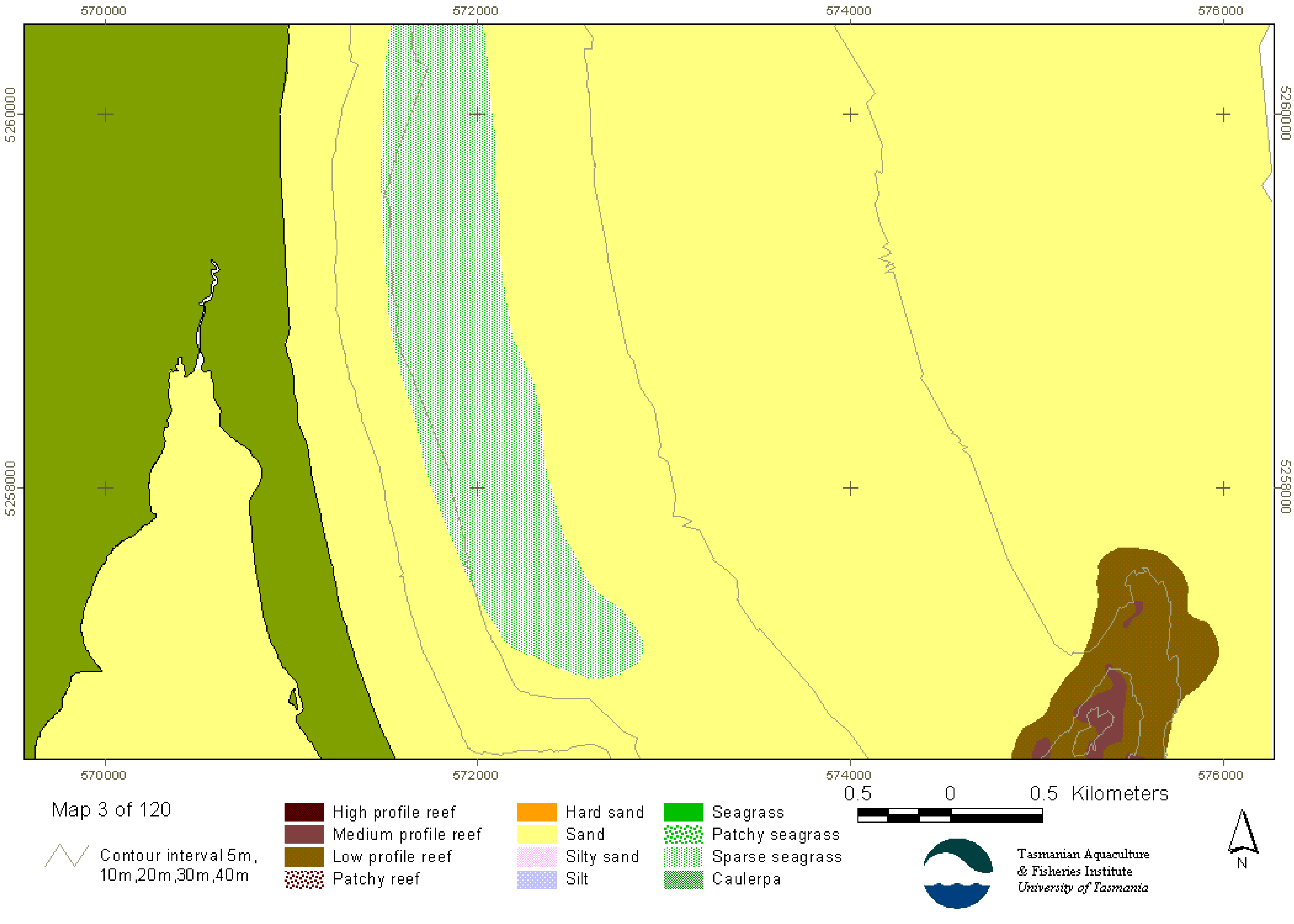
570000
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Map 3 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
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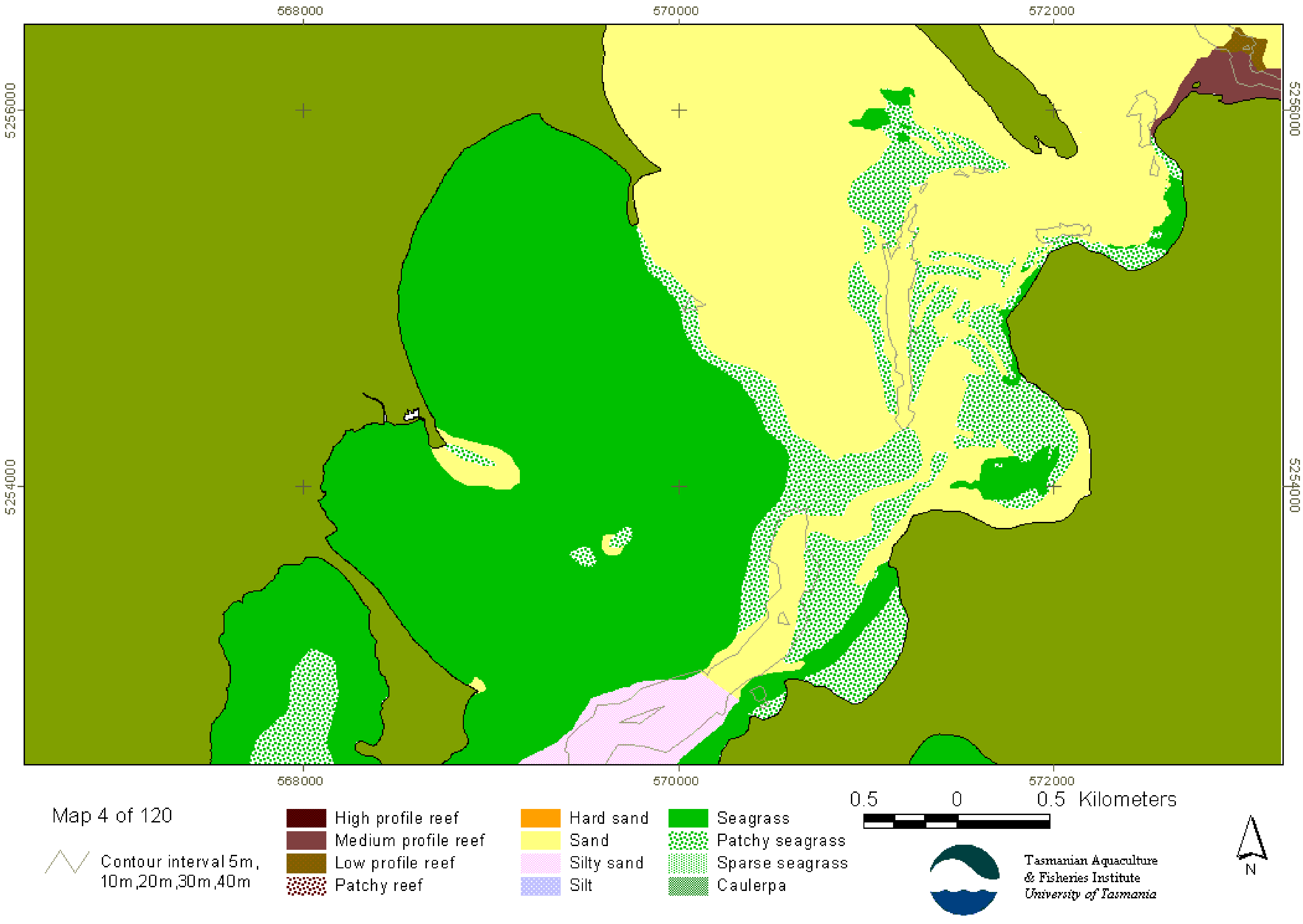
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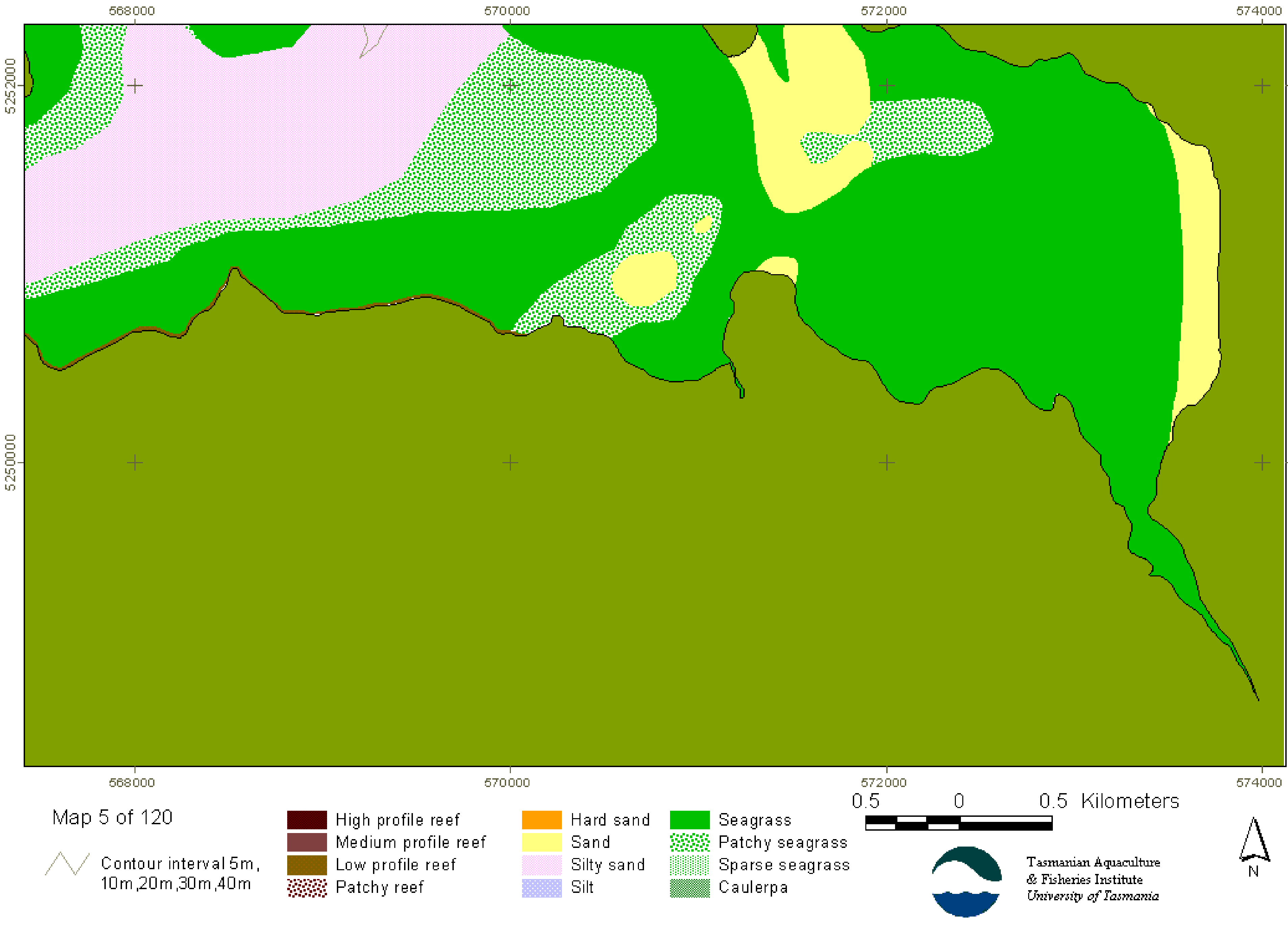
Map 4 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back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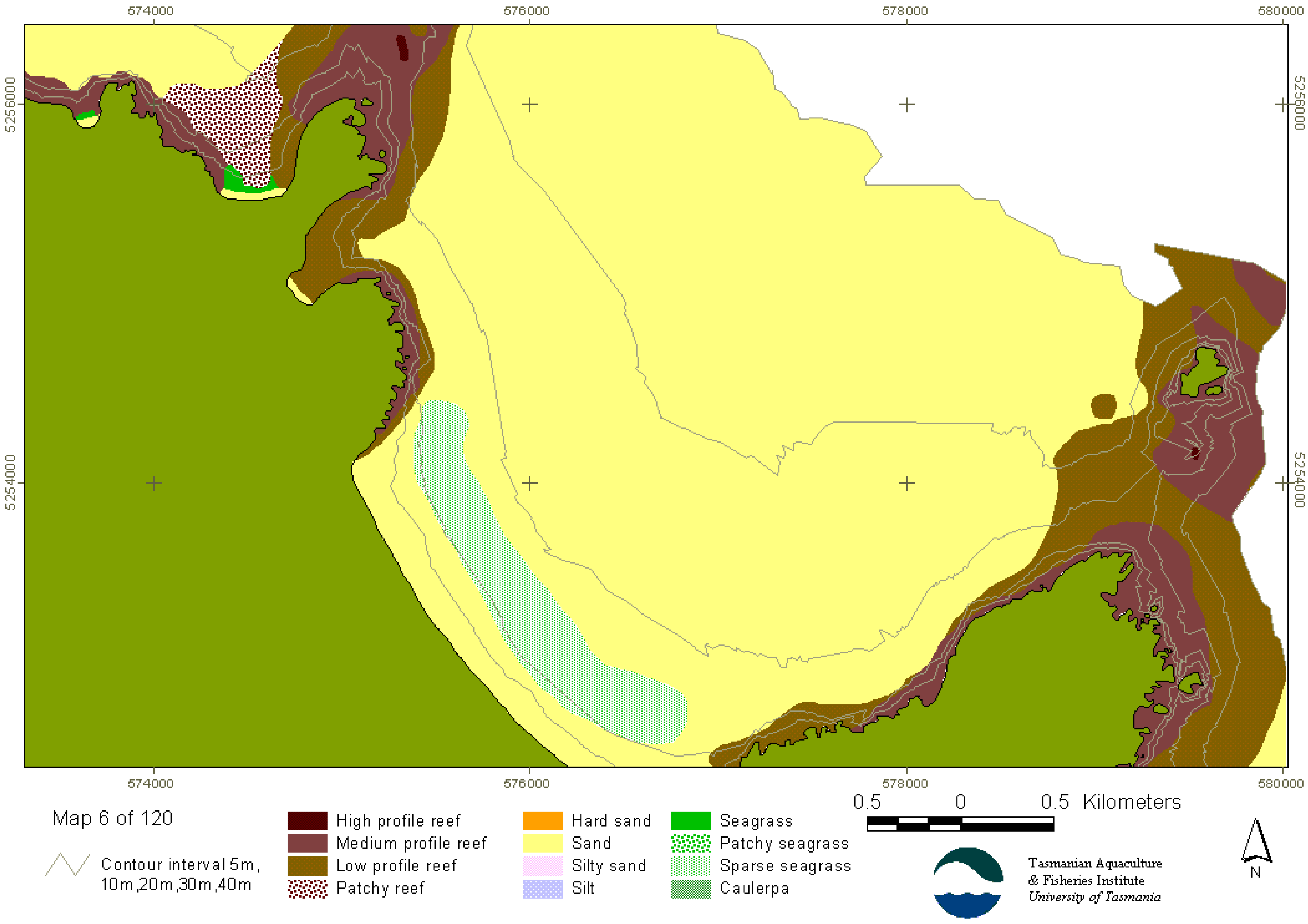
Map 5 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania

[Back]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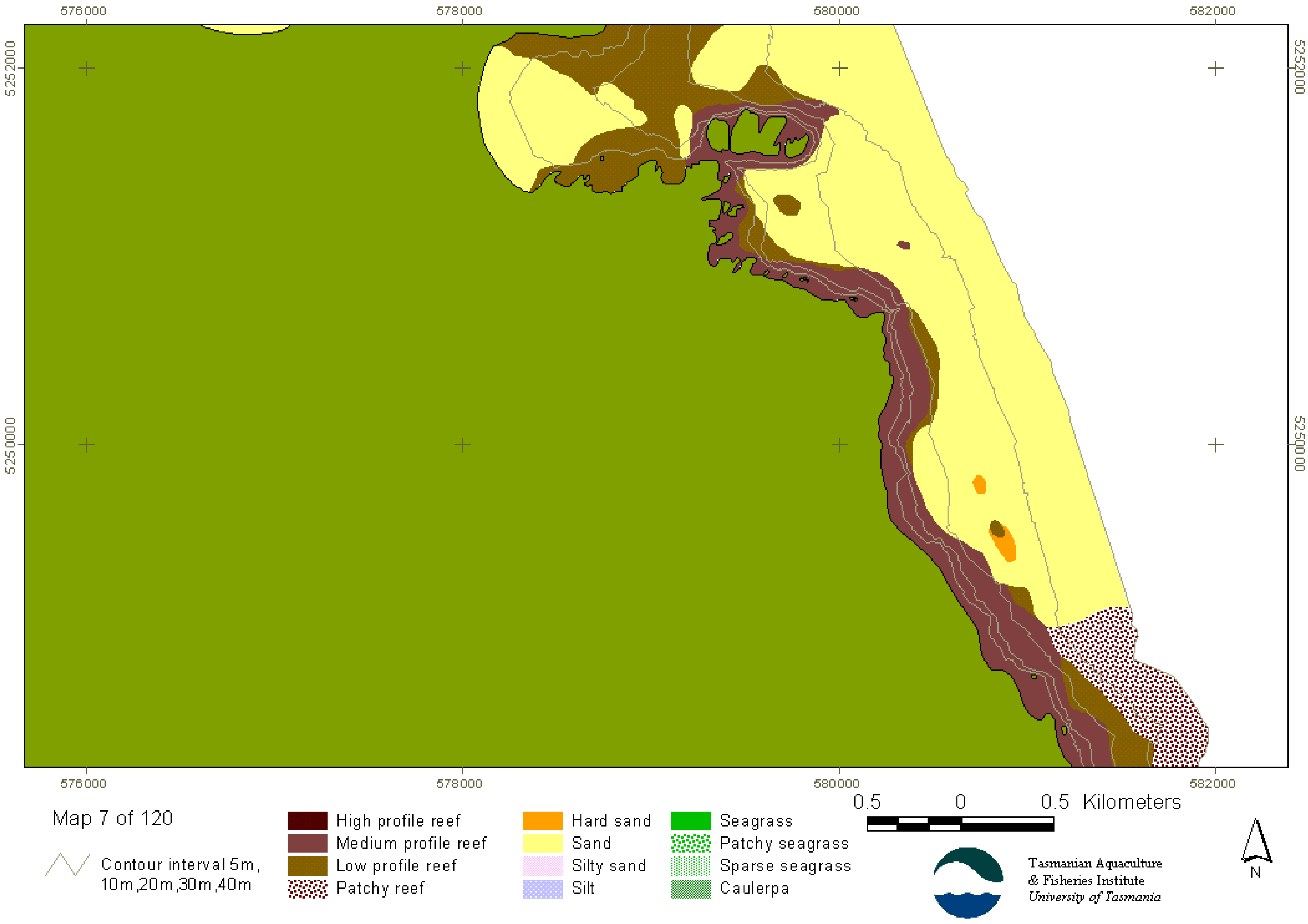
Map 6 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back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Map 7 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Contour interval 5m, 10m,20m,30m,40m
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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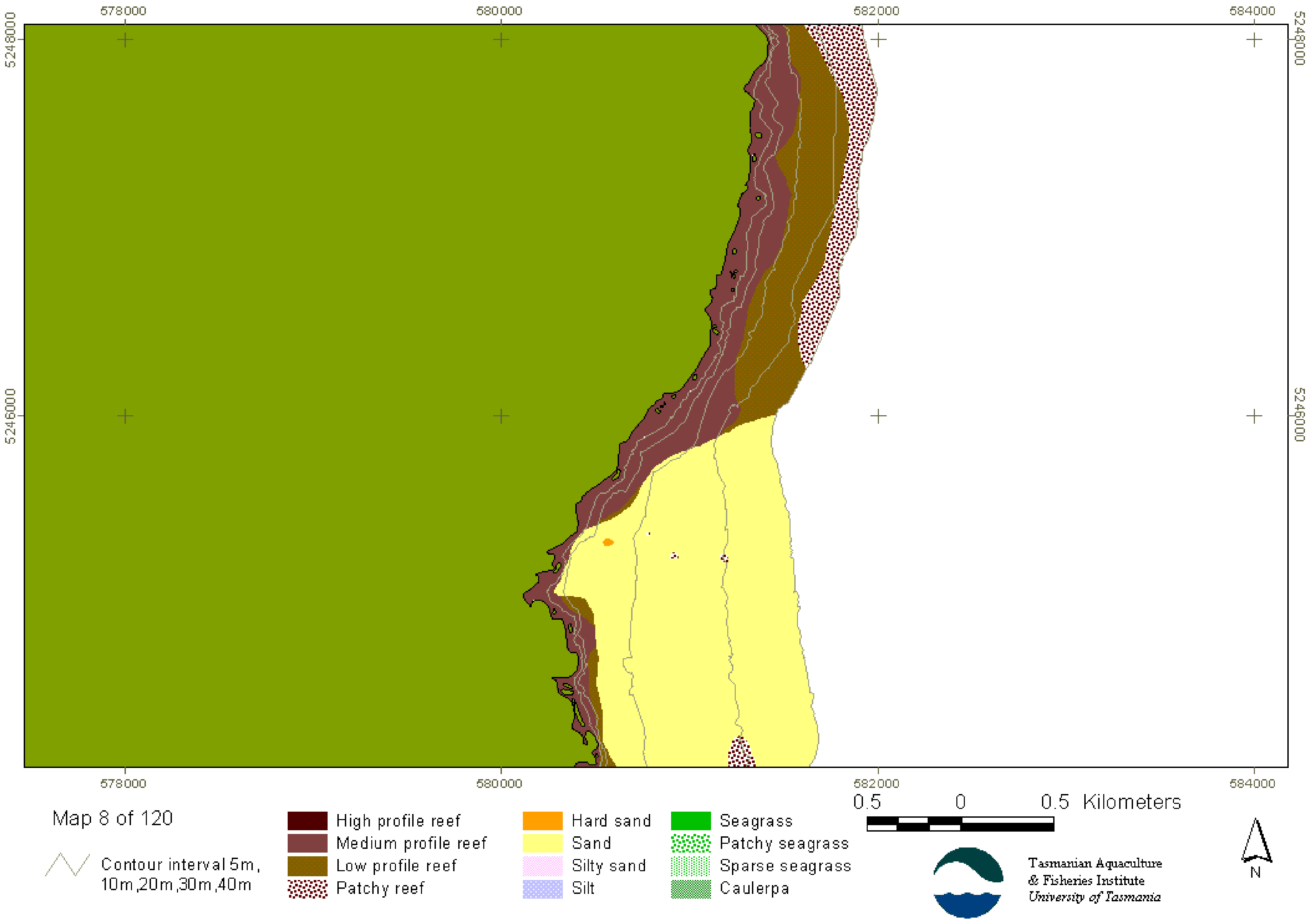
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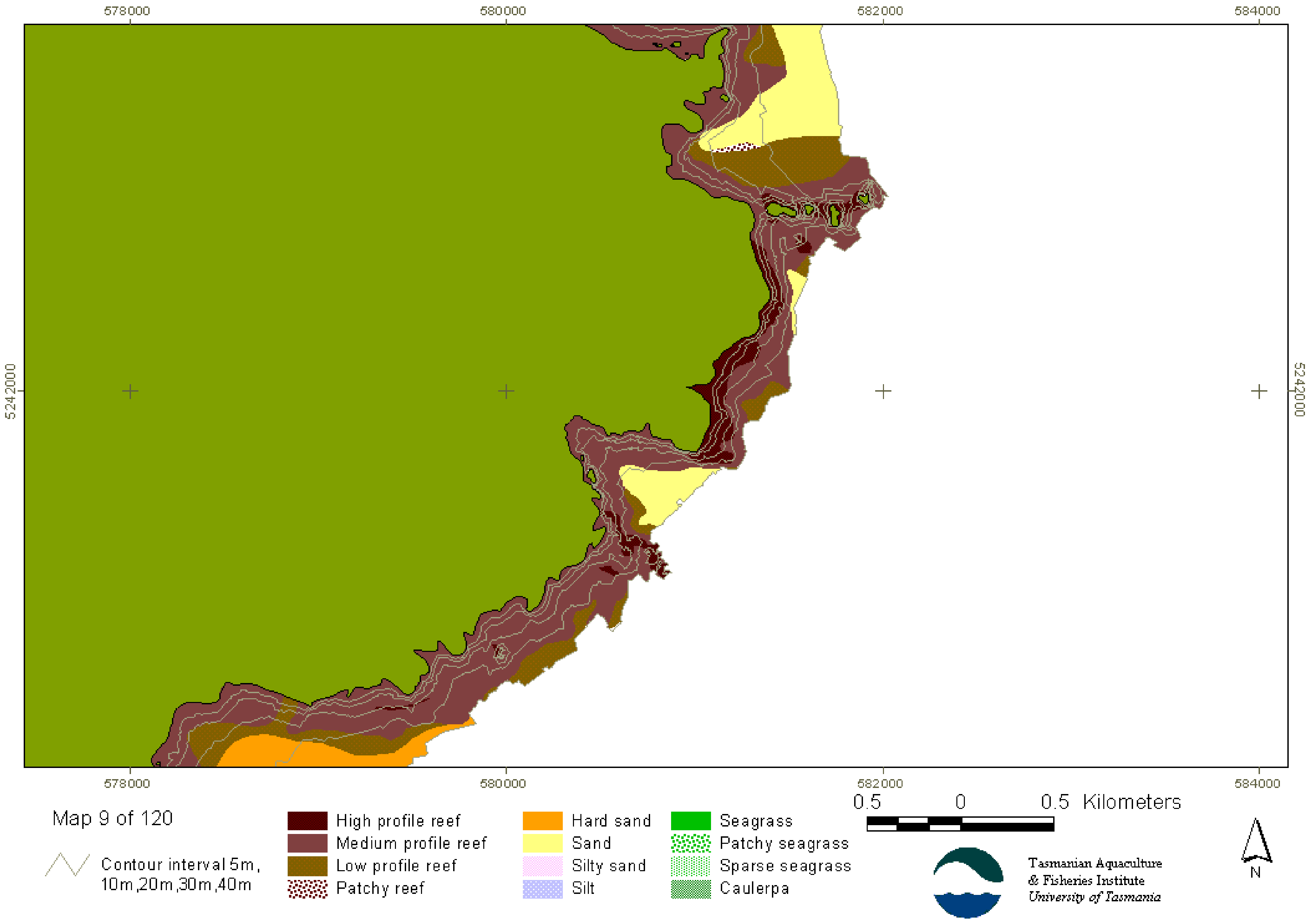
Map 8 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania
N

Back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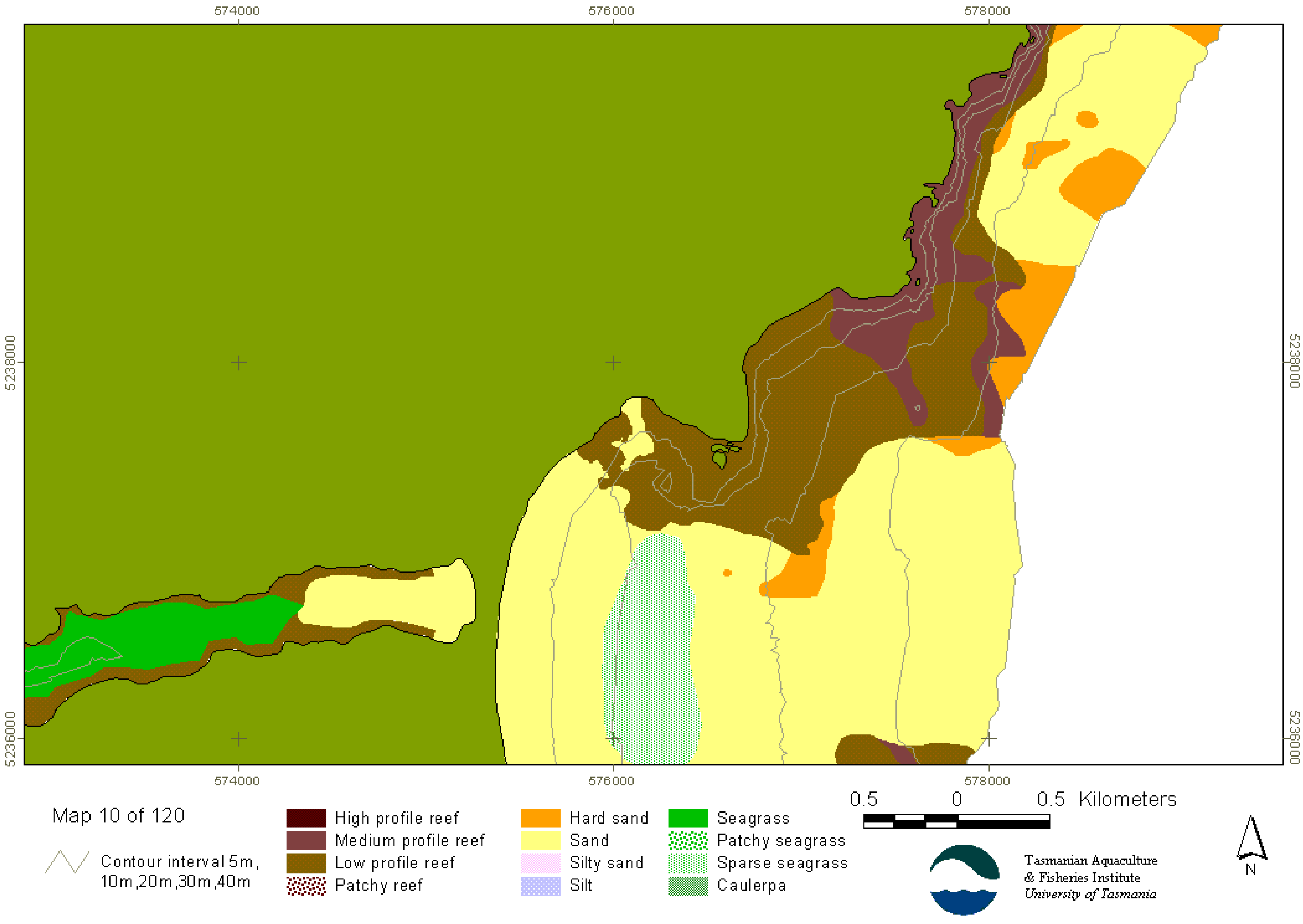
Map 9 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back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Map 10 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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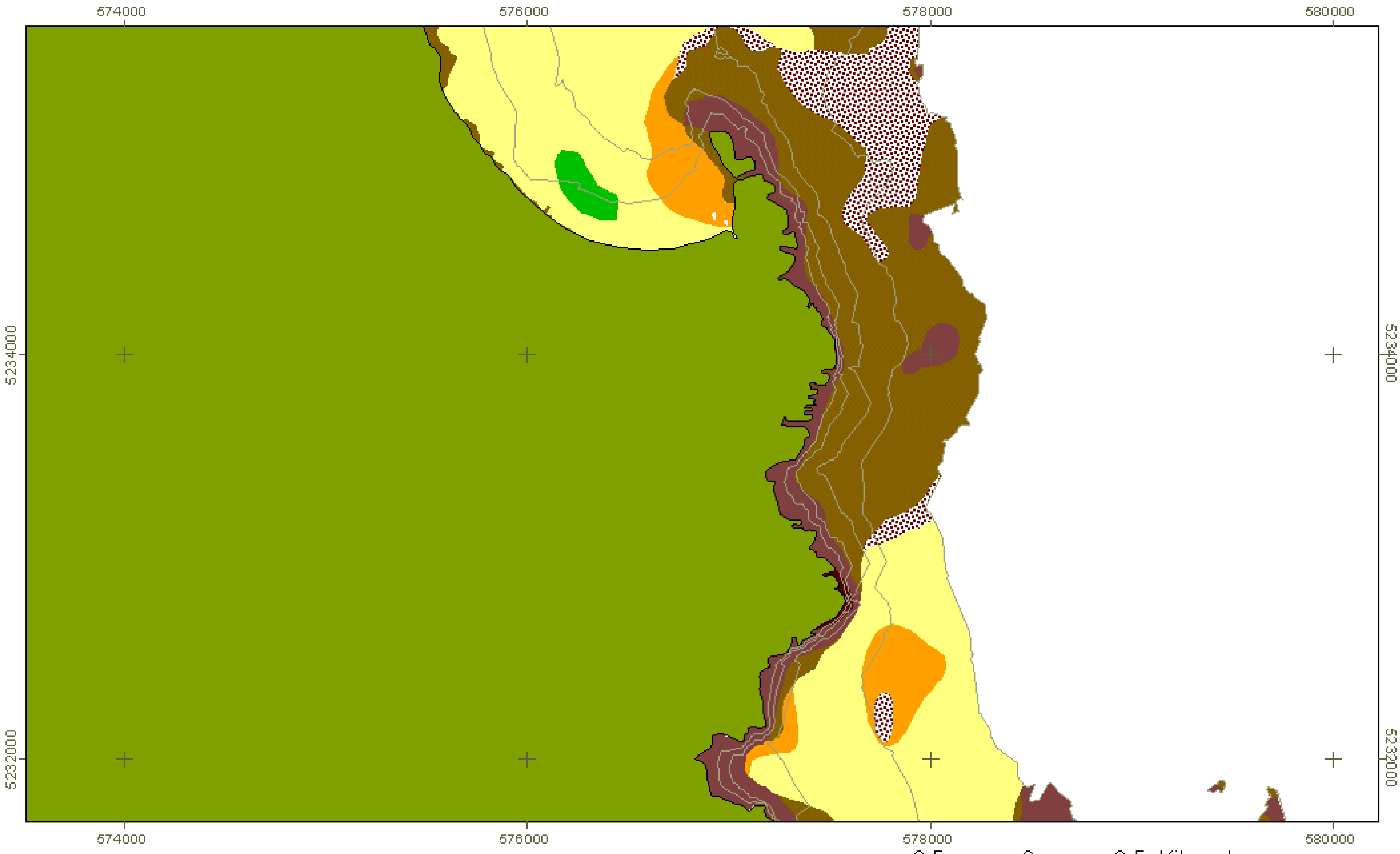
[Back]



Map 11 of 120

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

Contour interval 5m, 10m,20m,30m,40m

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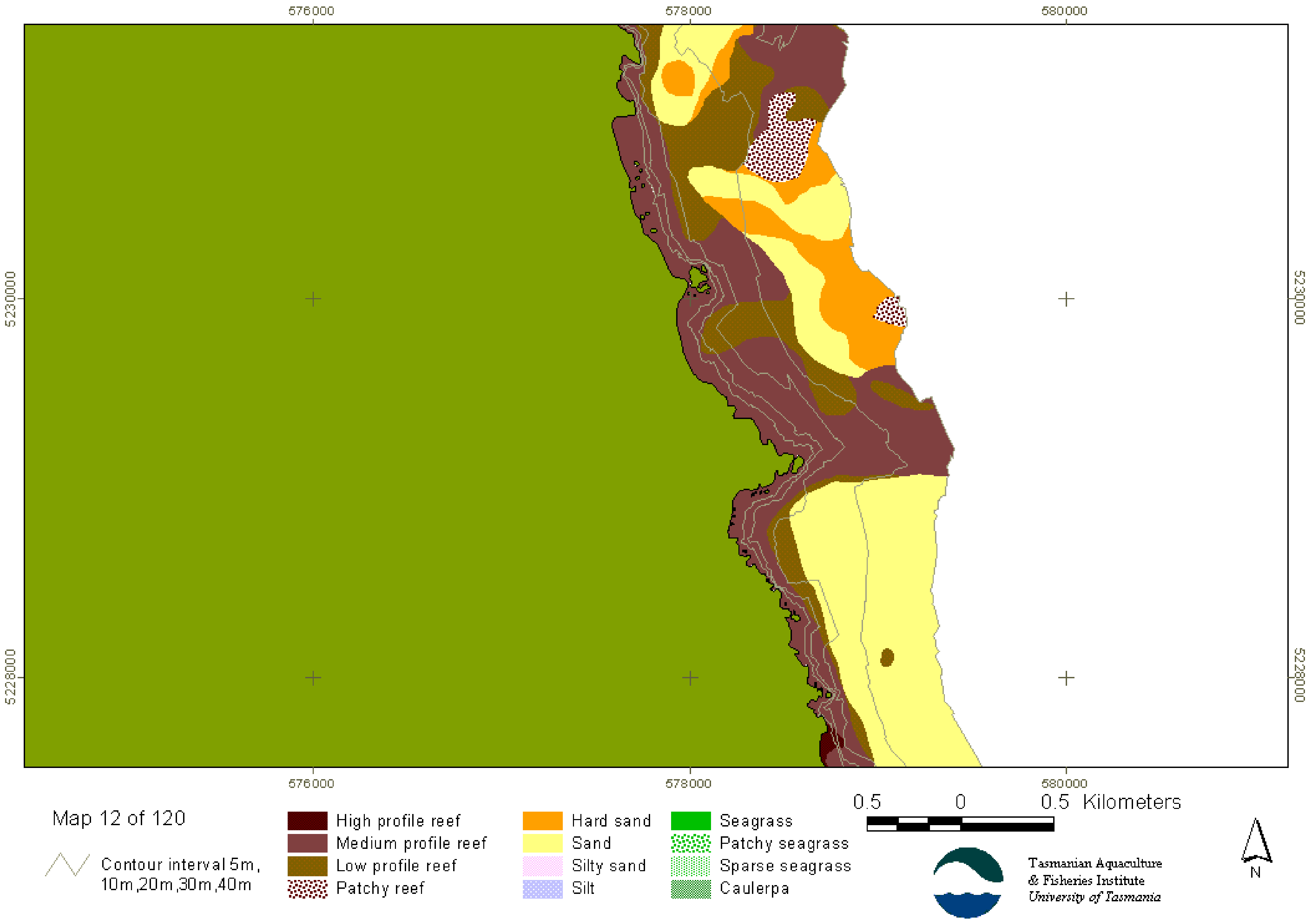
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Map 12 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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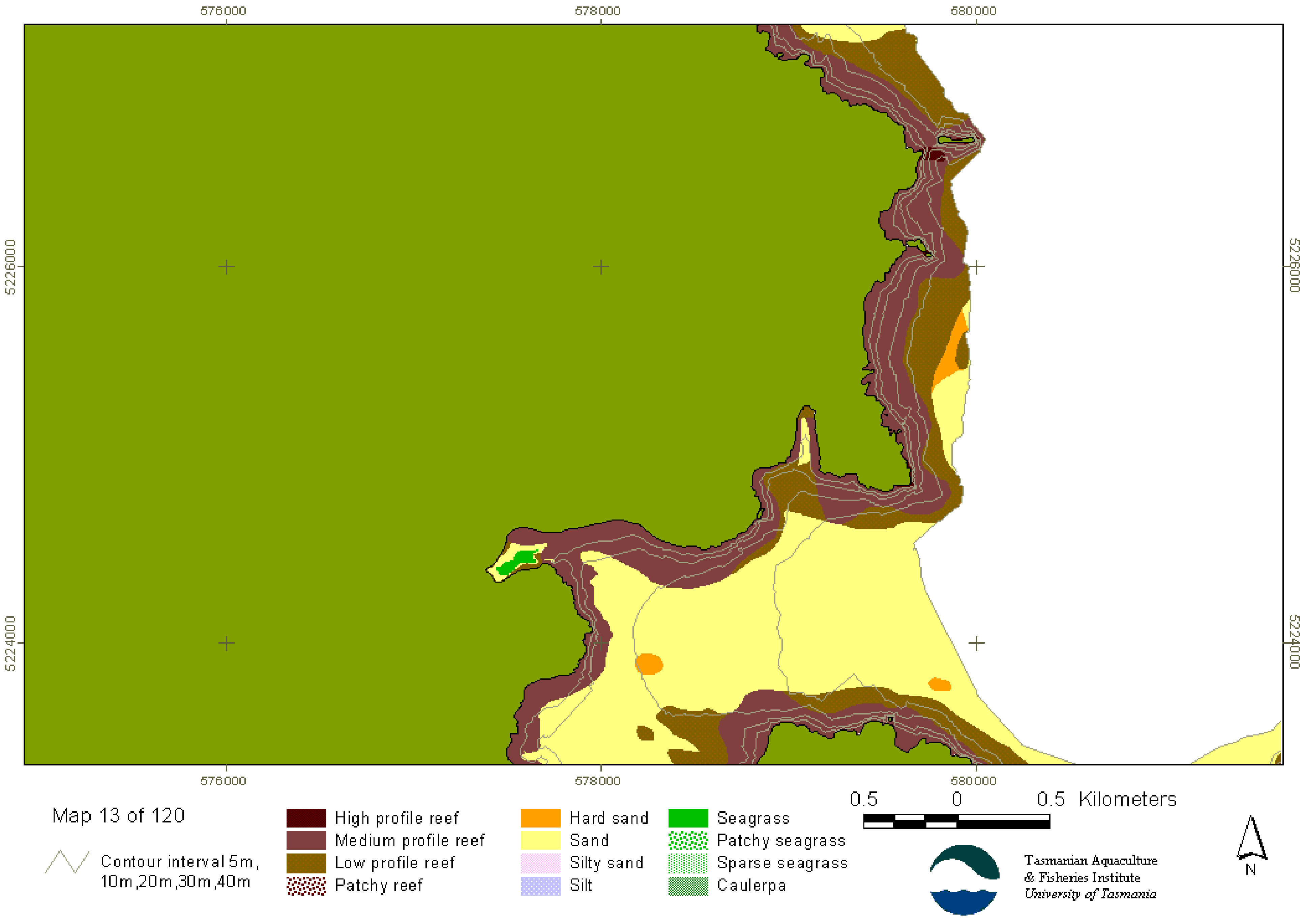
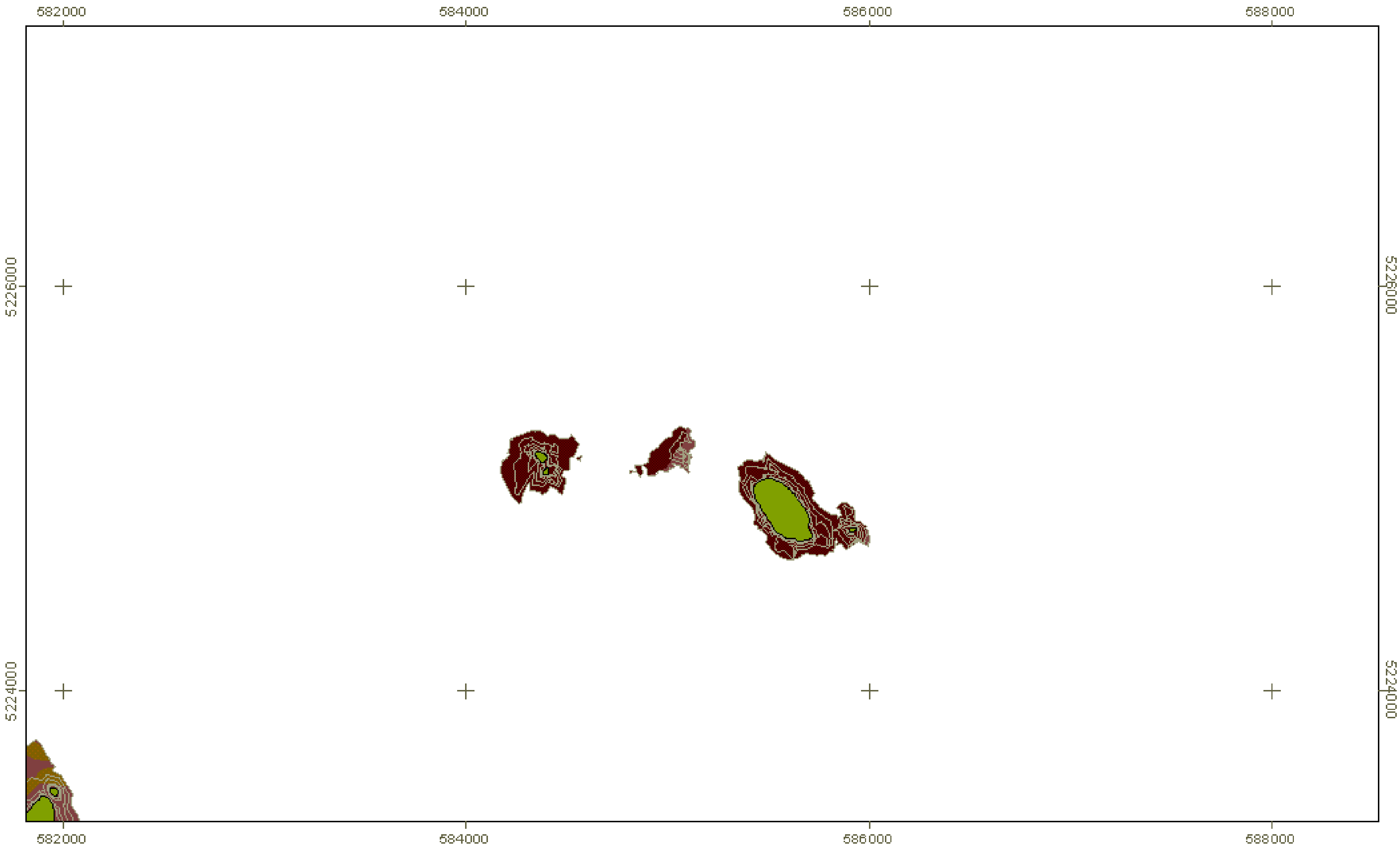


Map 13 of 120

Contour interval 5m, 10m, 20m, 30m, 40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

Back



Map 14 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

0.5 0 0.5 Kilometers

N

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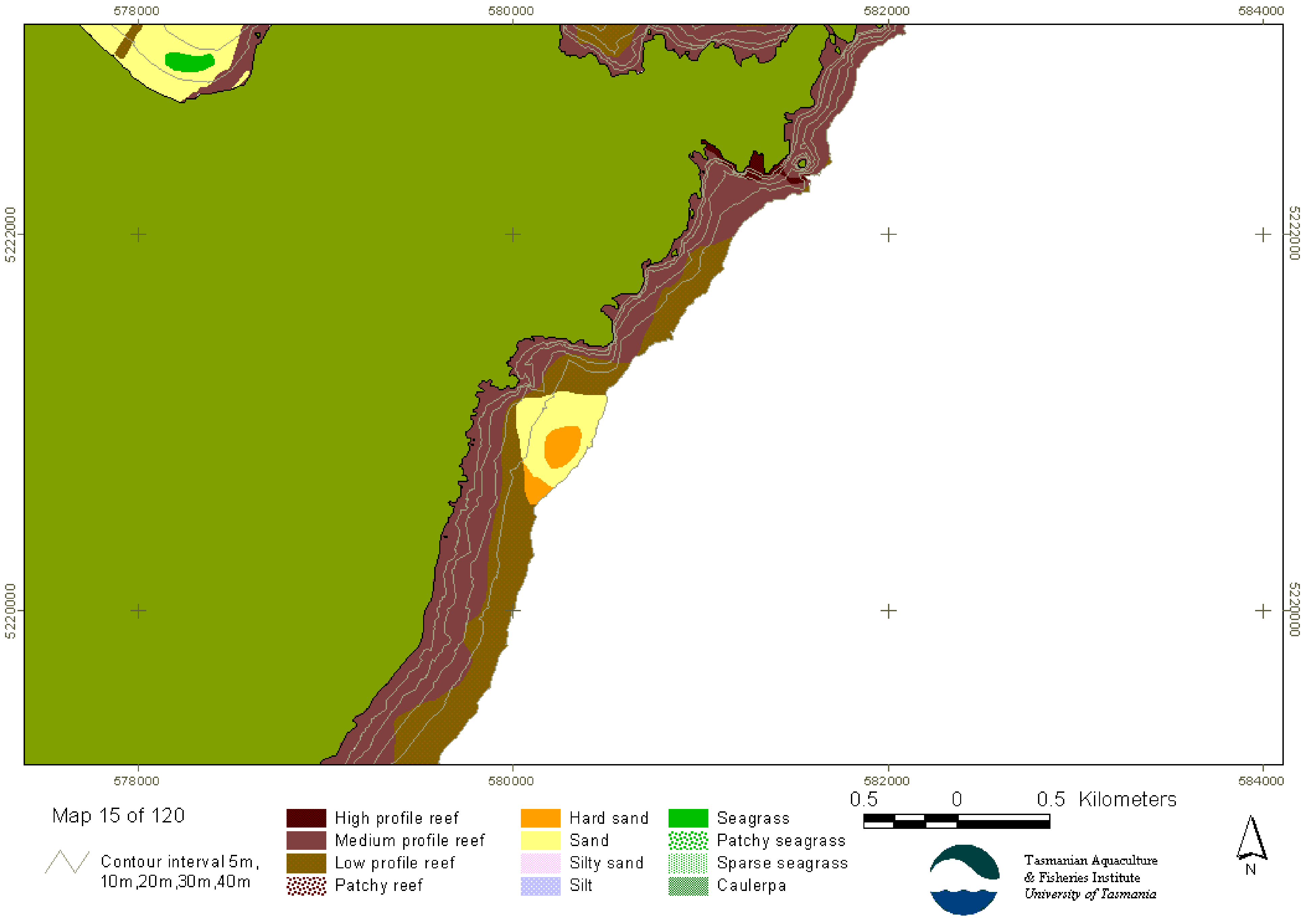
Back



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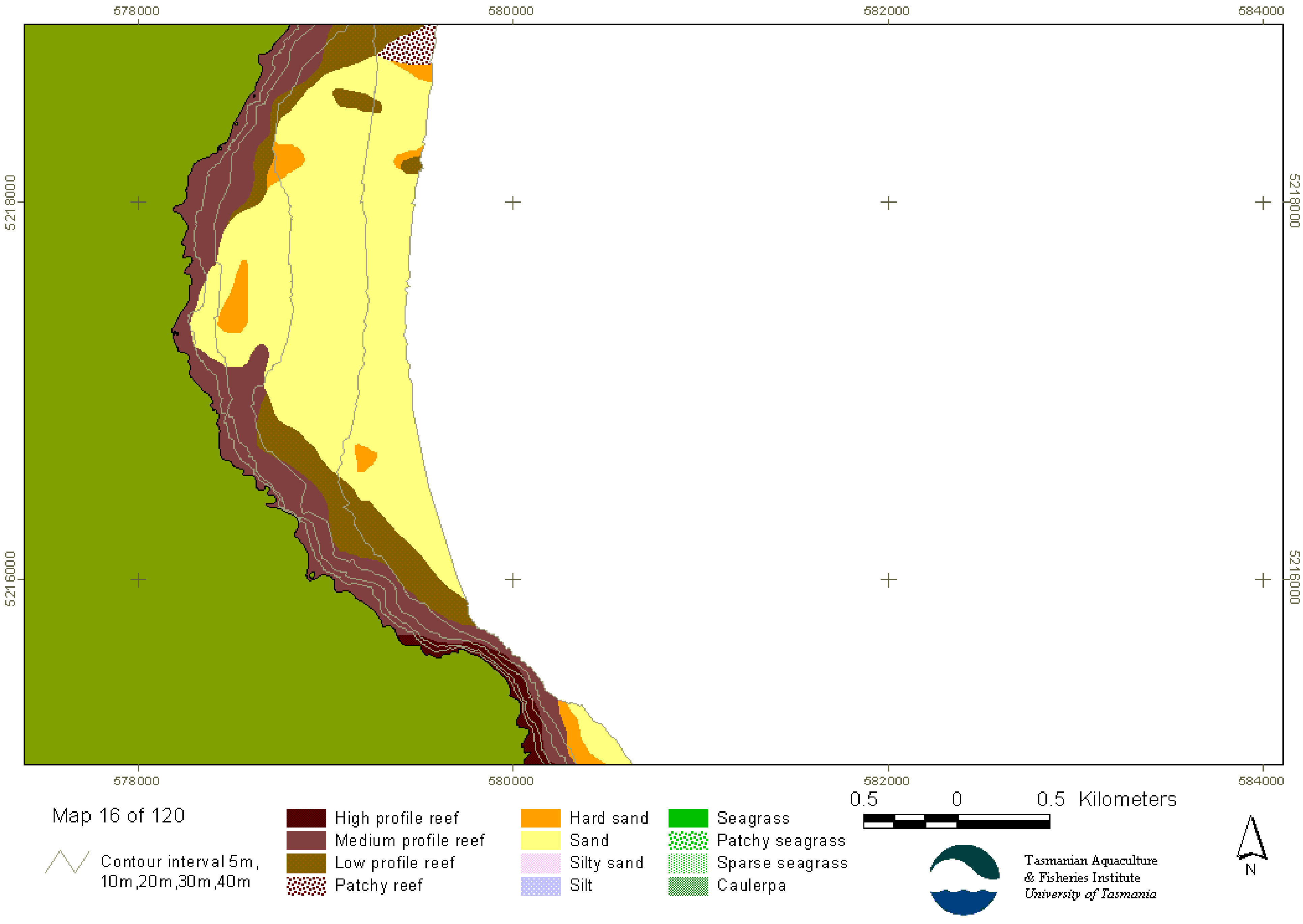
Map 15 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

[Back]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584000
5218000
5216000
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High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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University of Tasmania

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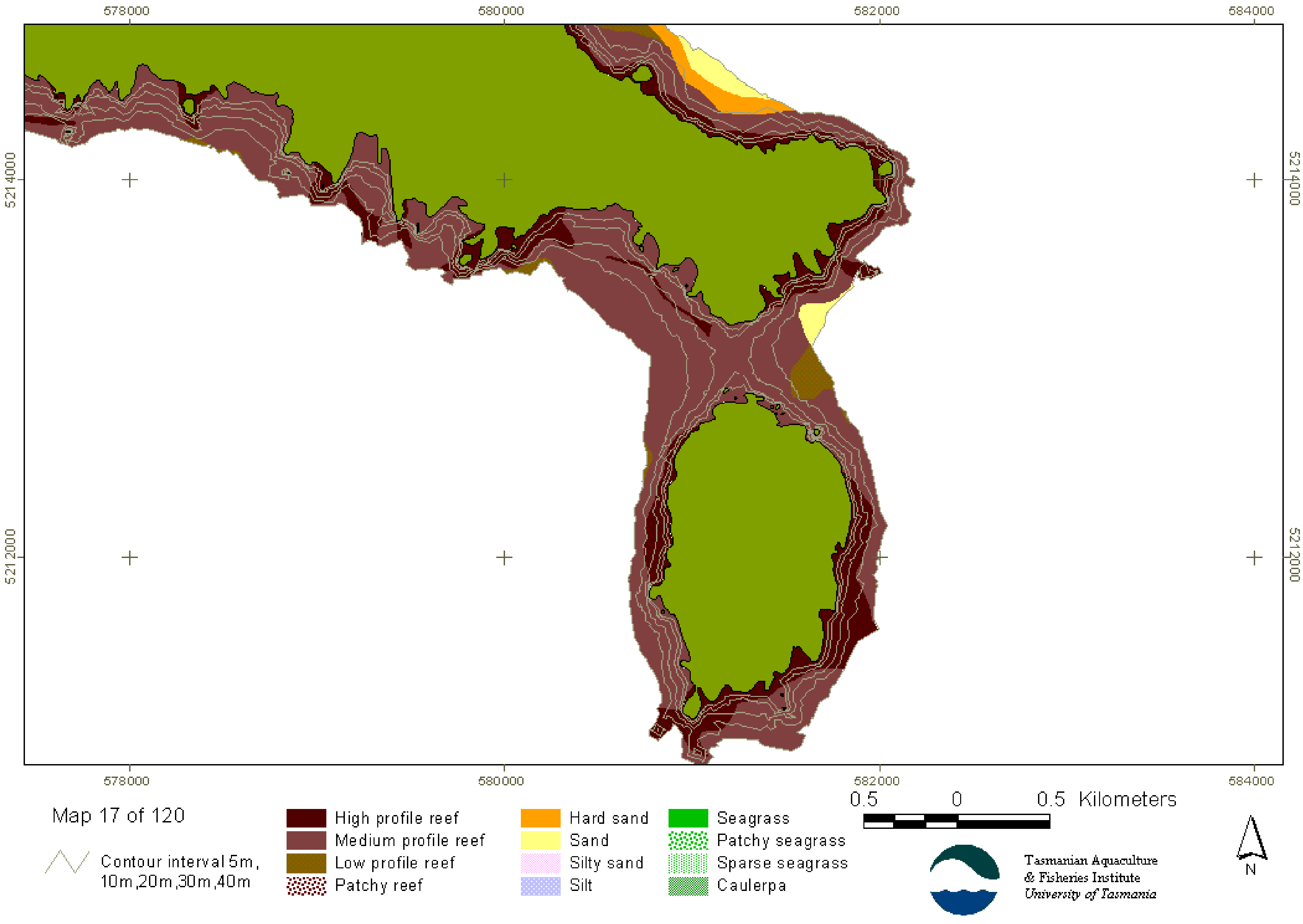
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Map 17 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Contour interval 5m, 10m,20m,30m,40m
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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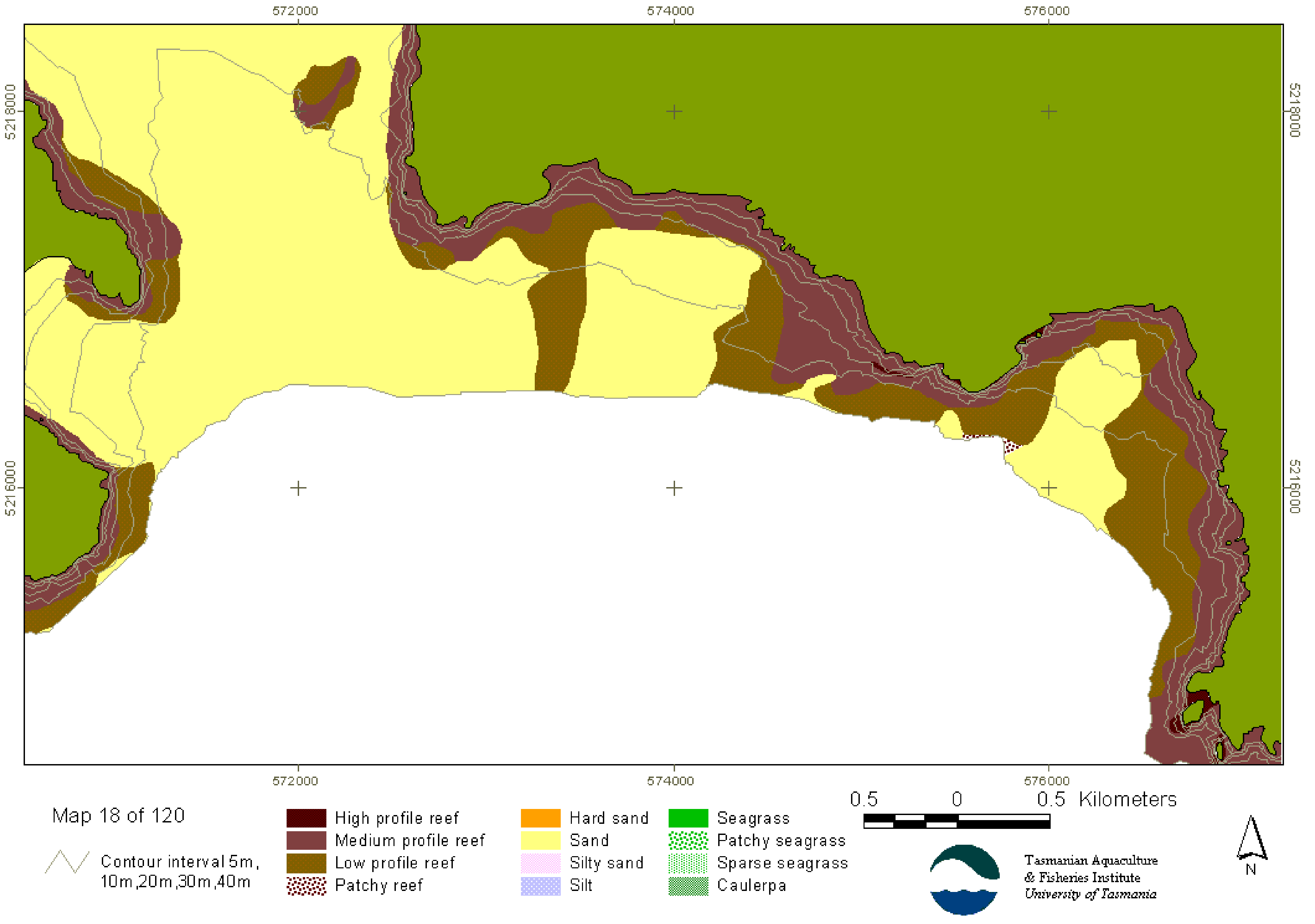
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Map 18 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

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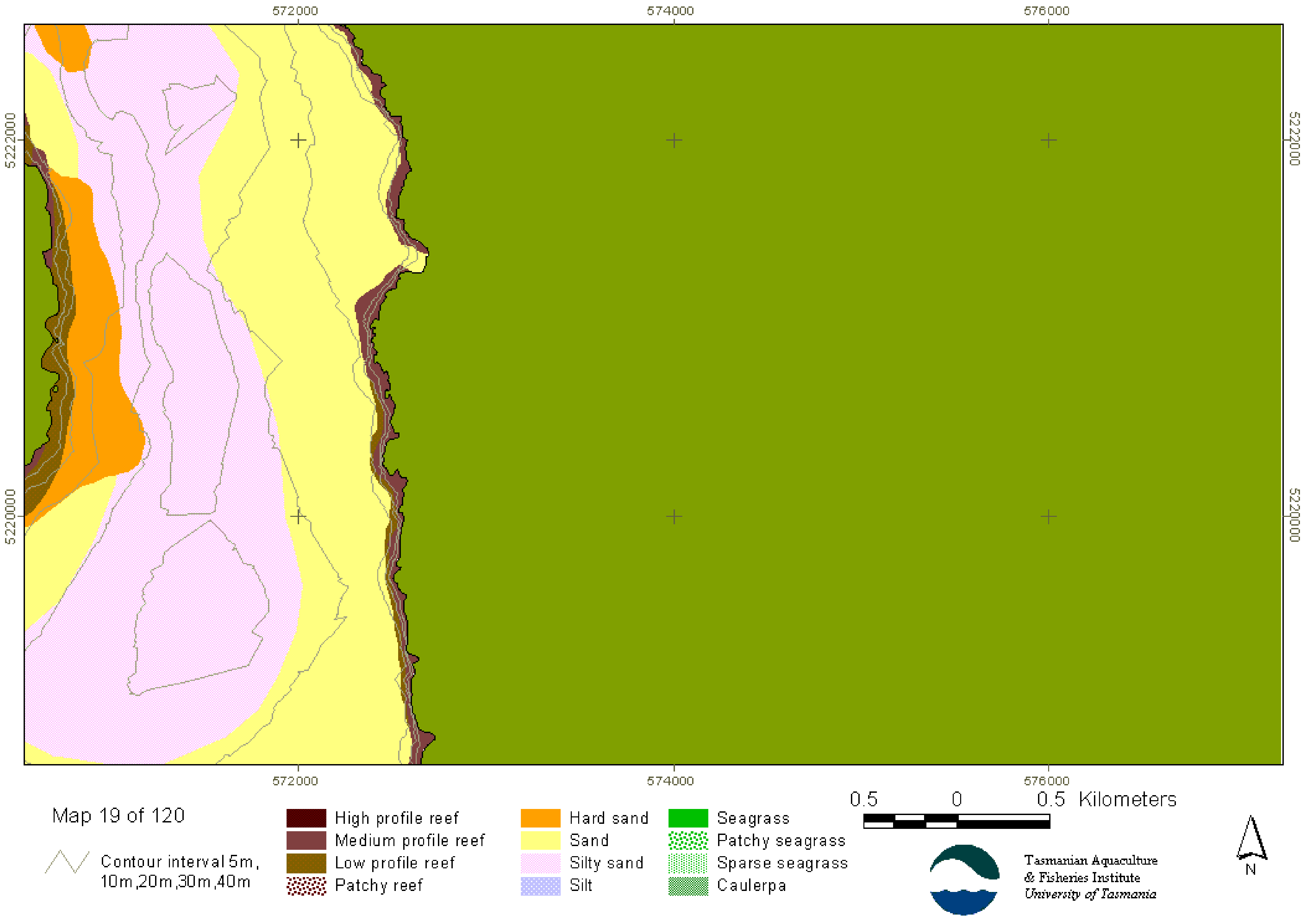
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Map 19 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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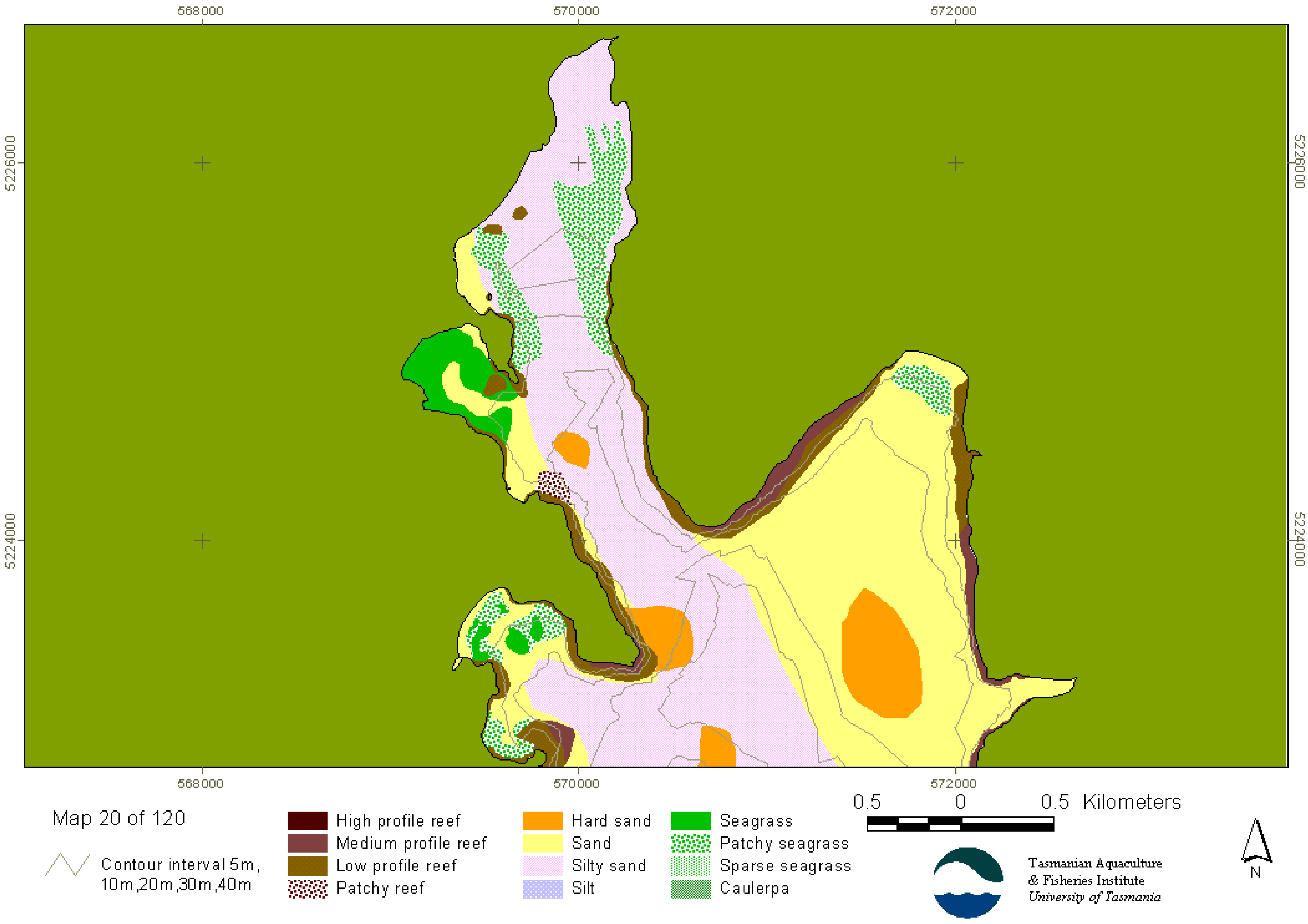
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Map 20 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
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Tasmanian Aquaculture
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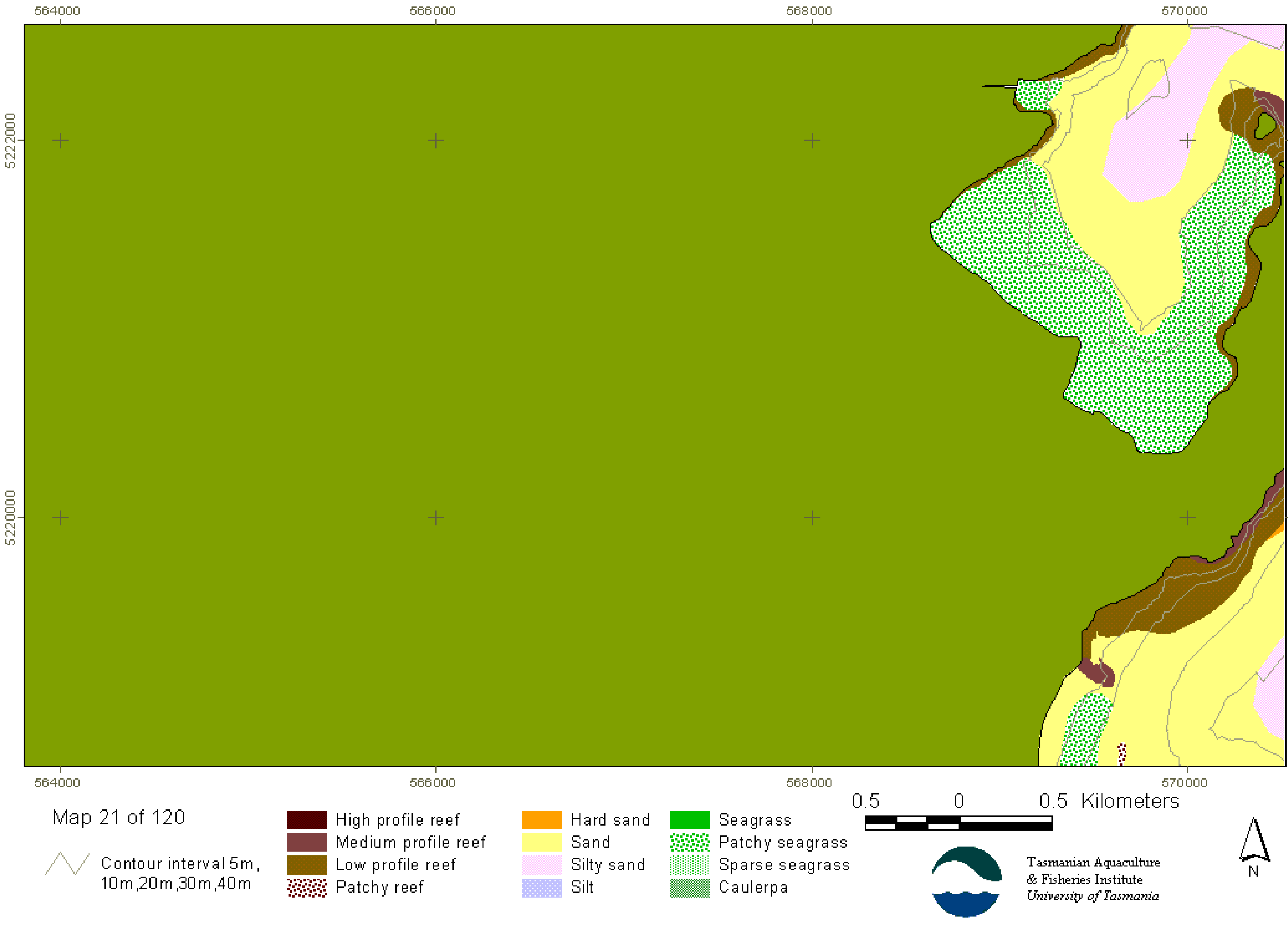
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5220000
Map 21 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Contour interval 5m, 10m,20m,30m,40m
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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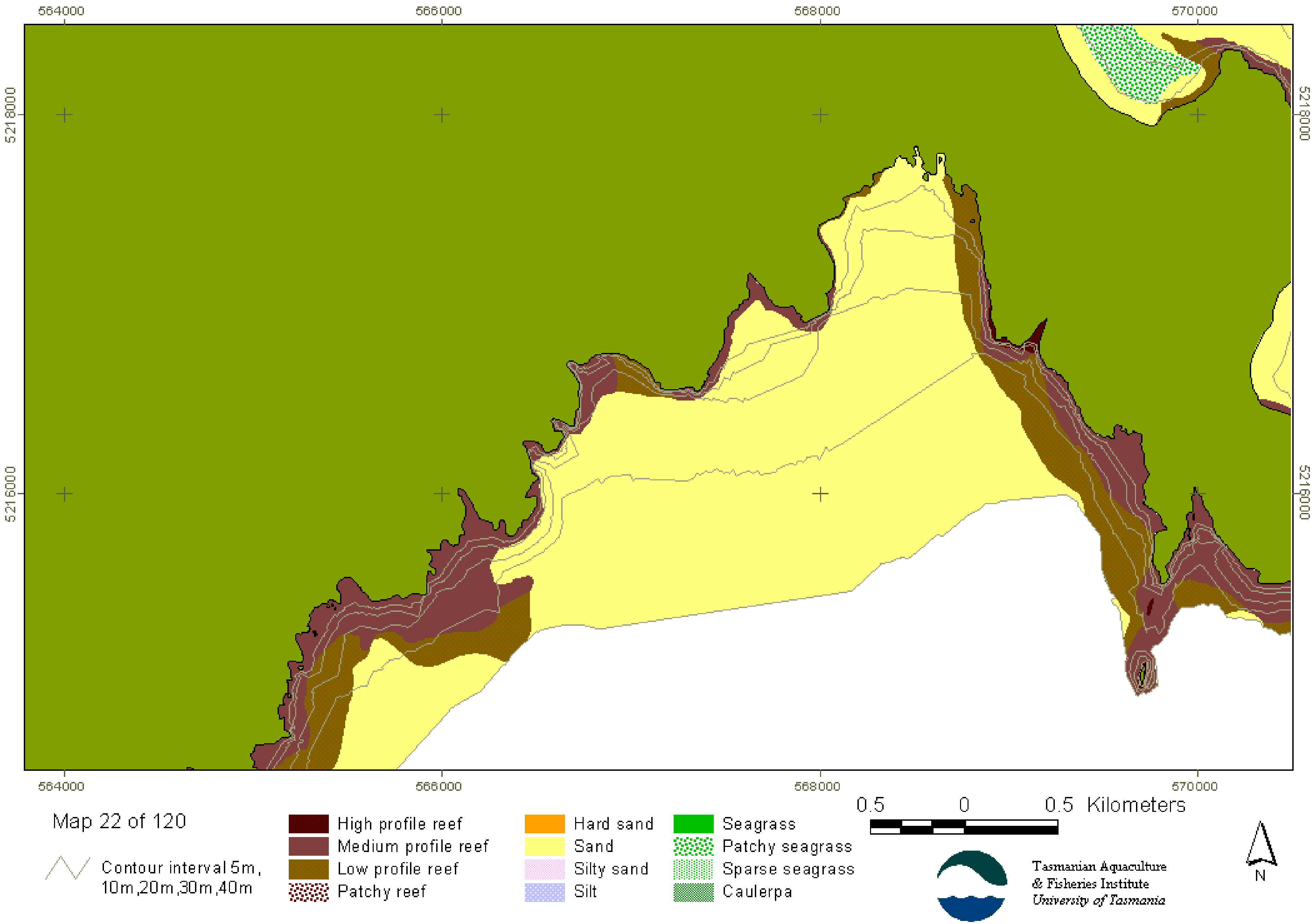
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5216000
Map 22 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania
N

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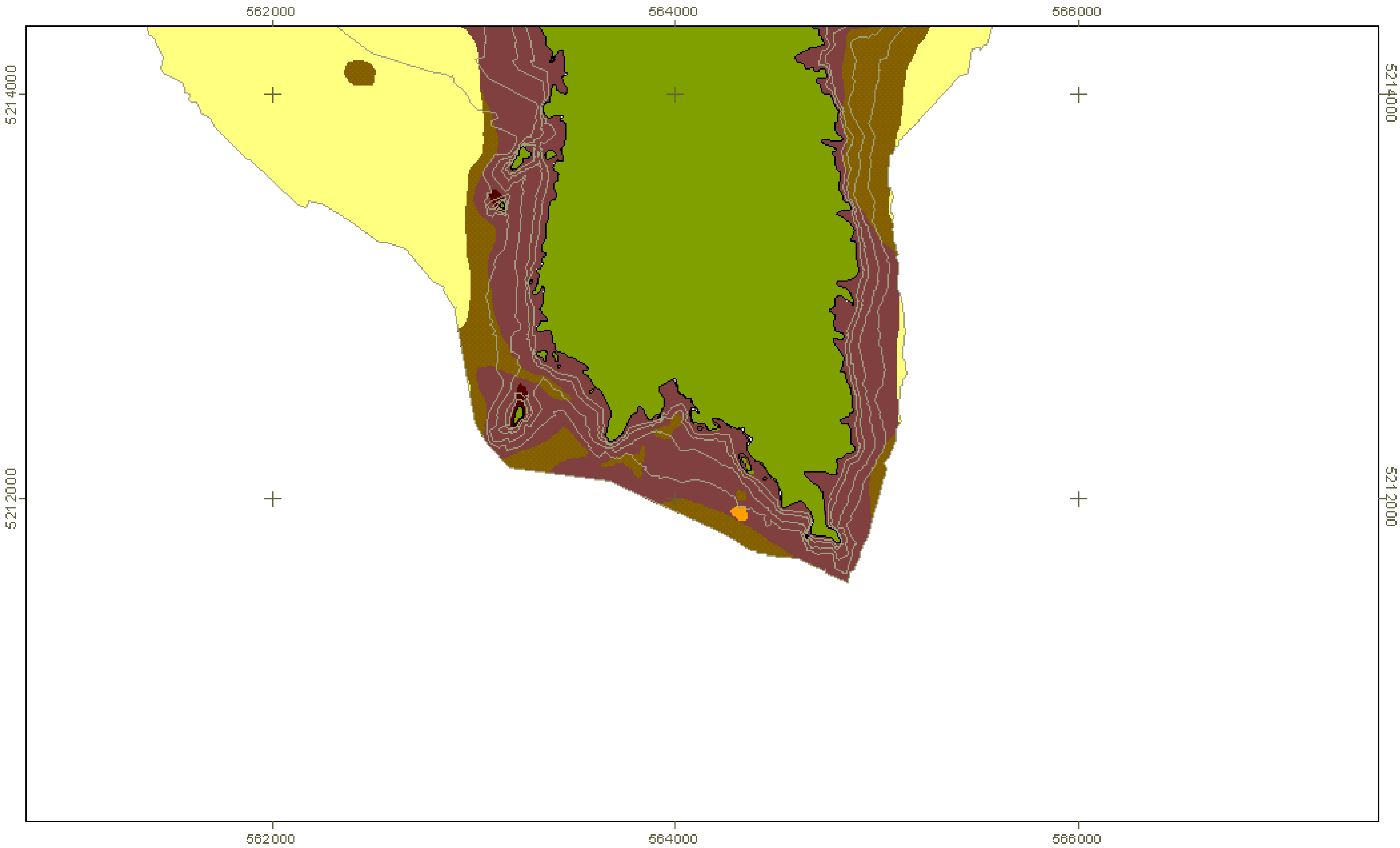

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

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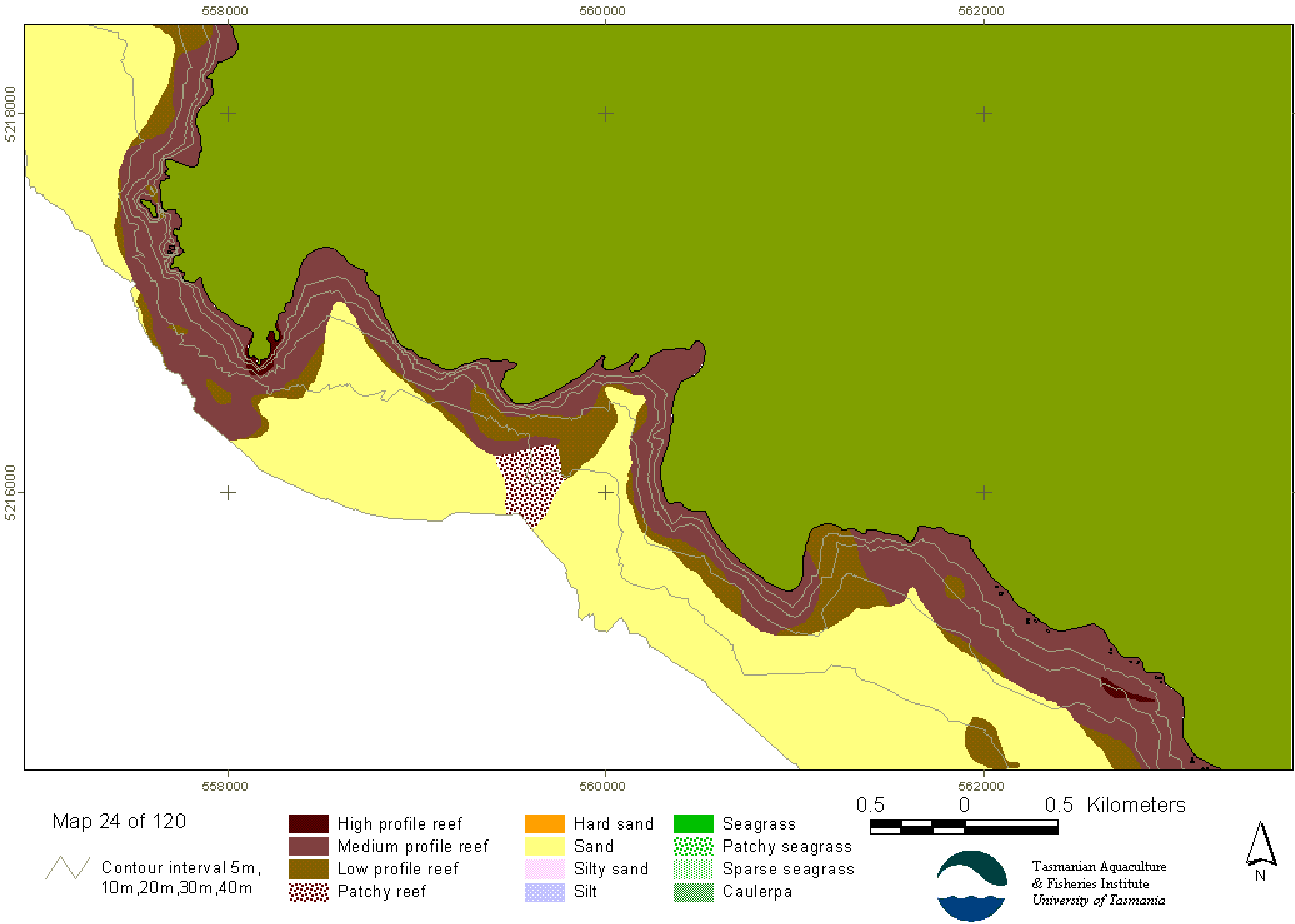
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Map 24 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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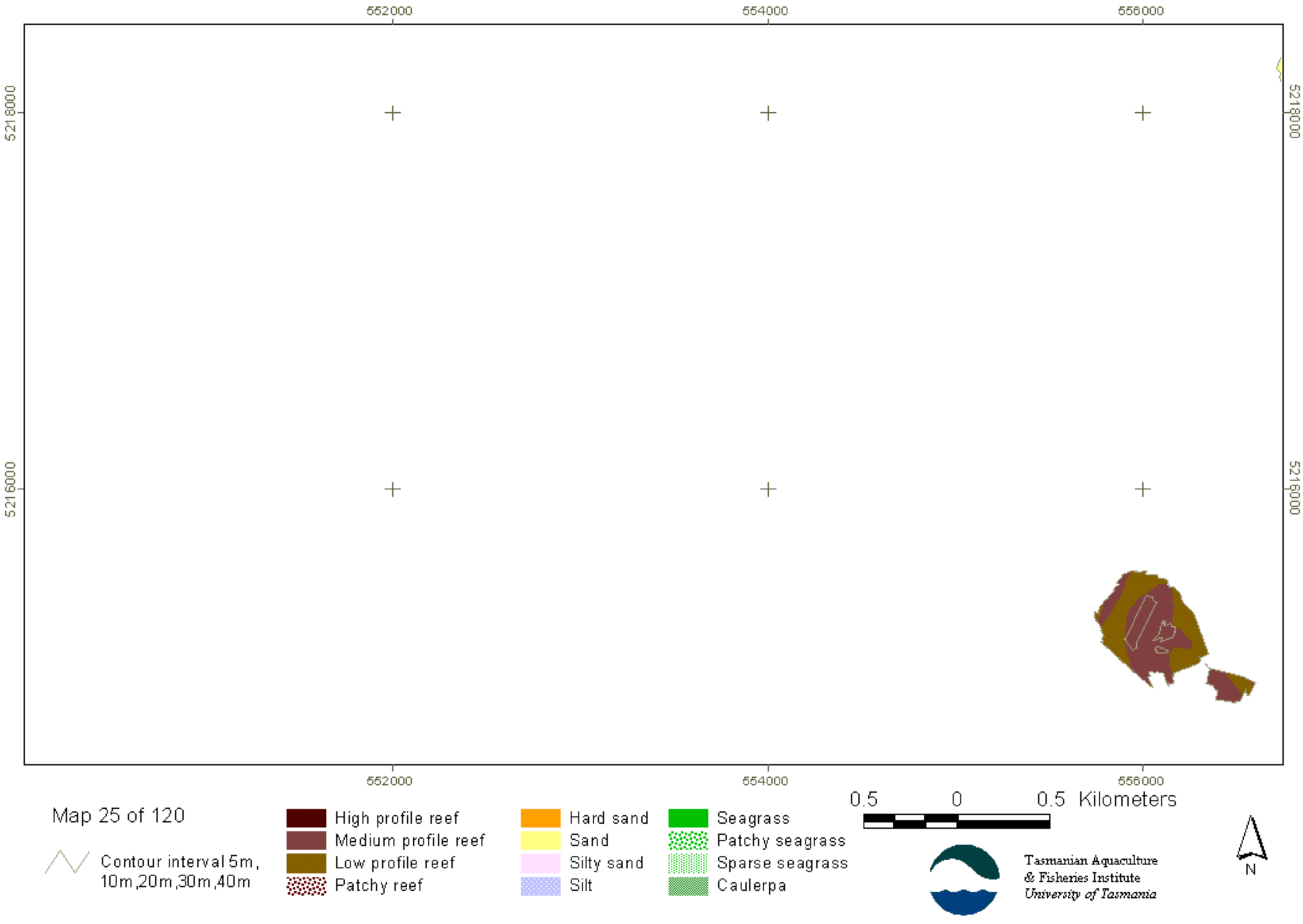
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Map 25 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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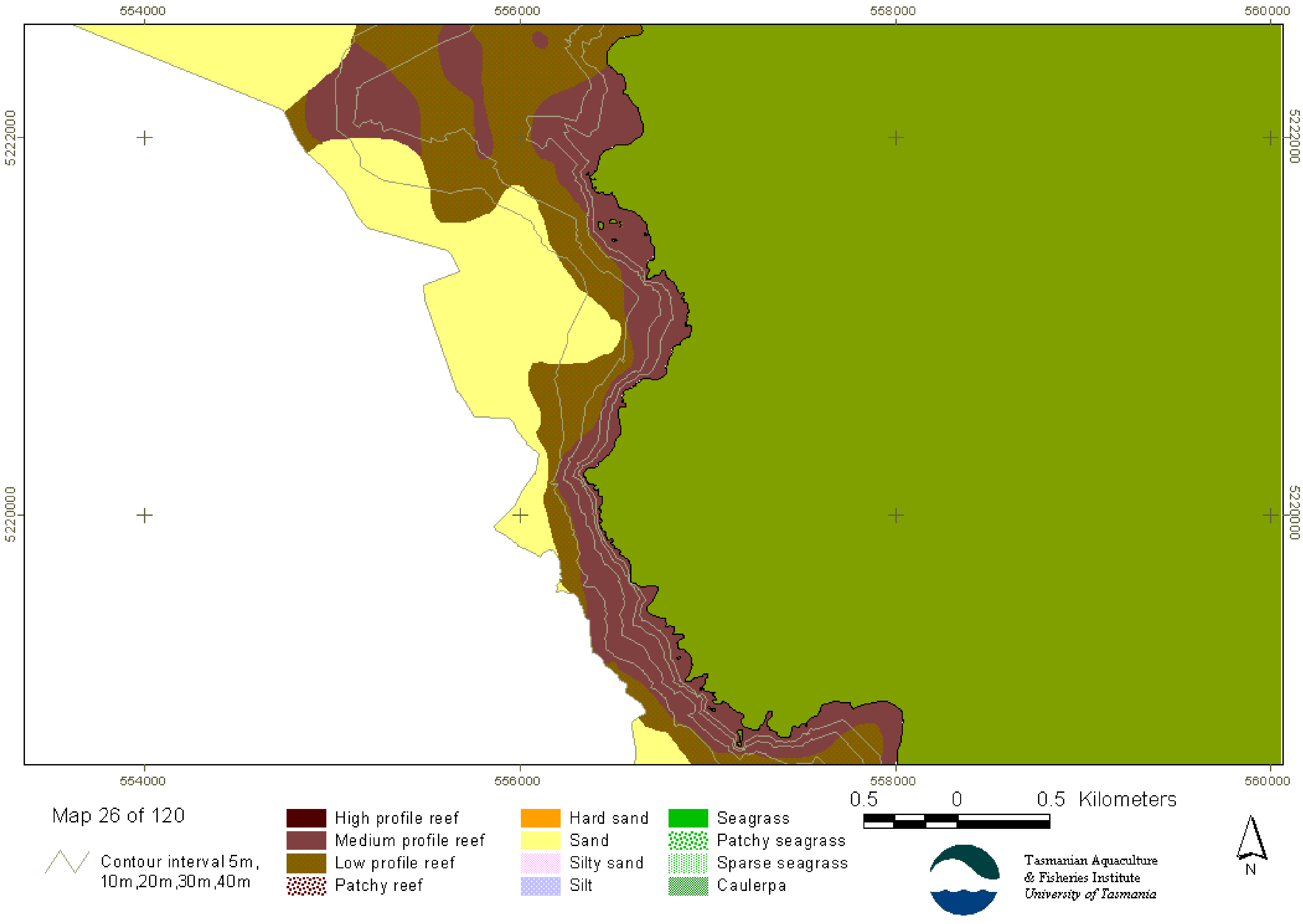
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Map 26 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
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Tasmanian Aquaculture
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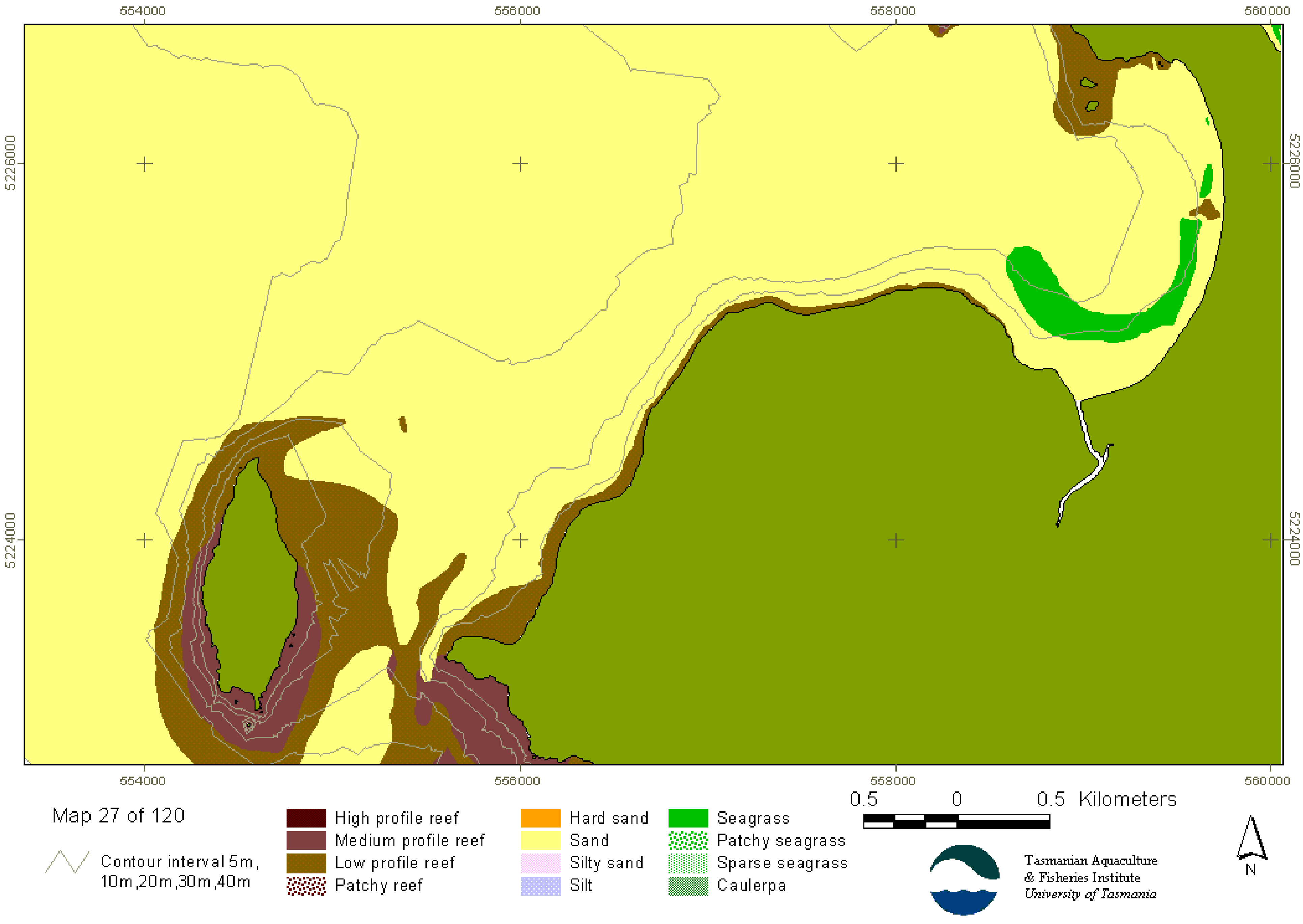

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Map 27 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Contour interval 5m, 10m,20m,30m,40m
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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Map 28 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

0.5 0 0.5 Kilometers

N

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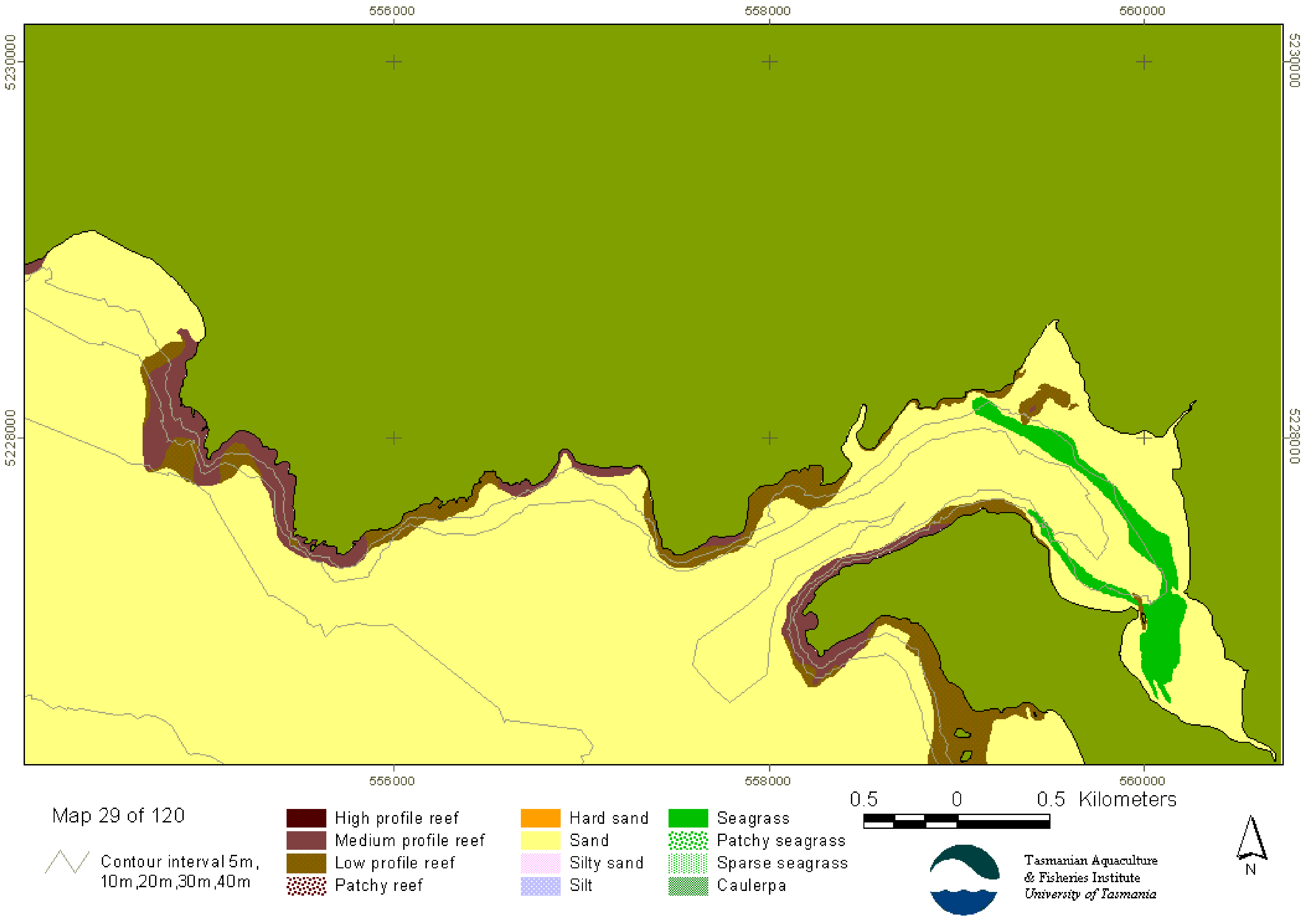
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Map 29 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Contour interval 5m, 10m,20m,30m,40m
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N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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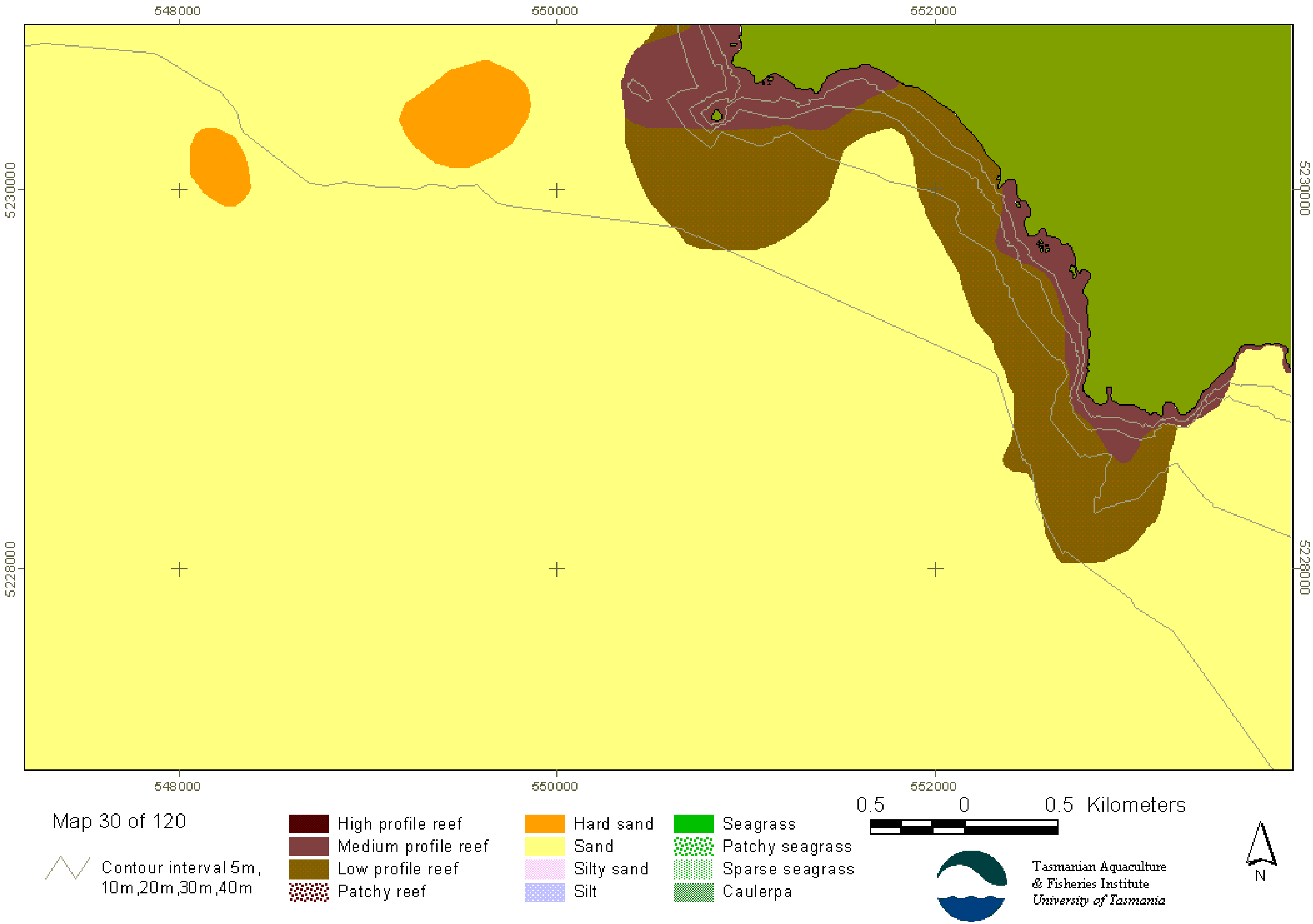
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Map 30 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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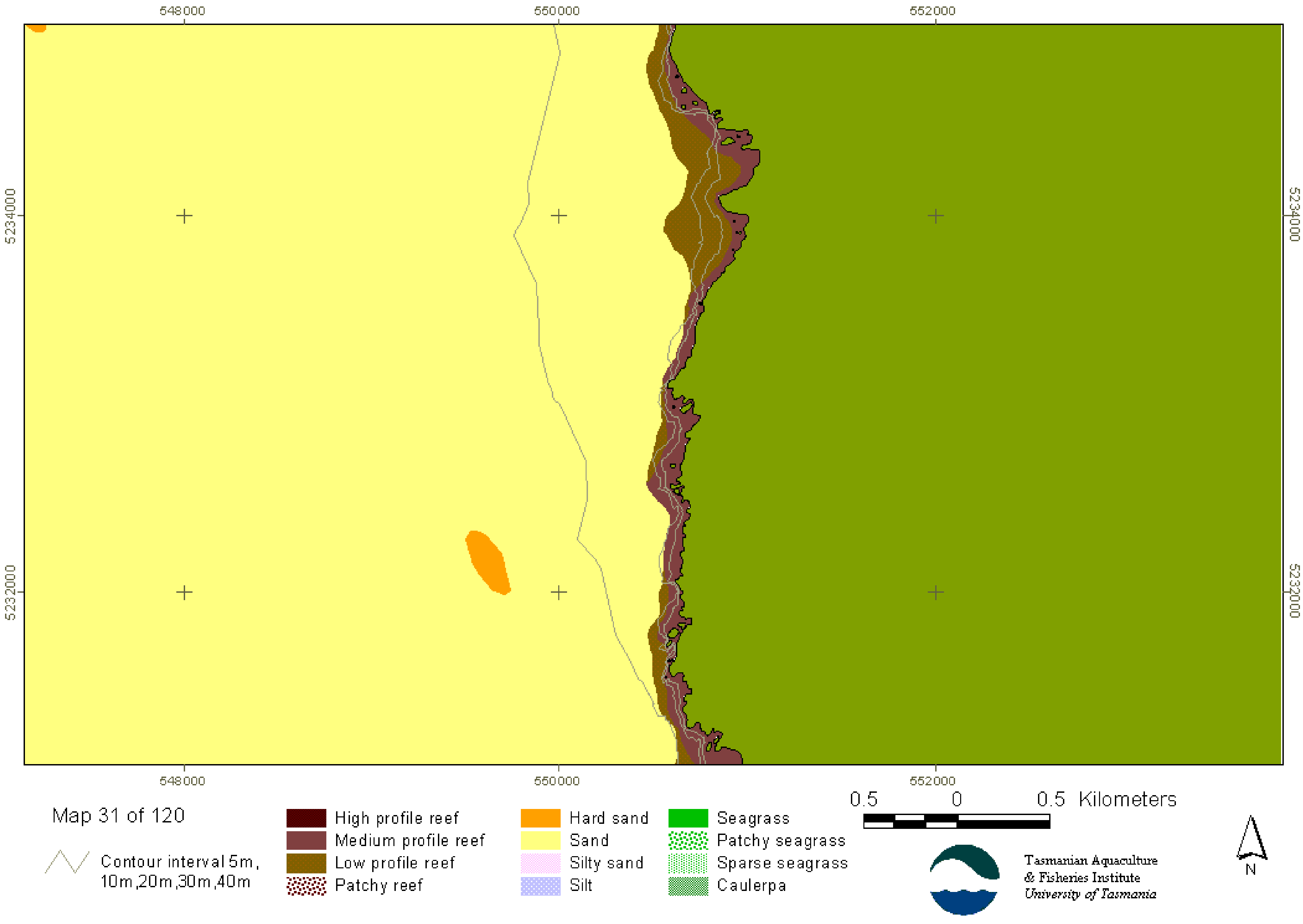
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Map 31 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

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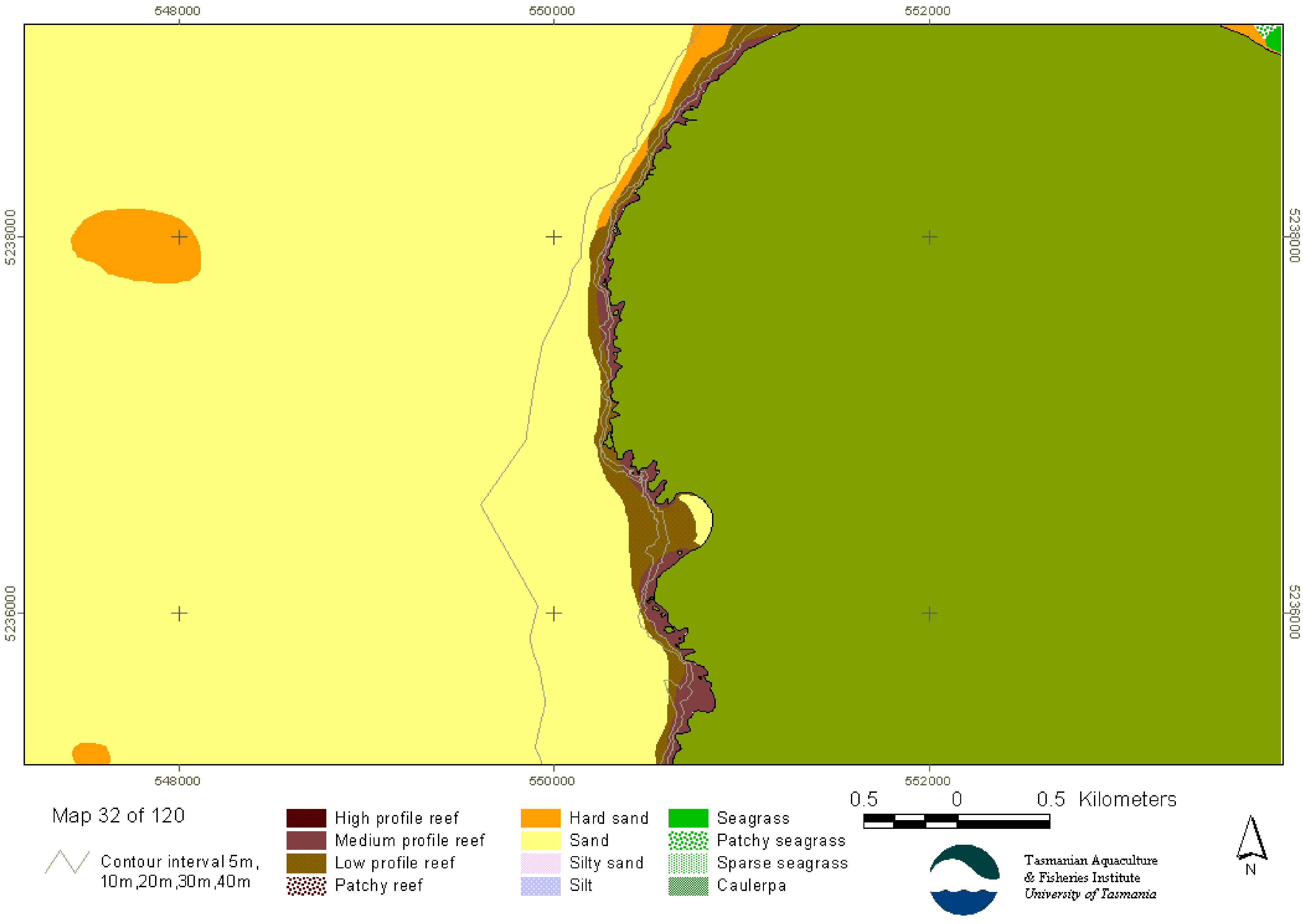
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Map 32 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
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Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania

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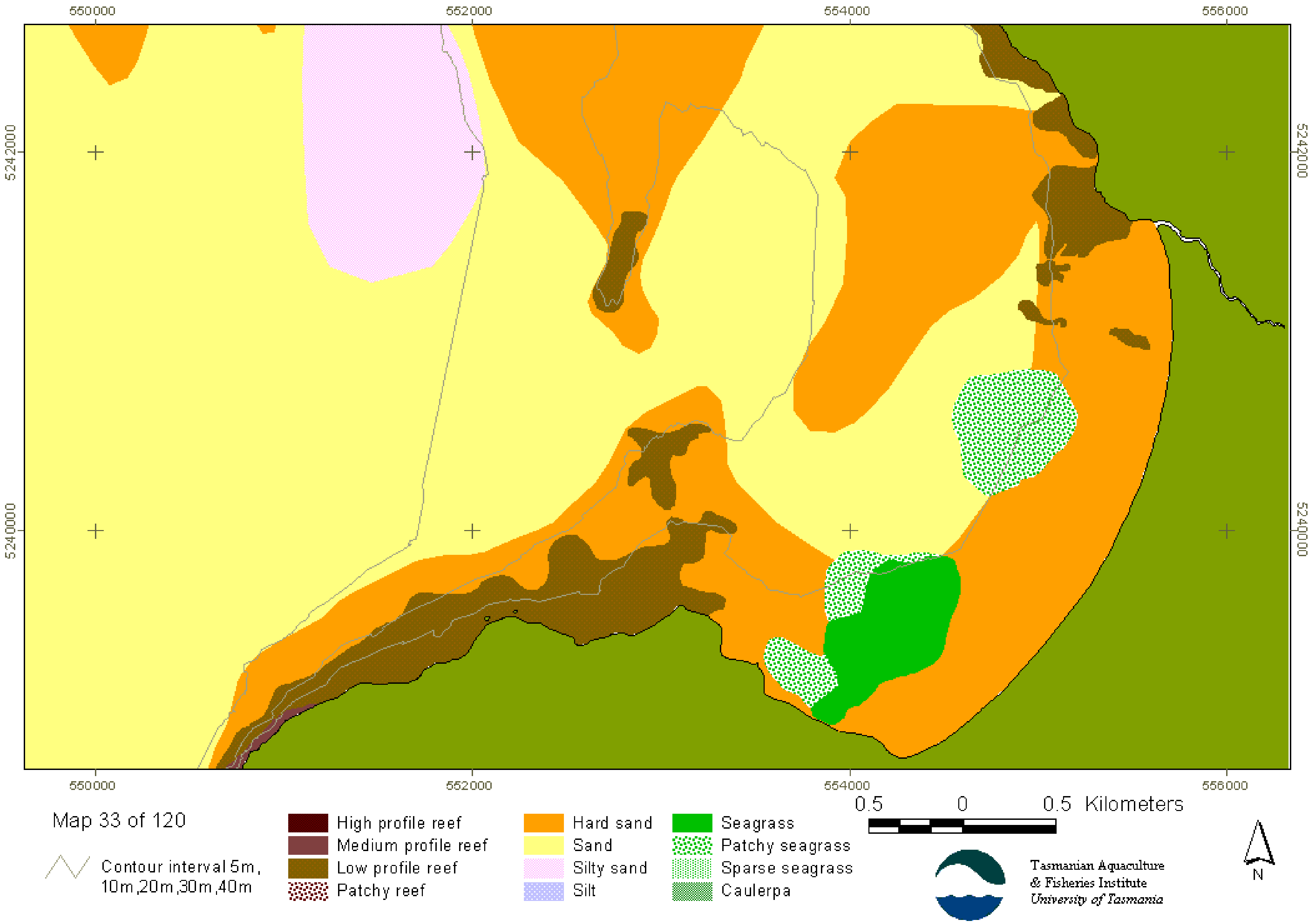

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Map 33 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania
N

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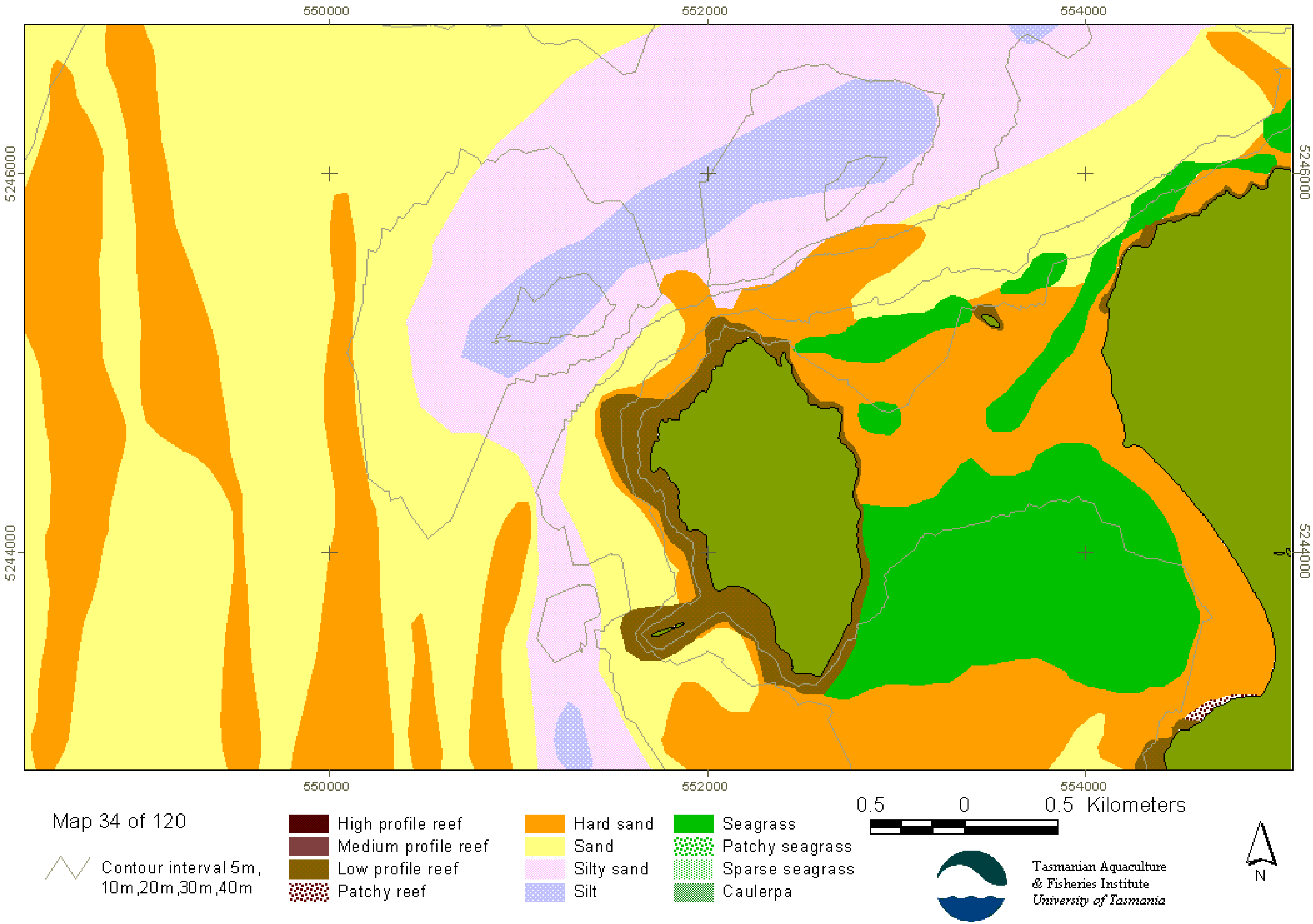
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Map 34 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

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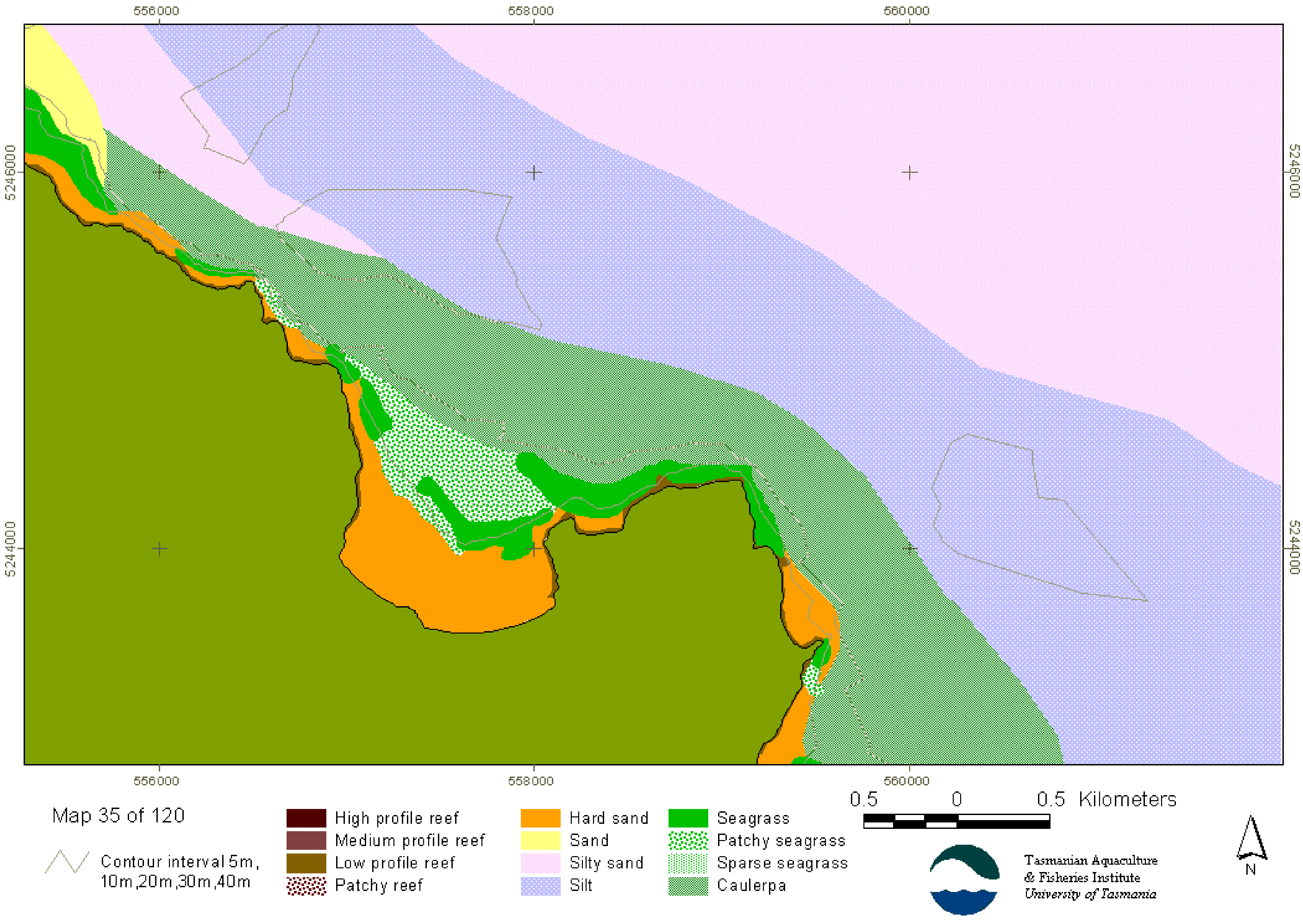
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Map 35 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
& Fisheries Institute
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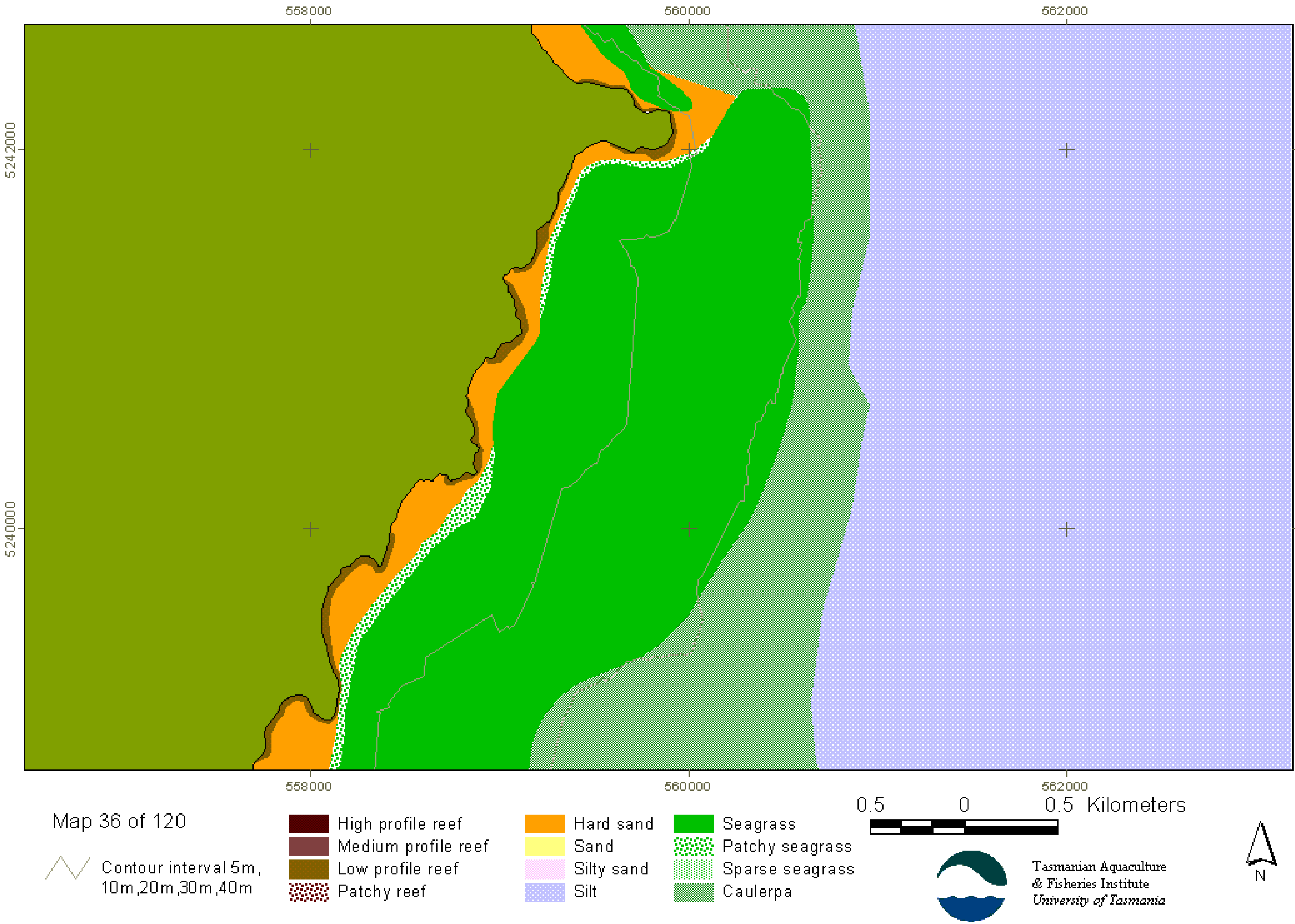
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Map 36 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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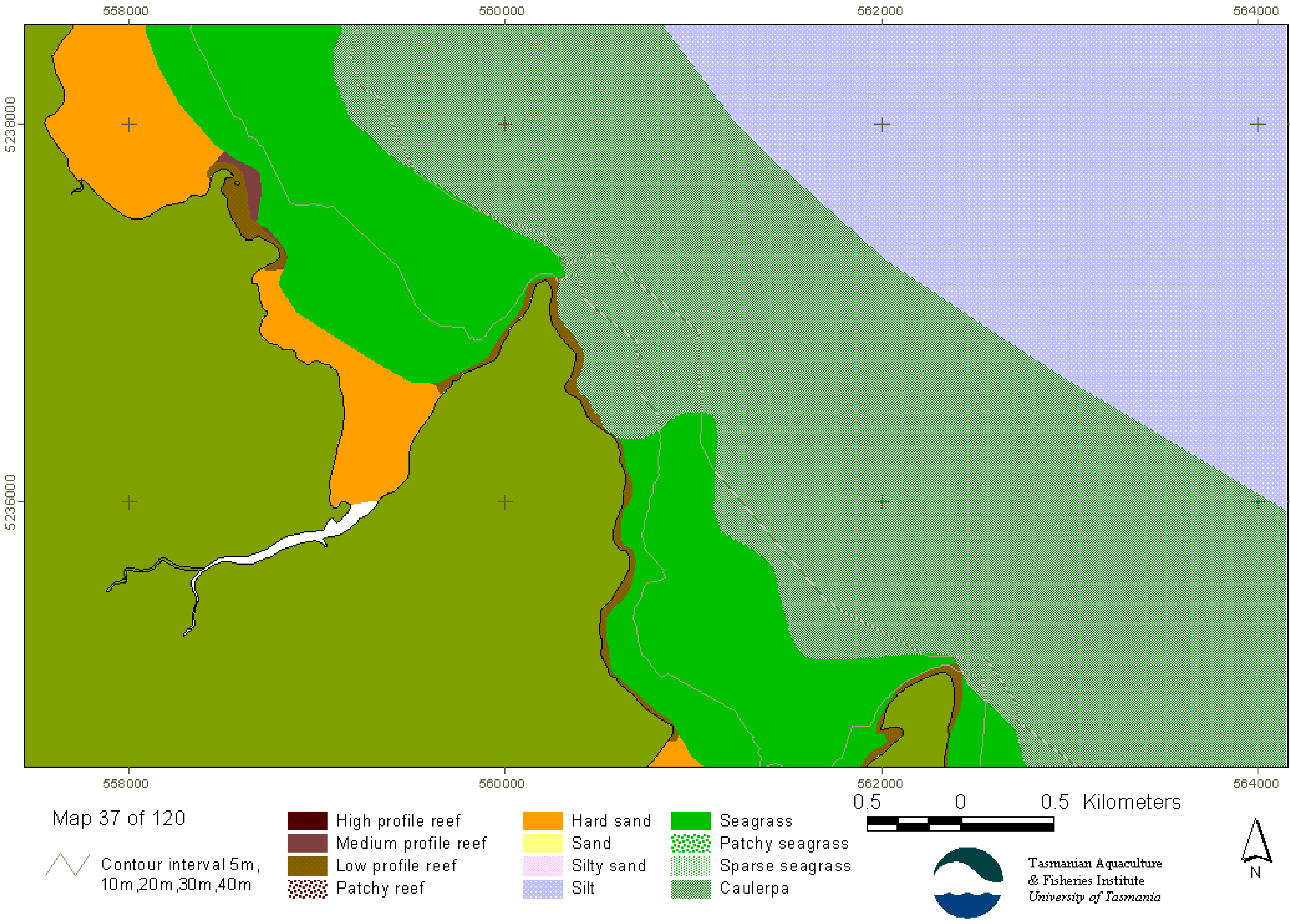
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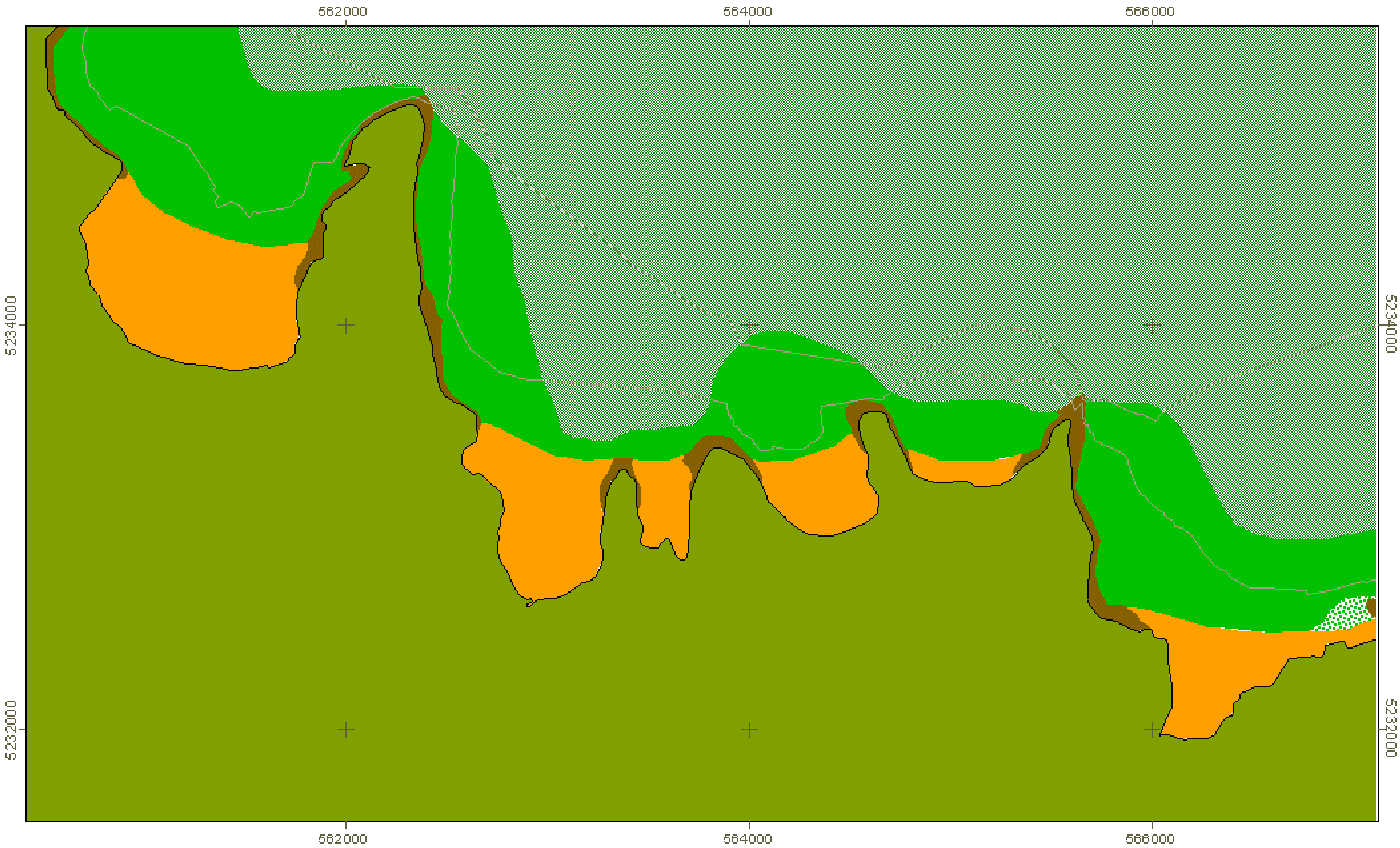
5238000
5236000
Map 37 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania

Back



Map 38 of 120

Contour interval 5m, 10m,20m,30m,40m

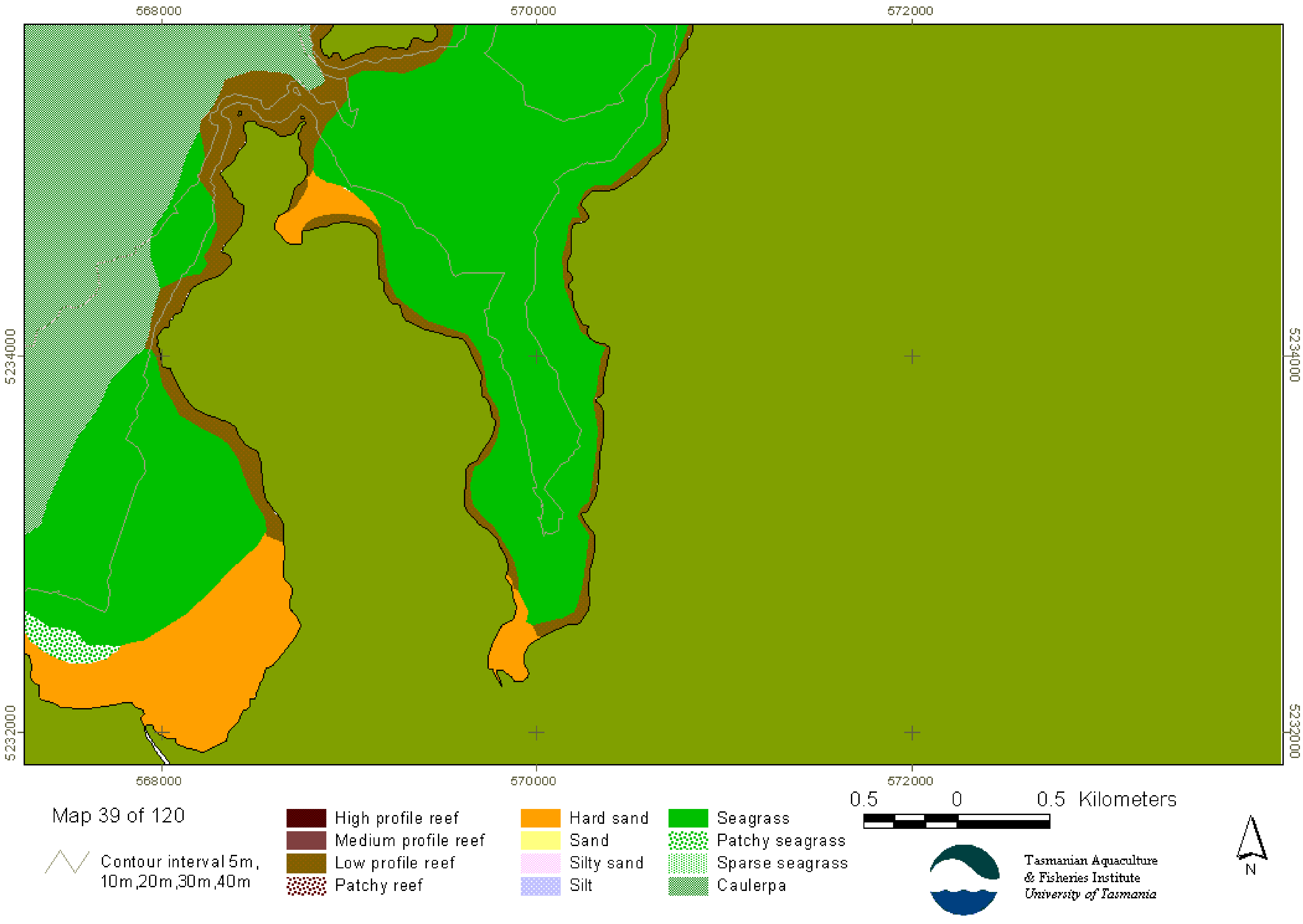
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

0.5 0 0.5 Kilometers

N

Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

Back


568000
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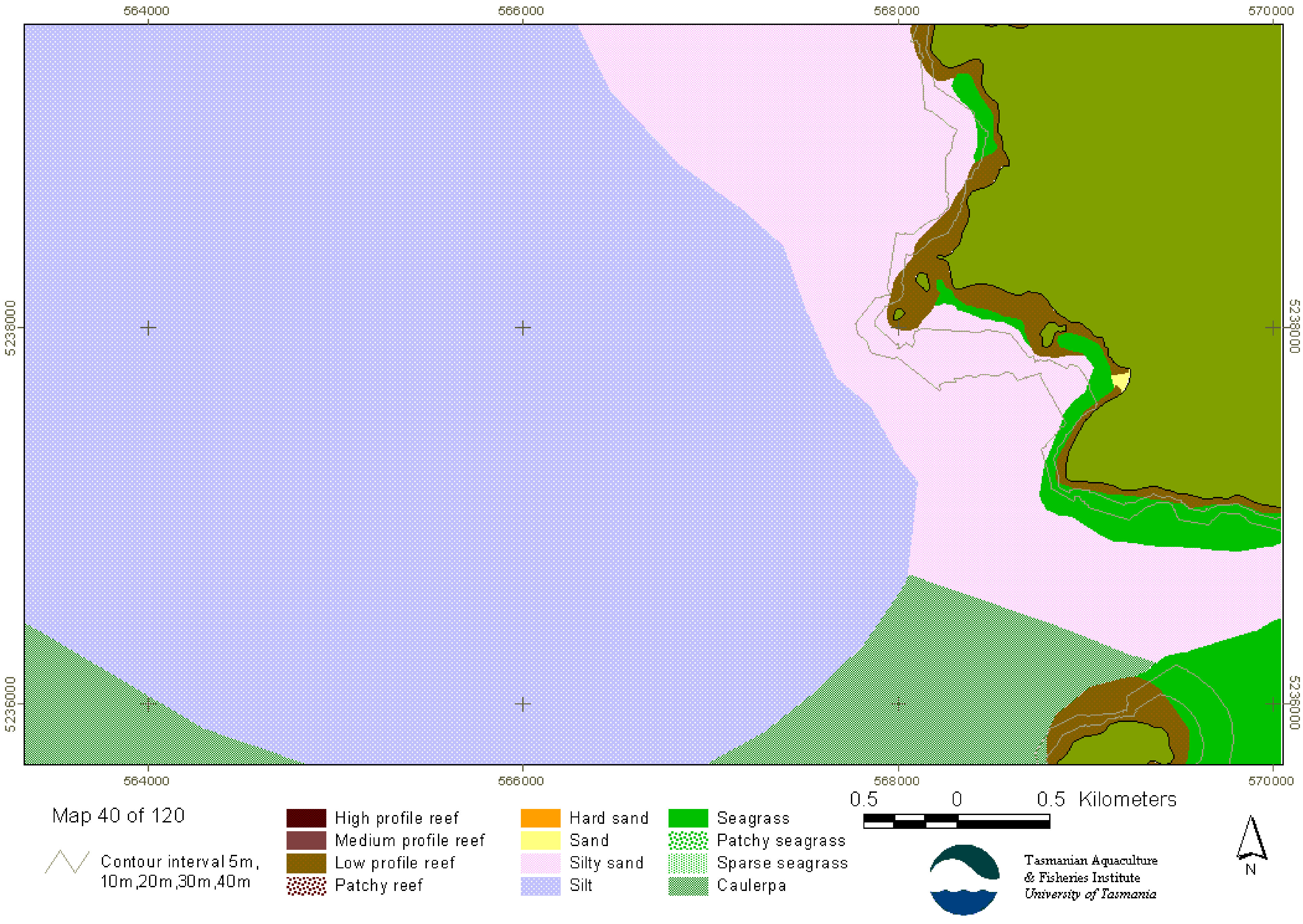
572000
5234000
5232000
Map 39 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back


564000
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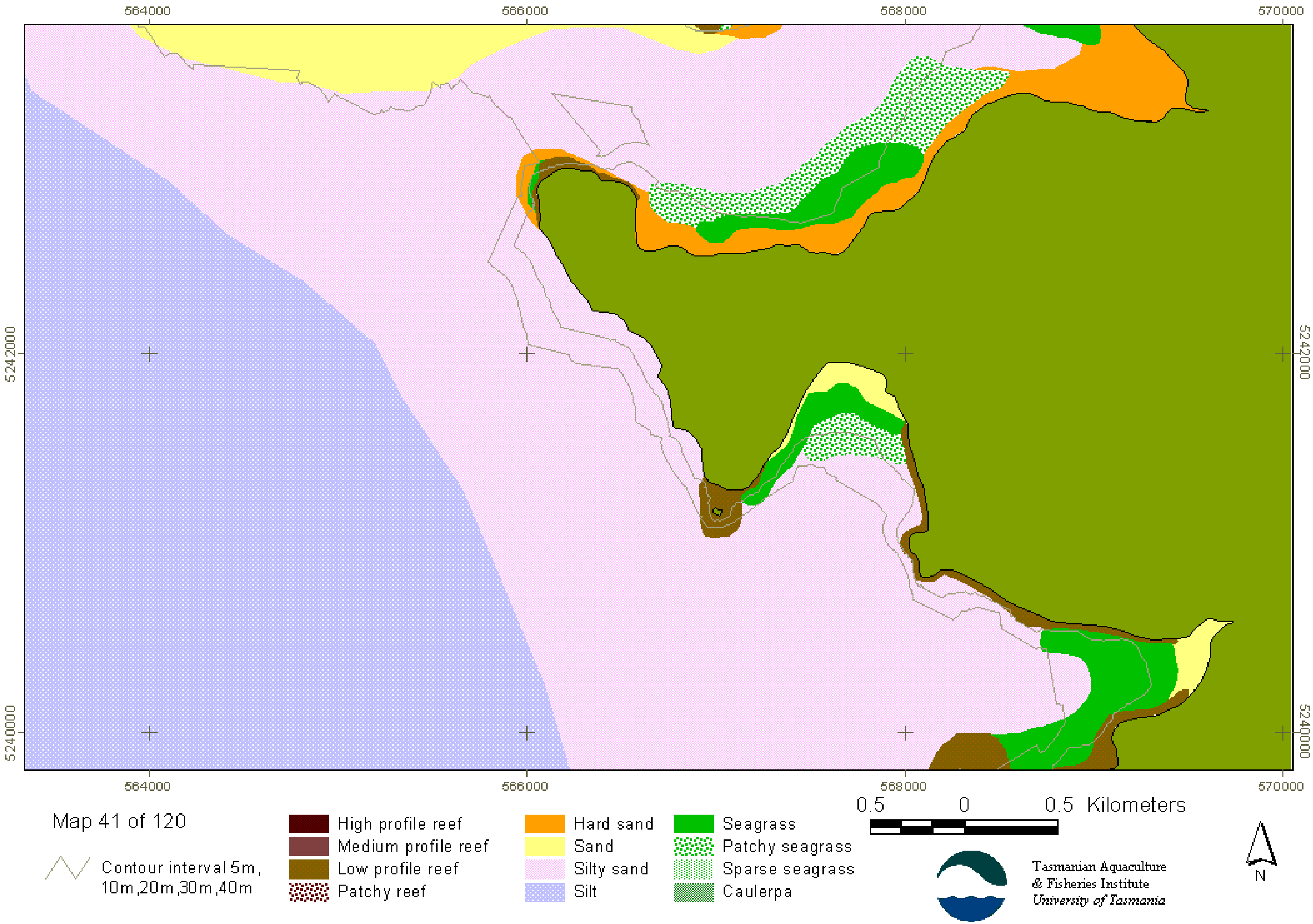
570000
5238000
5236000
Map 40 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania

[Back](#)



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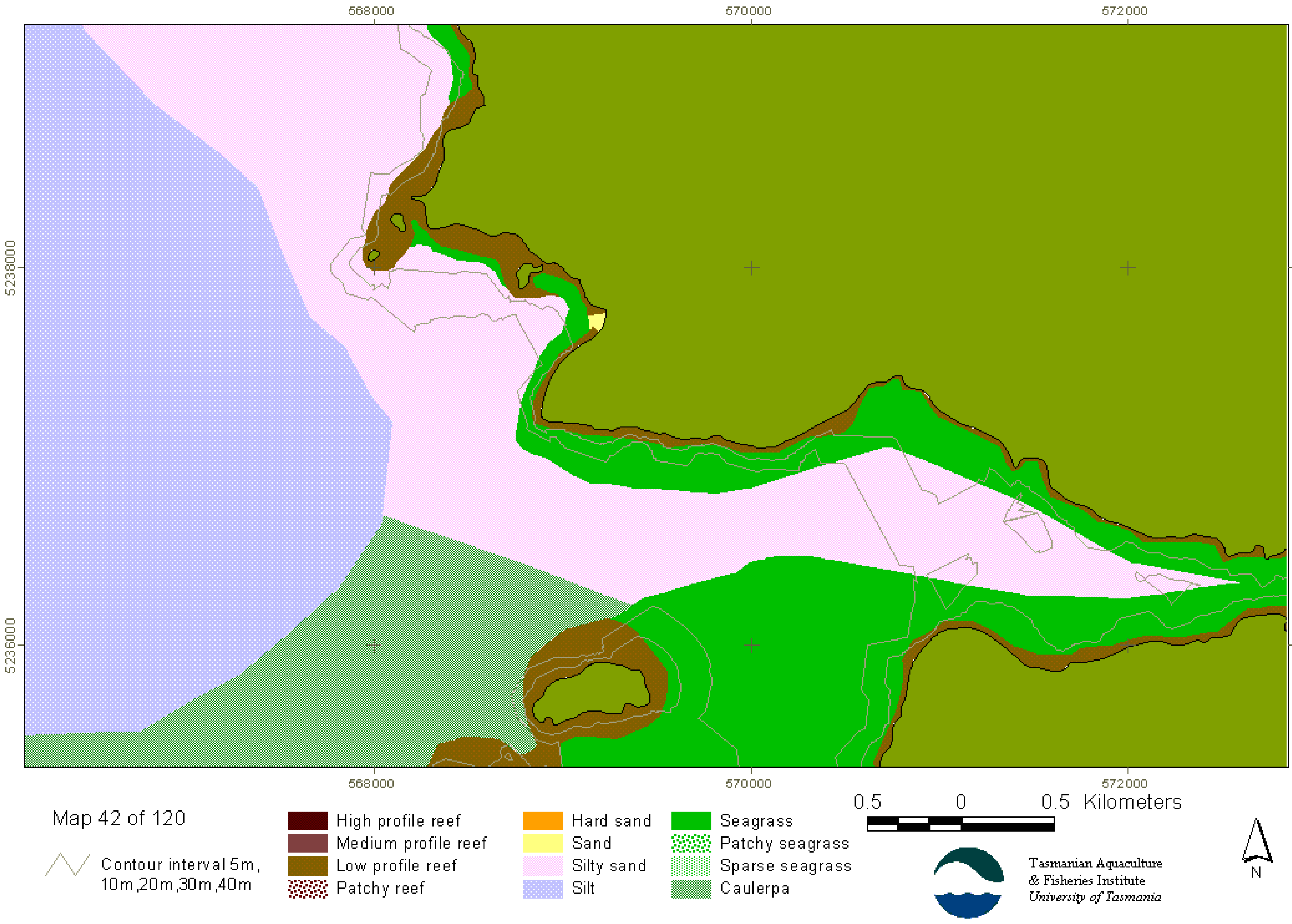
5242000
5240000
Map 41 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania

Back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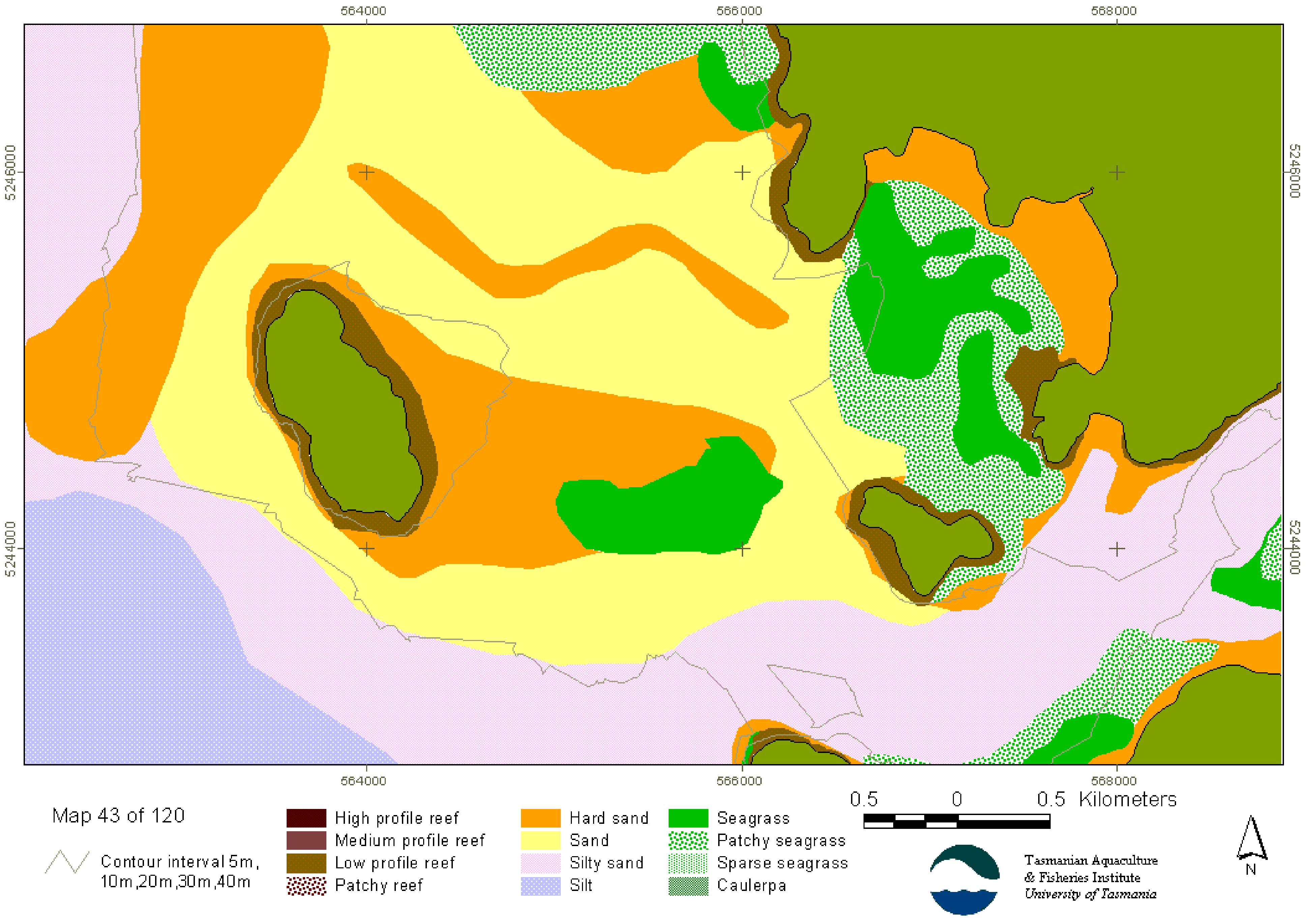
5238000
5236000
Map 42 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania
N

Back



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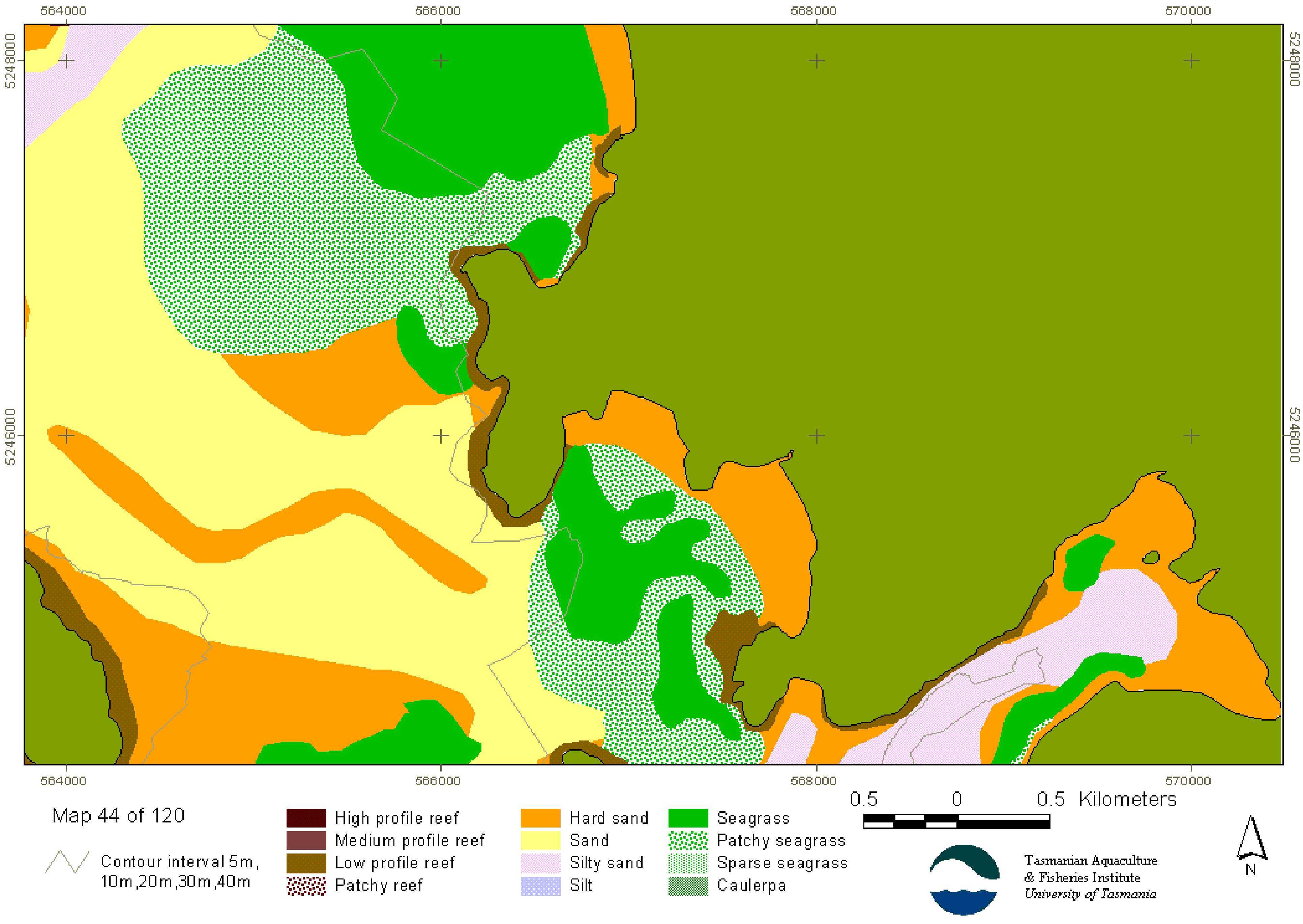
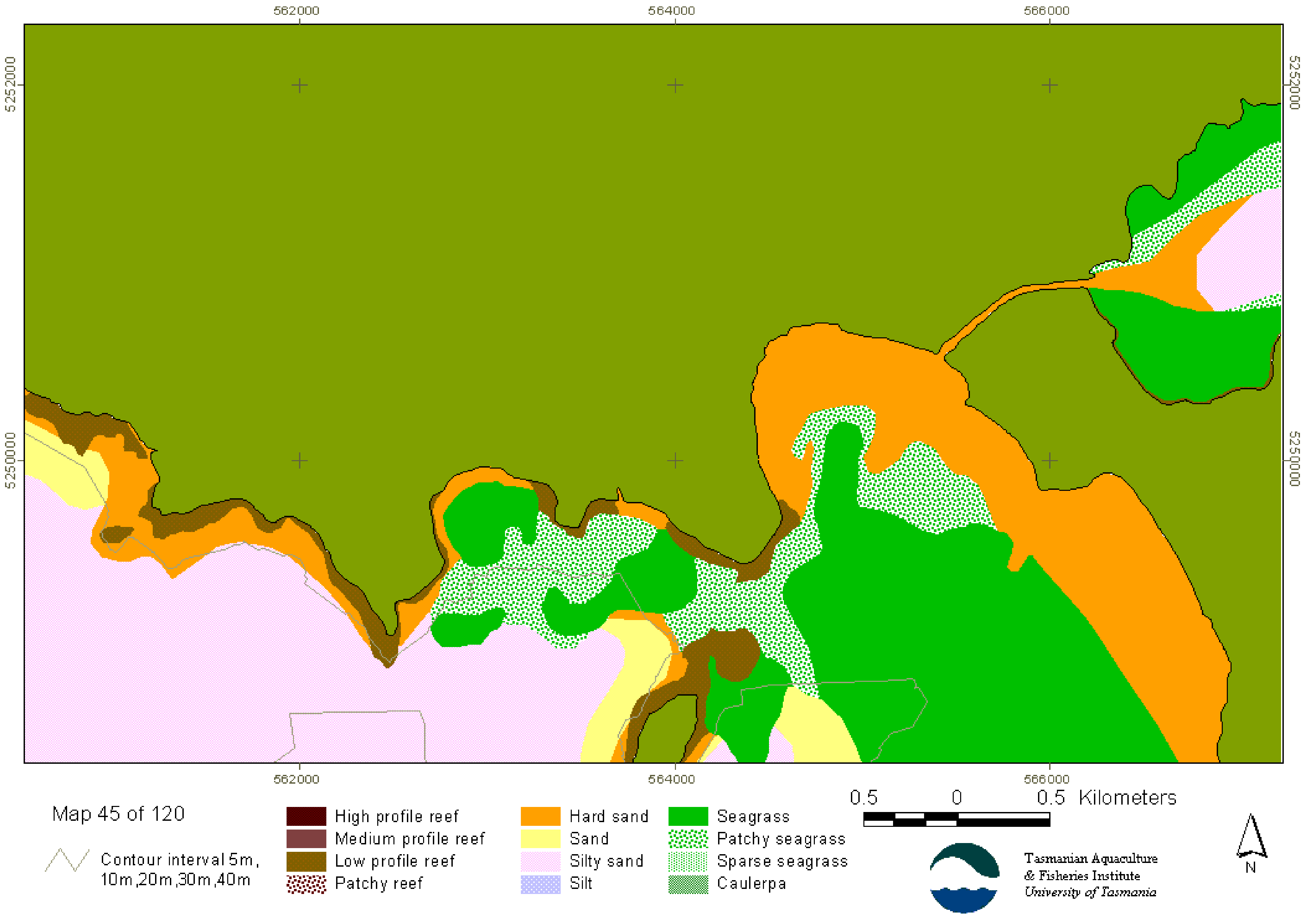
568000
5246000
5244000
Map 43 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania

Back


564000
566000
568000
570000
5248000
5246000
0.5
0
0.5 Kilometers
N
Map 44 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back


562000
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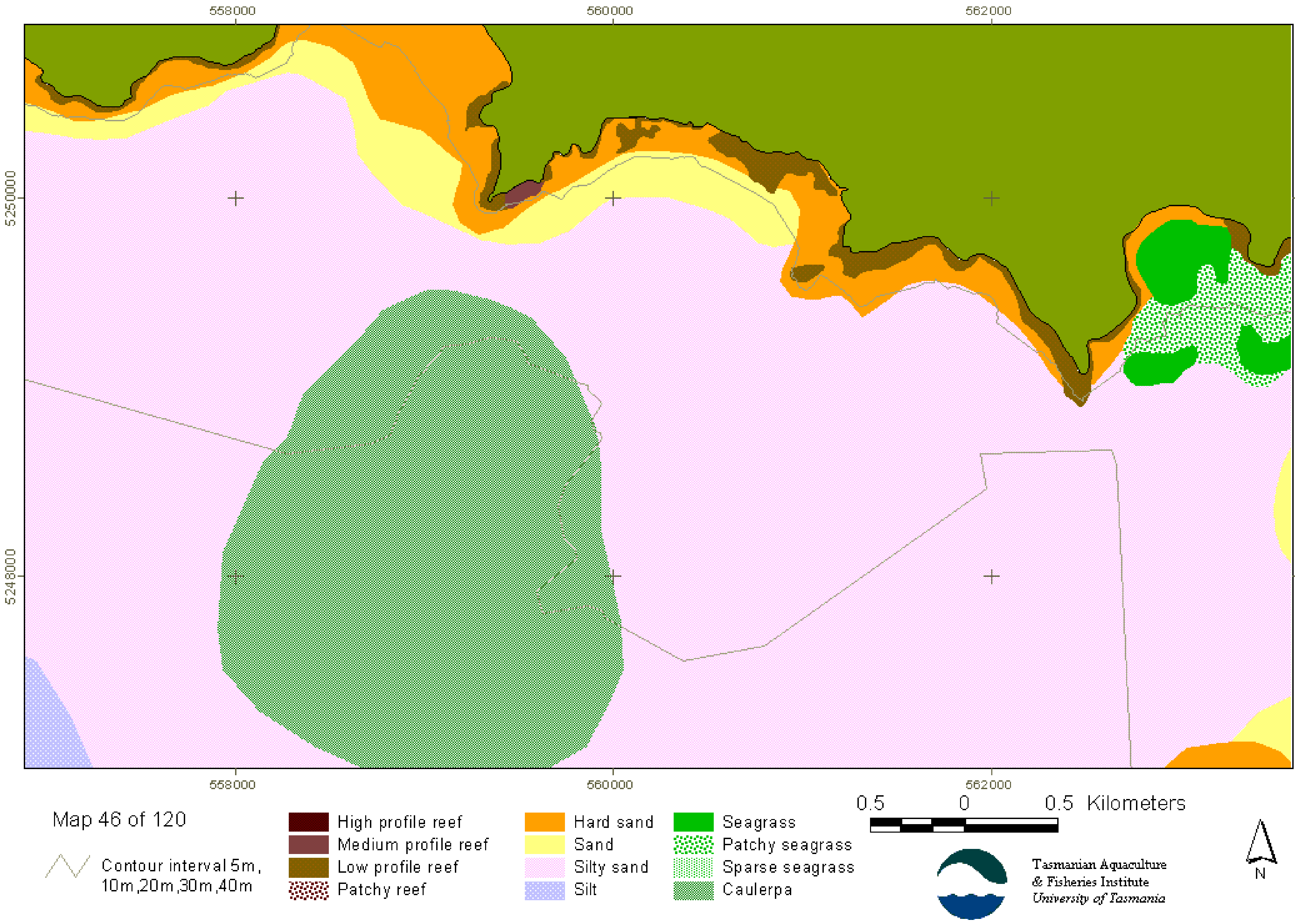
5252000
5250000
Map 45 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back



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562000
5250000
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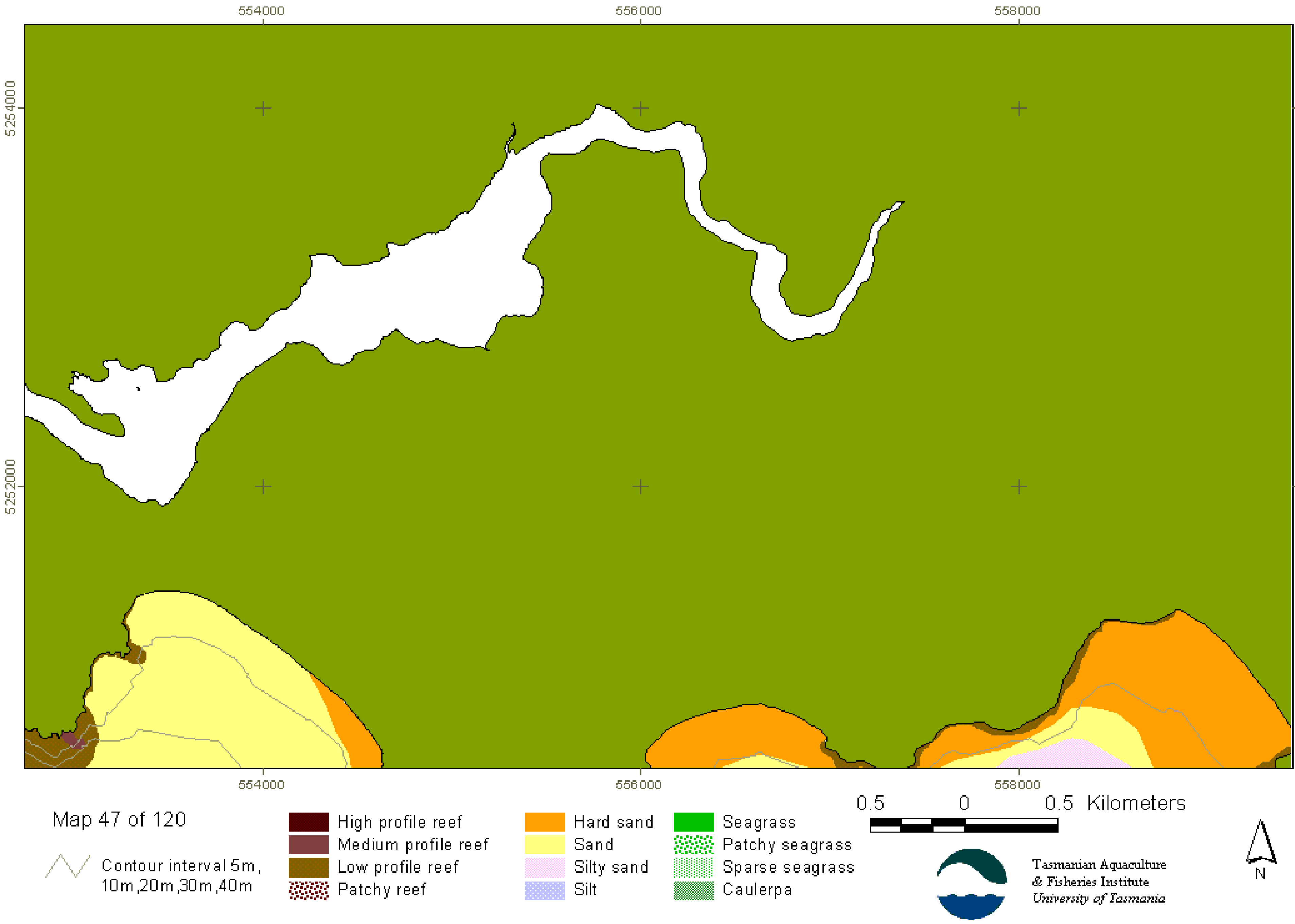
Map 46 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back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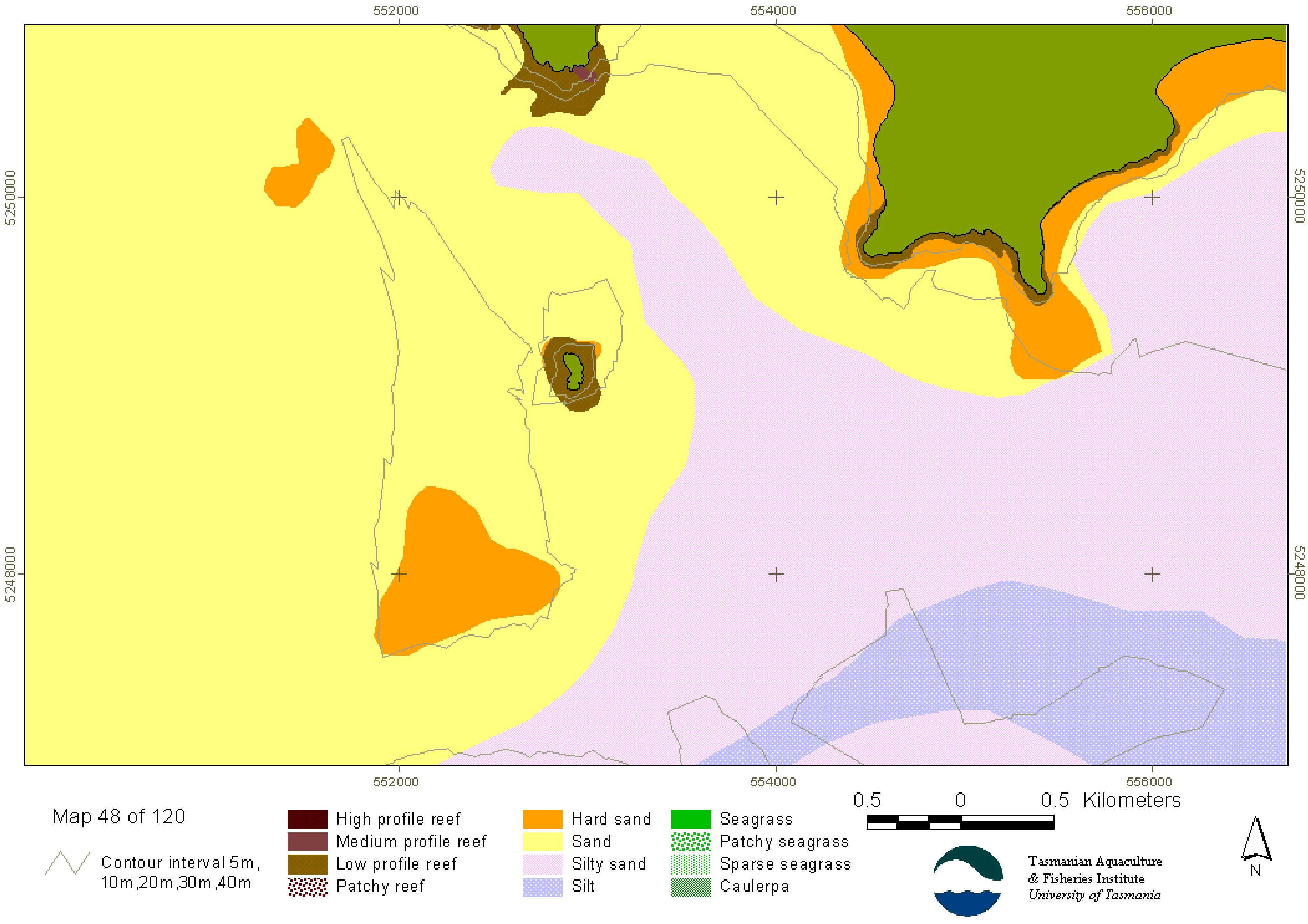
558000
5254000
5252000
Map 47 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back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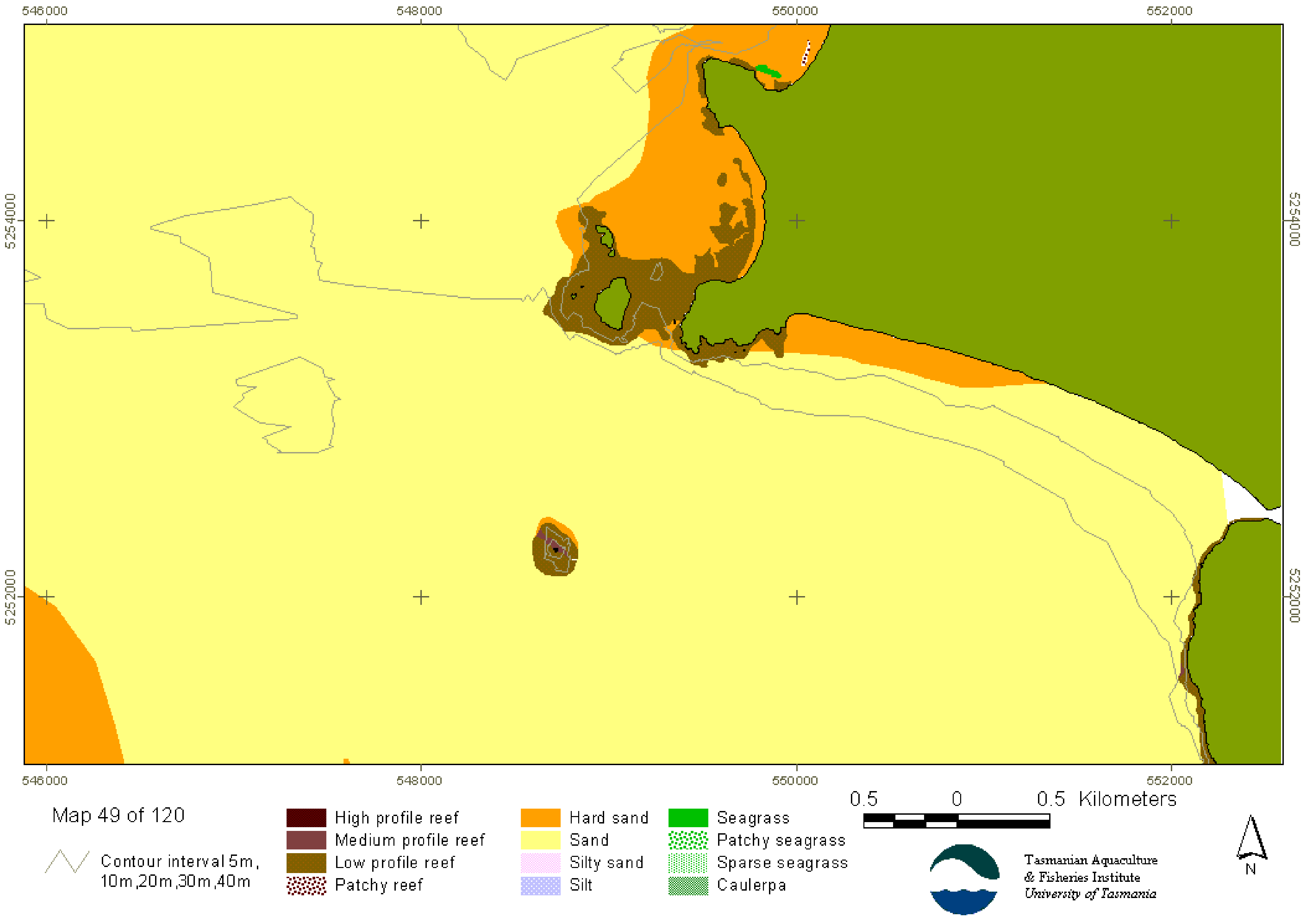
556000
5250000
5248000
Map 48 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

Back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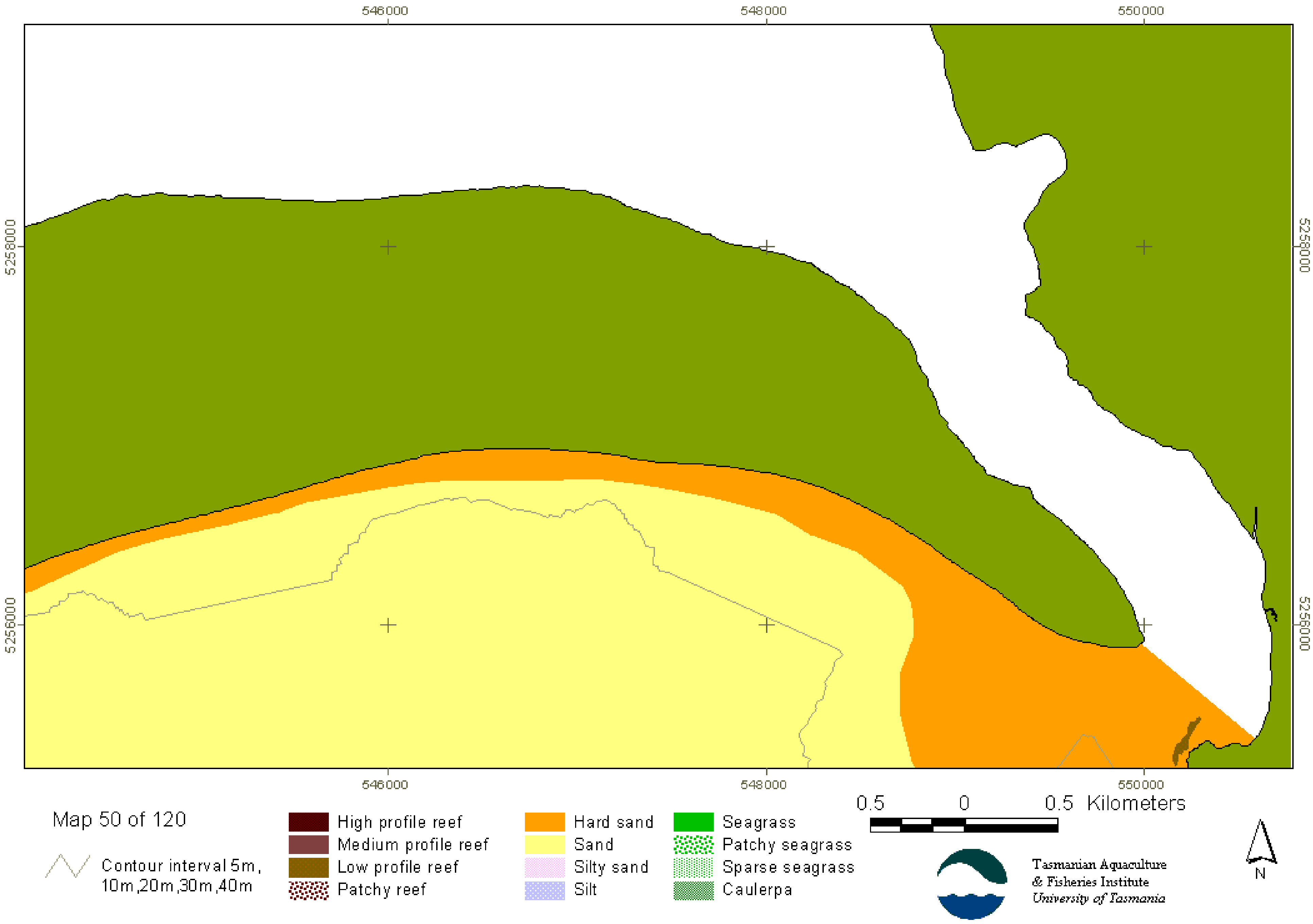
5252000
Map 49 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back



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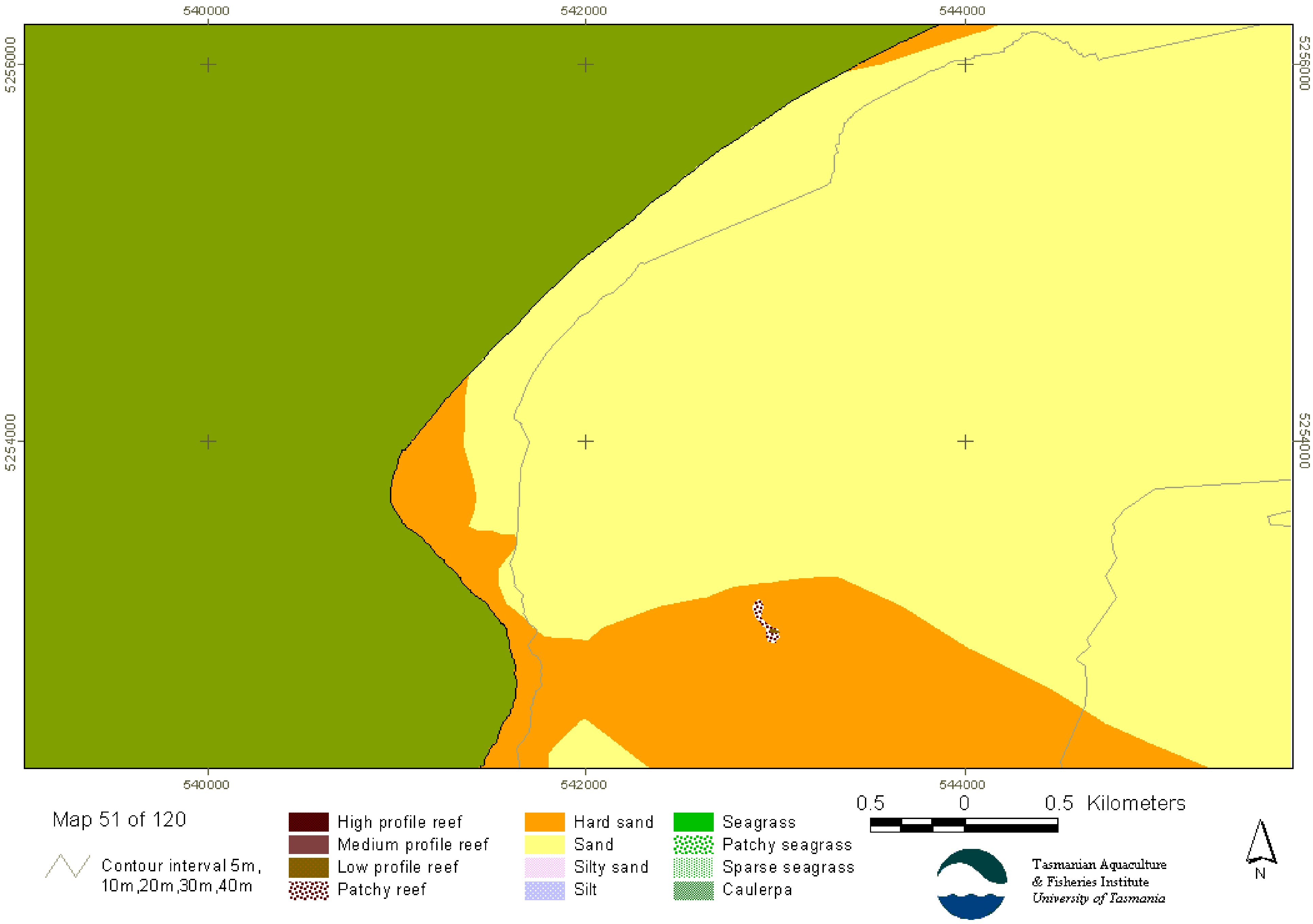
Map 50 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

Back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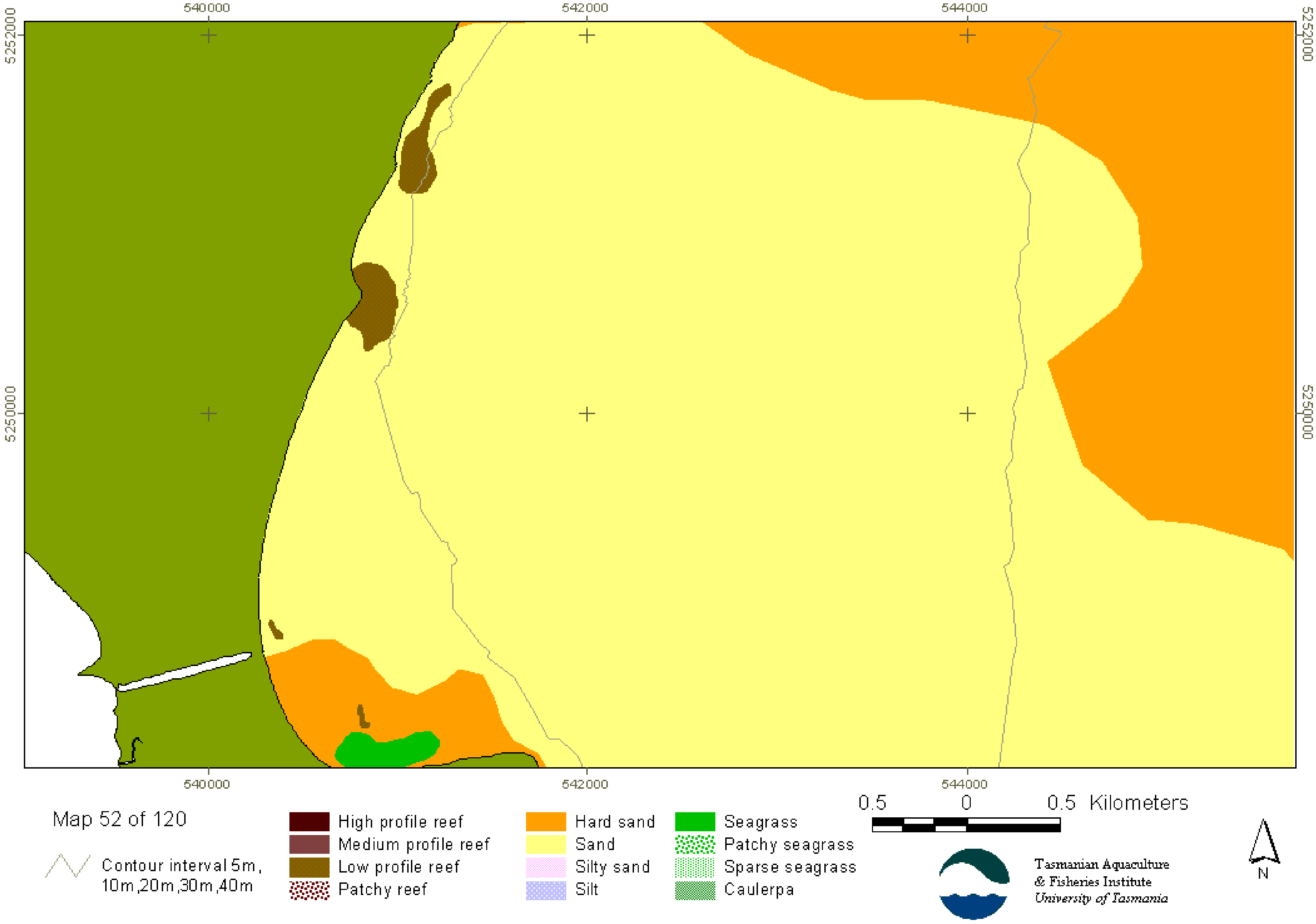
Map 51 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

Back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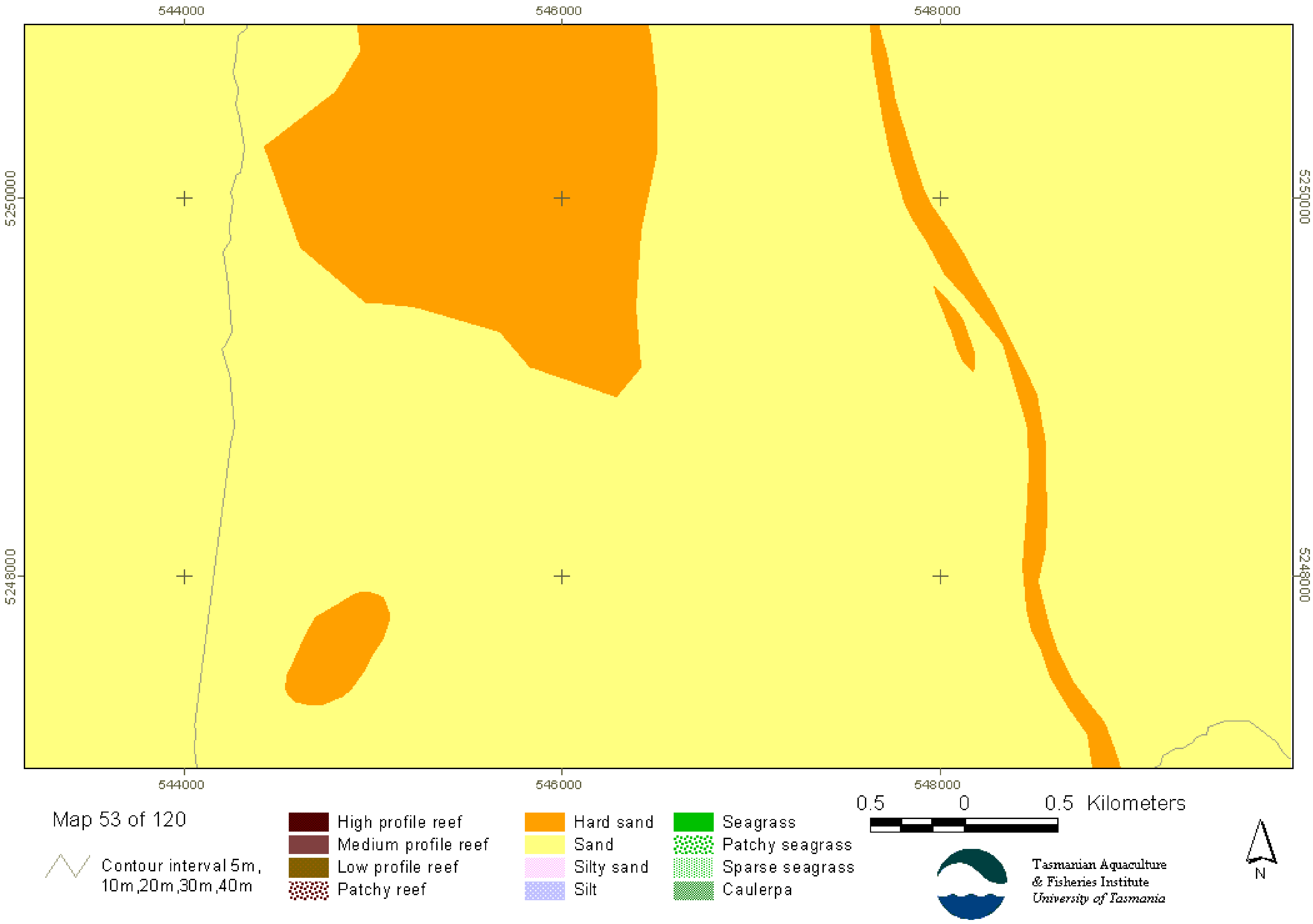
Map 52 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back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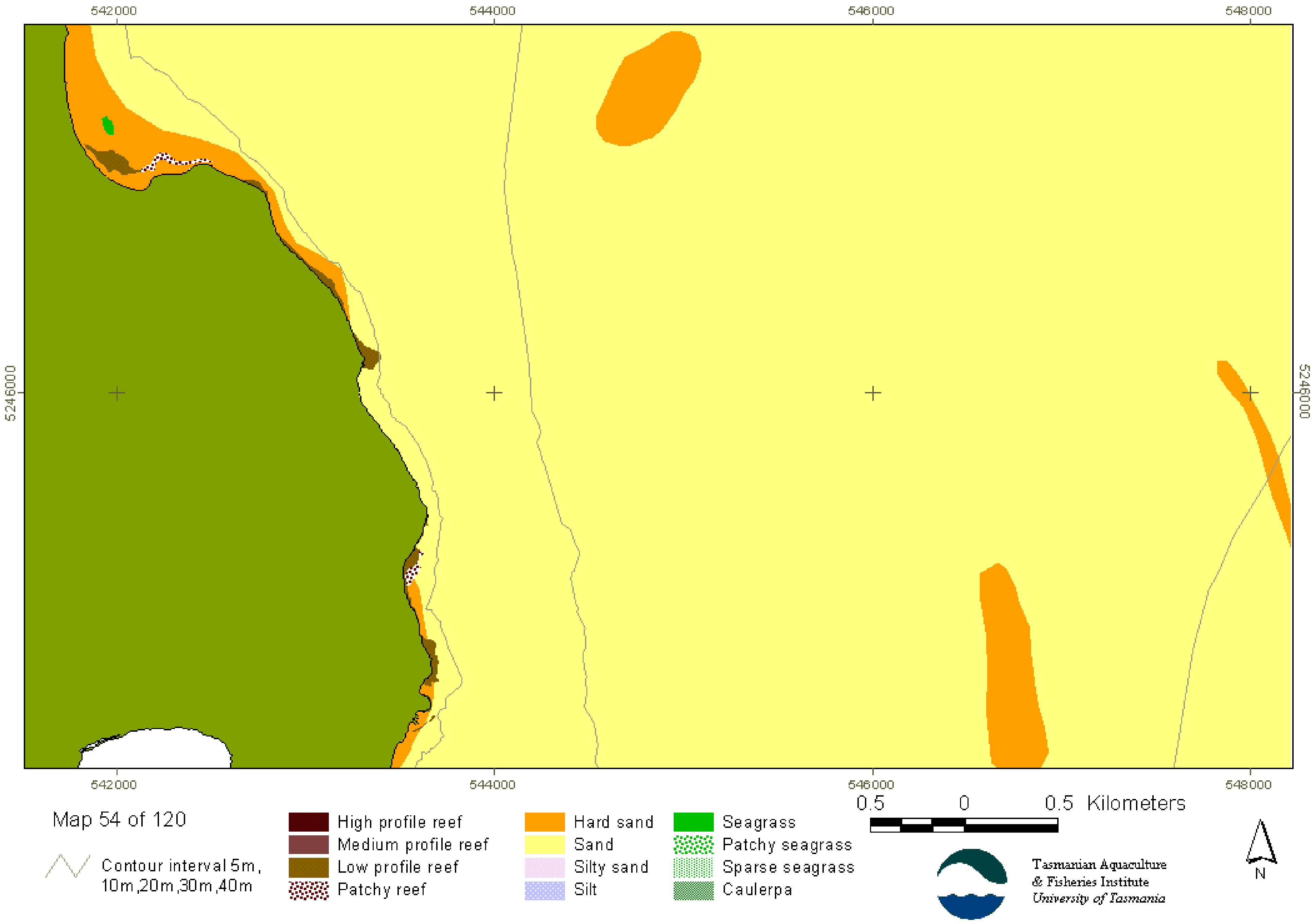
5248000
Map 53 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back



Map 54 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

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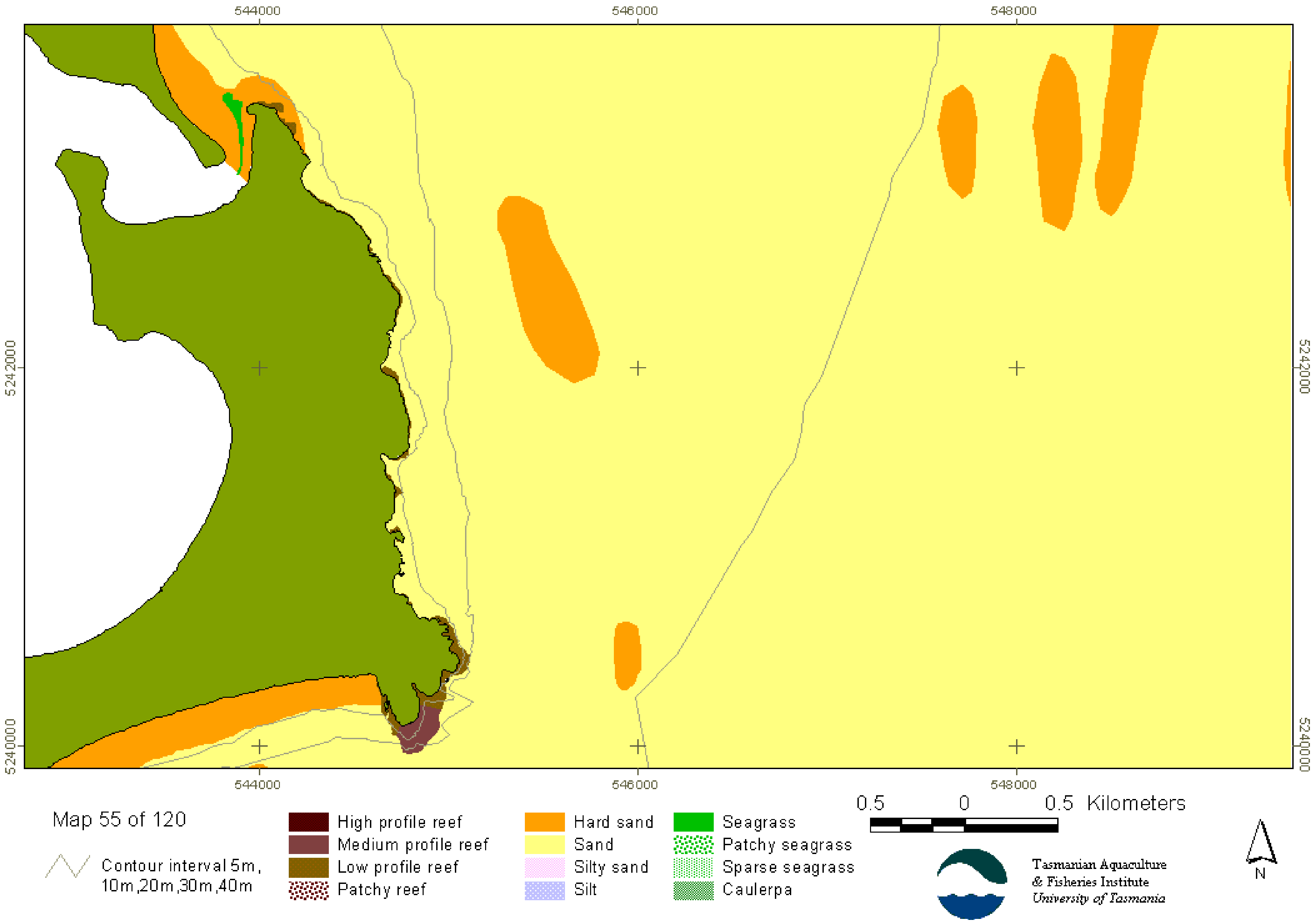
Back


544000
546000
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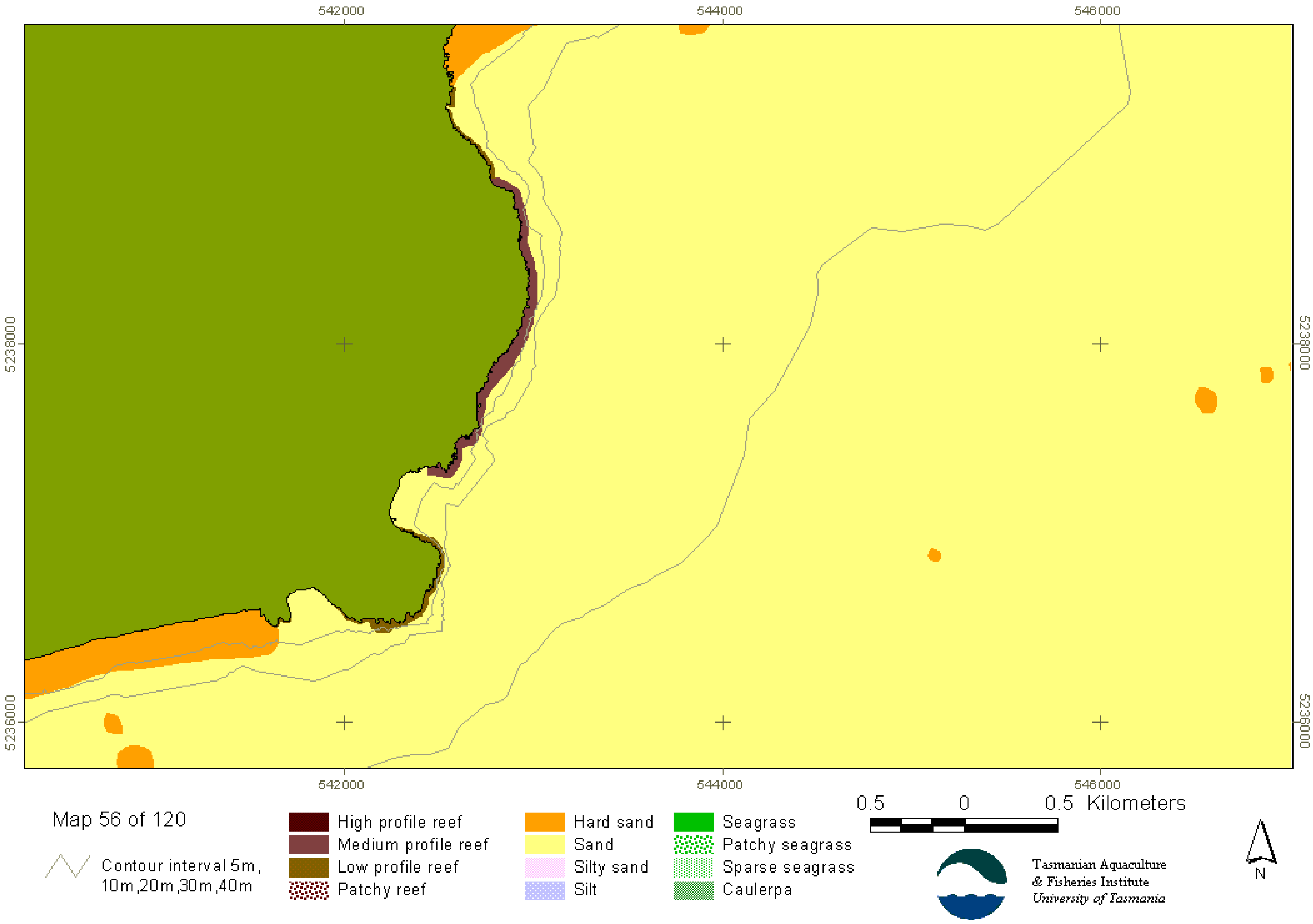
5242000
5240000
0.5
0
0.5 Kilometers
N
Map 55 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back



542000
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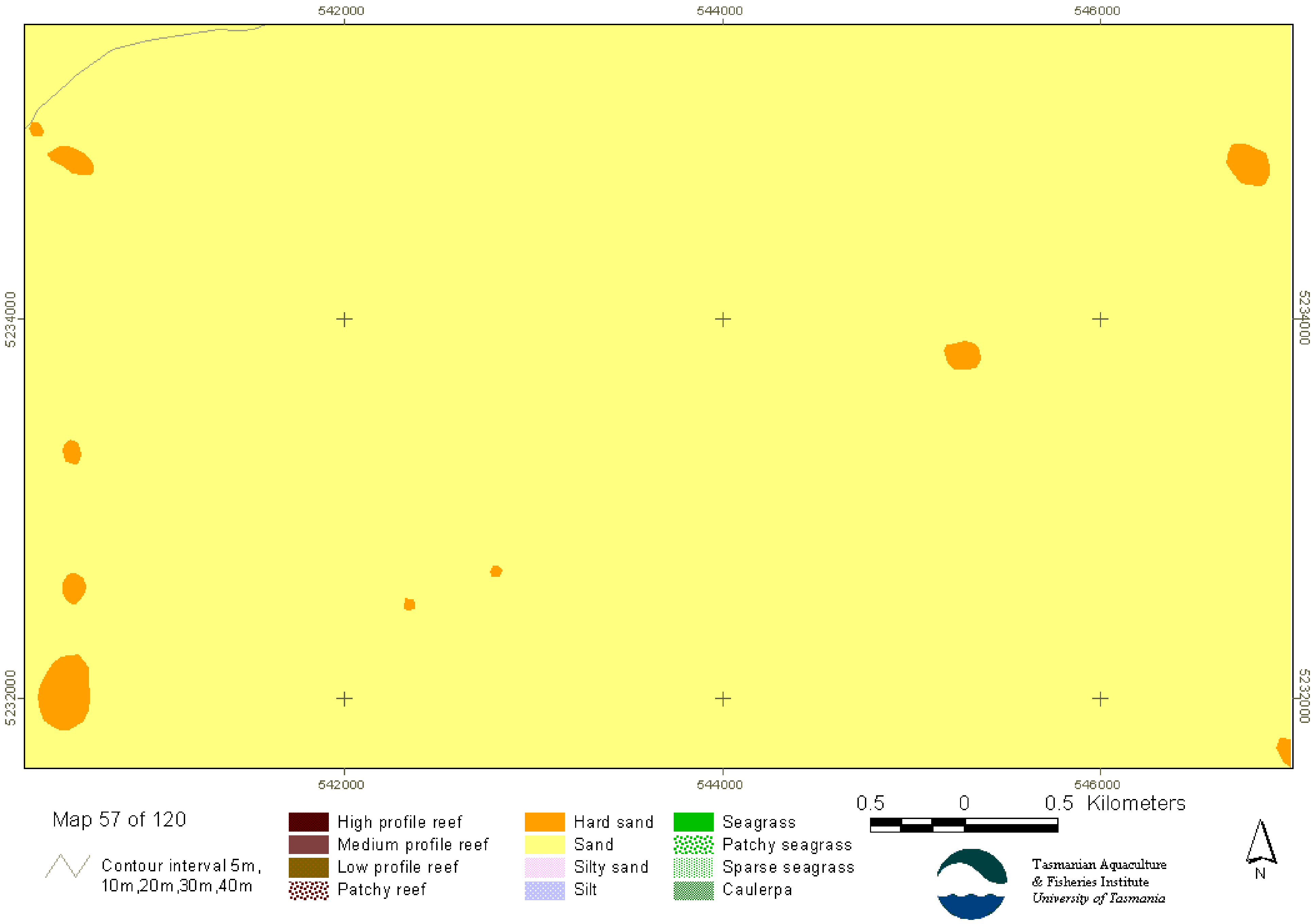
5238000
5236000
Map 56 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back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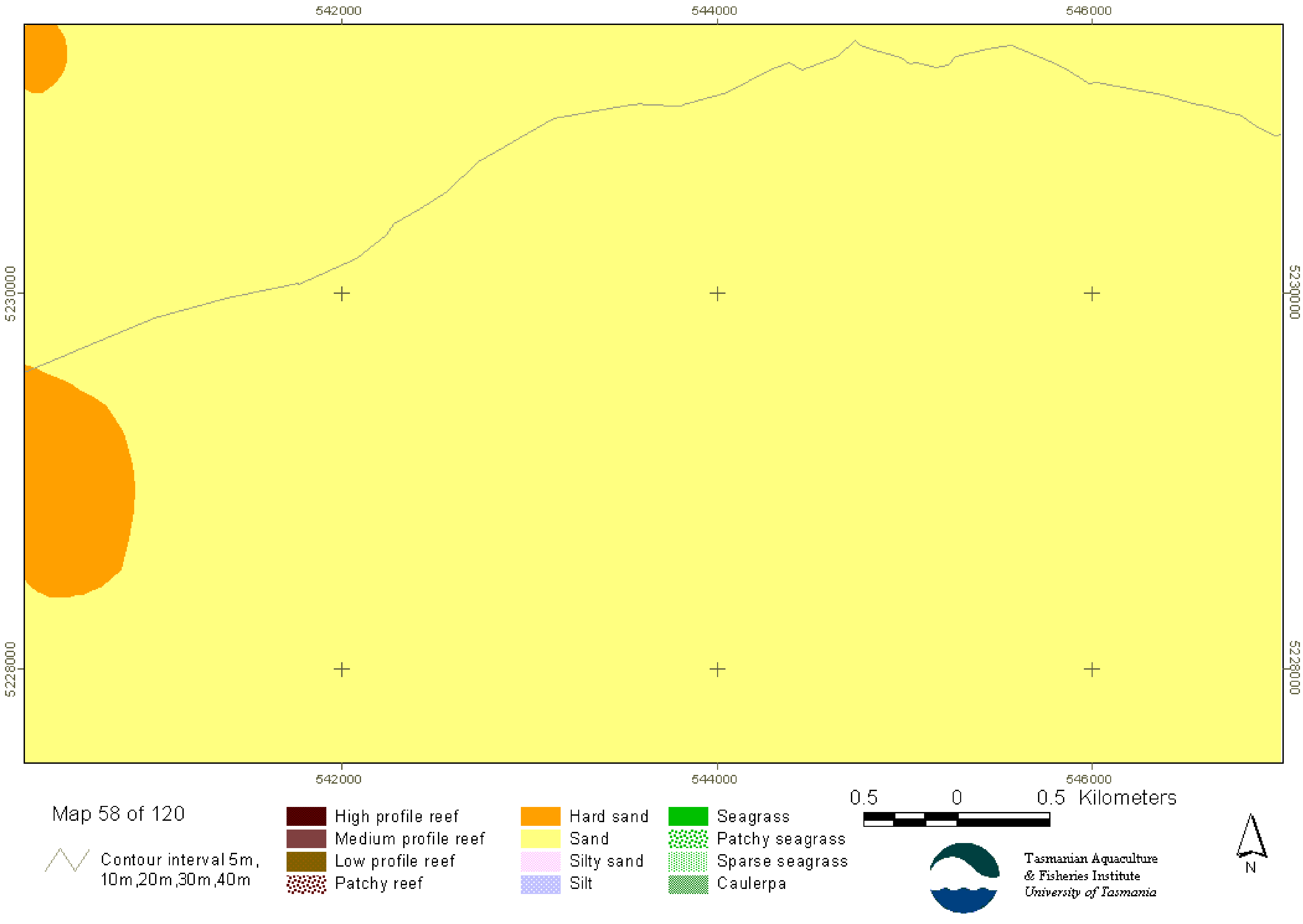
Map 57 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back



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5230000
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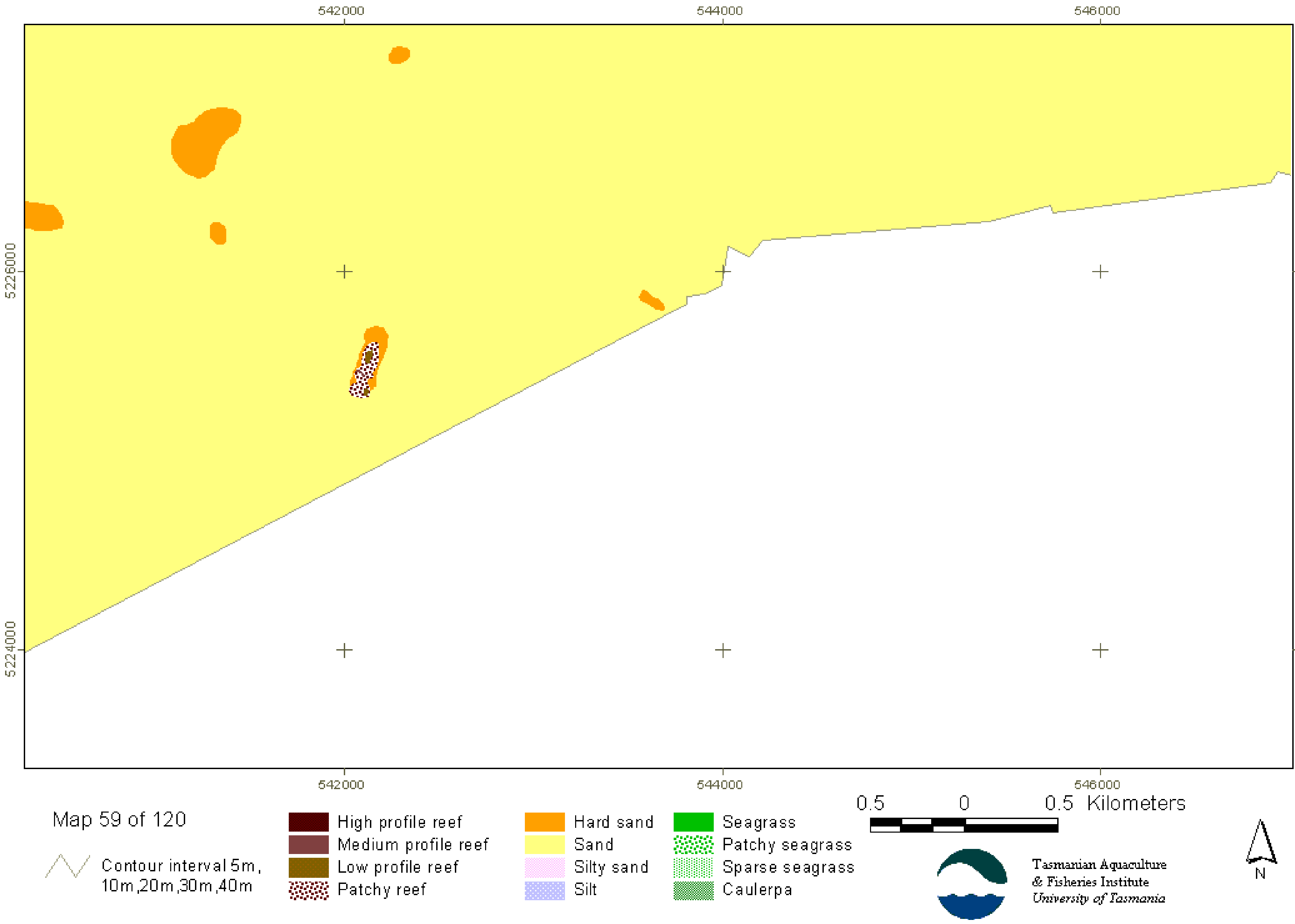
Map 58 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

[Back]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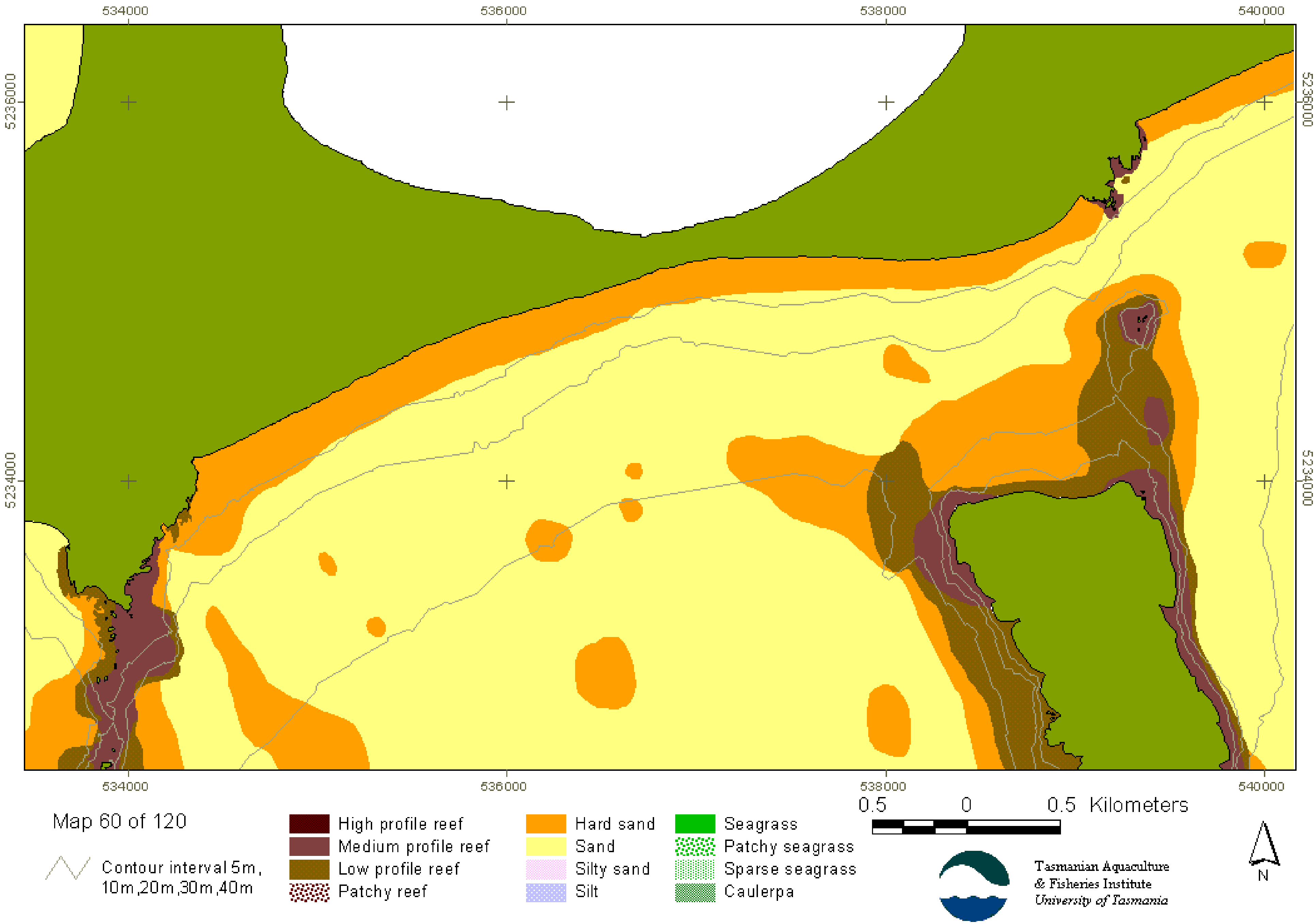
Map 59 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

[Back](#)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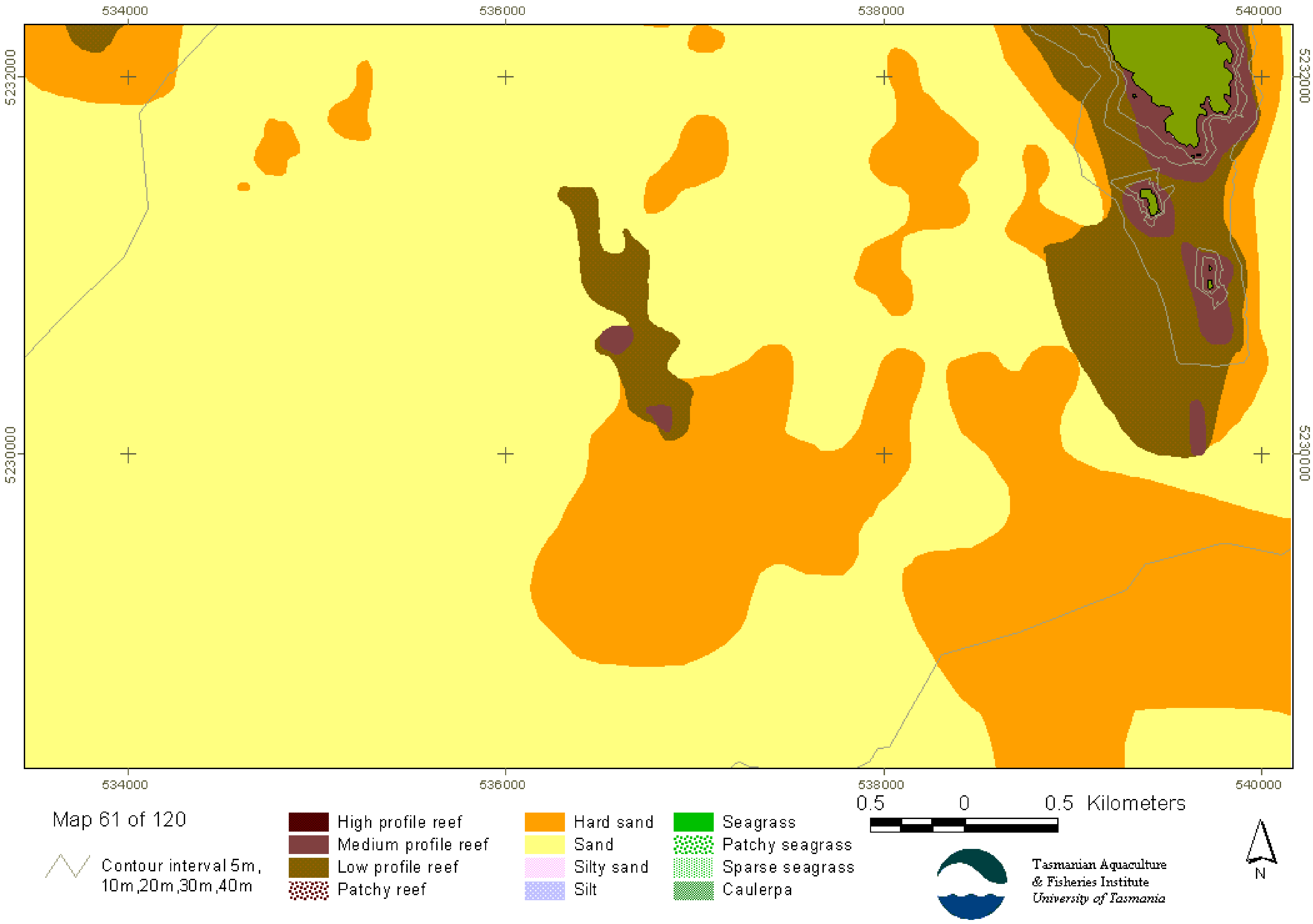
5234000
Map 60 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back

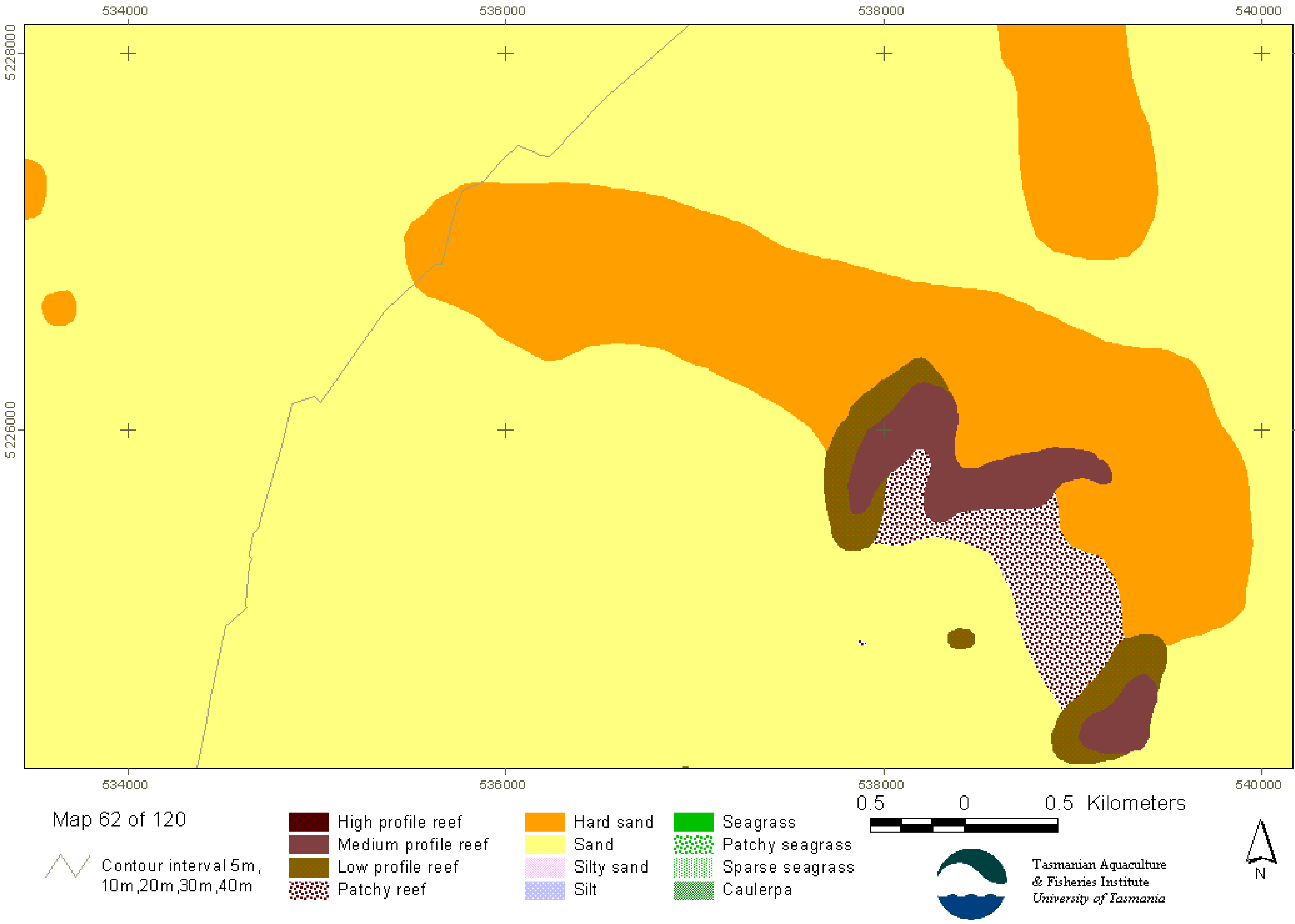


Map 61 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

Back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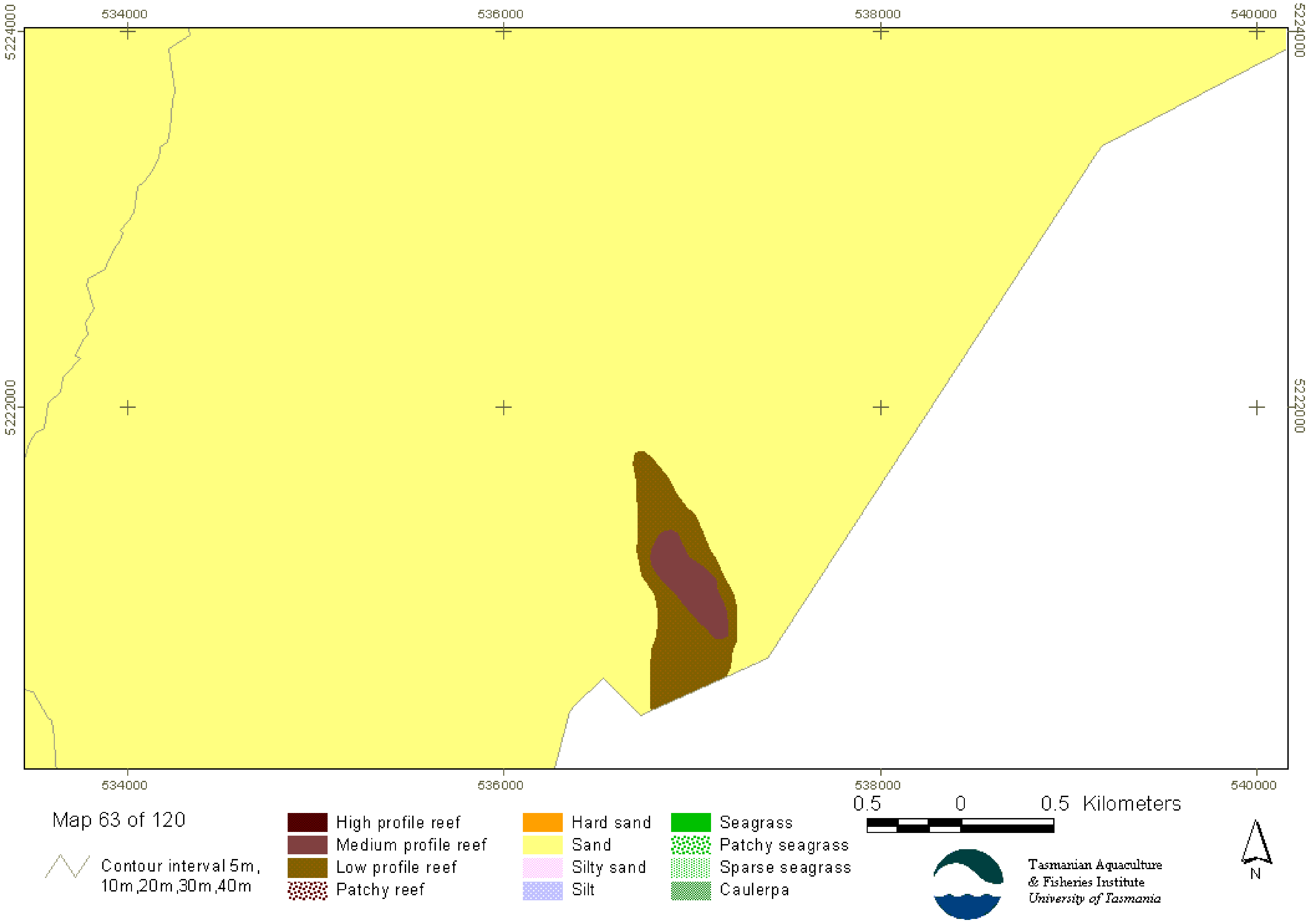
5226000
Map 62 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back



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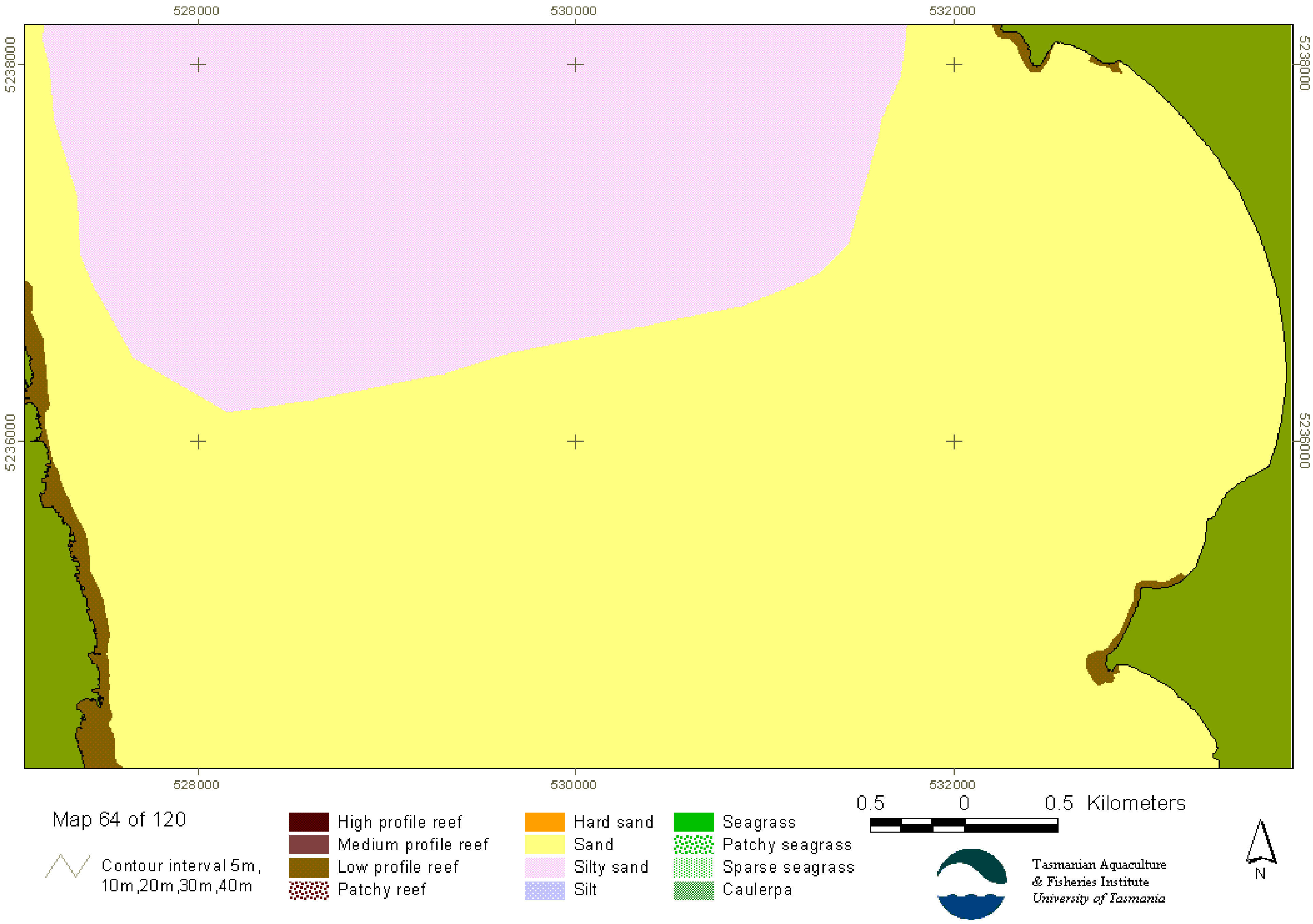
540000
5224000
5222000
Map 63 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

[Back]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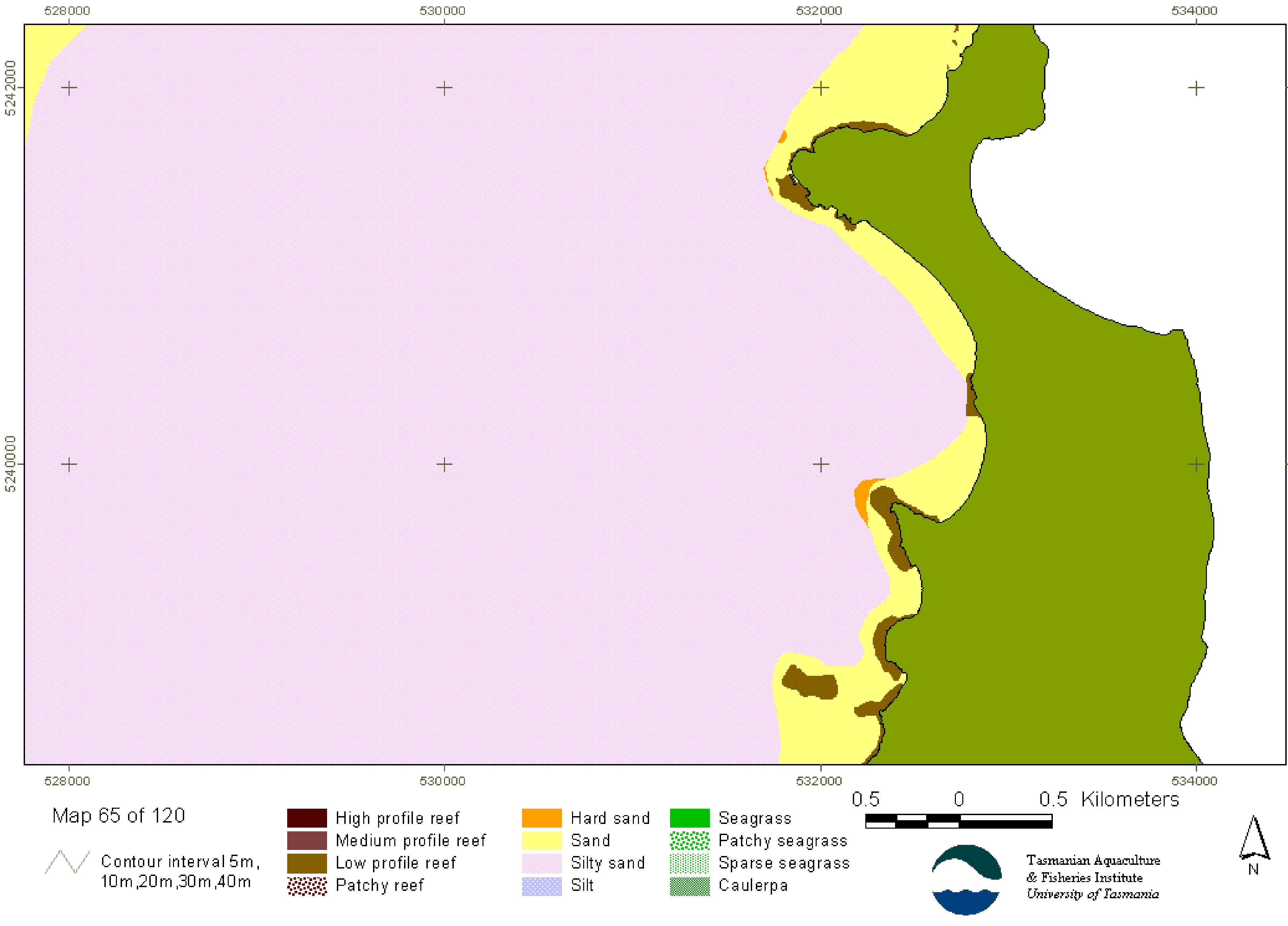
5236000
Map 64 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania
N

Back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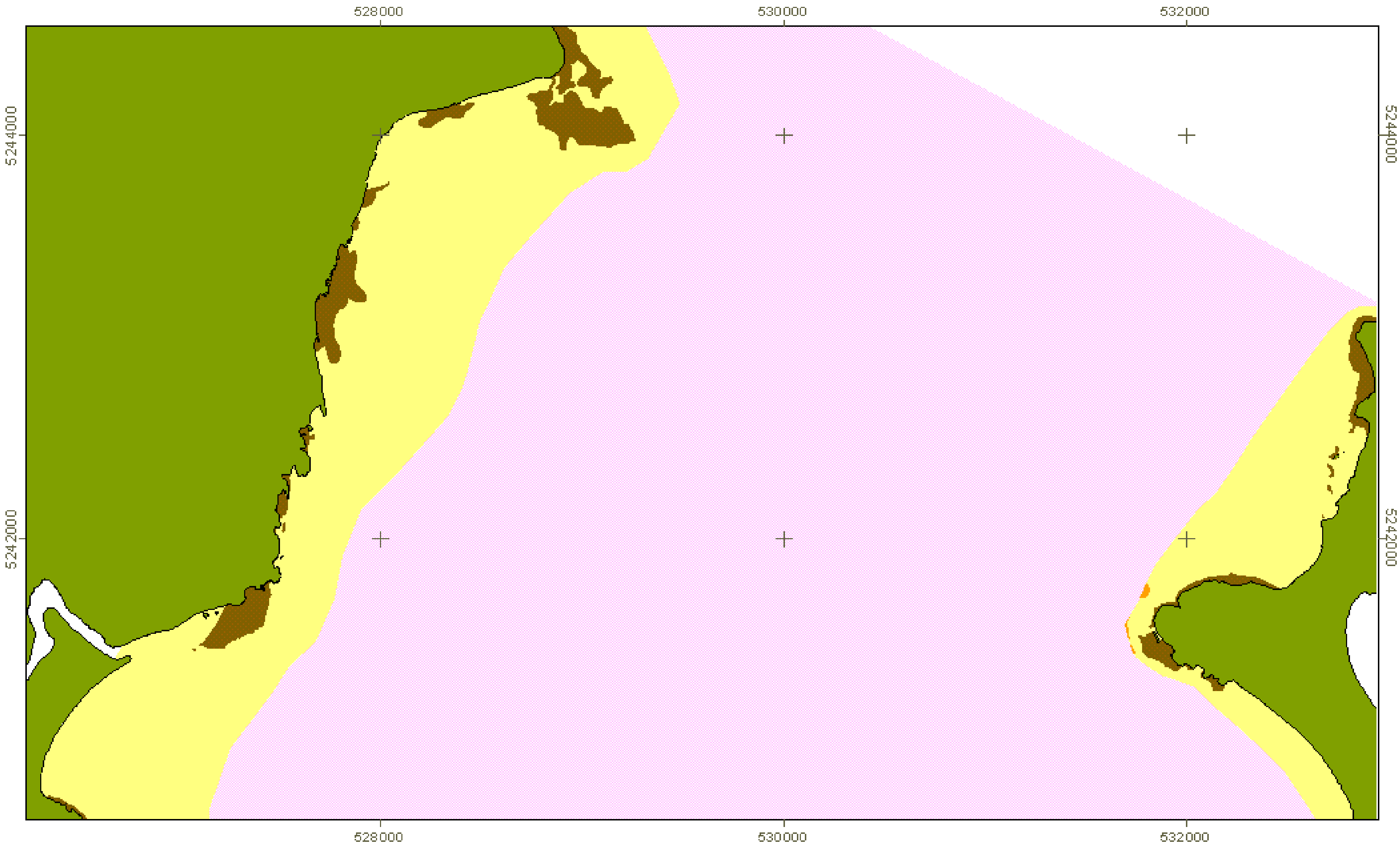
5240000
Map 65 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

Back



Map 66 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

0.5 0 0.5 Kilometers

N

Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

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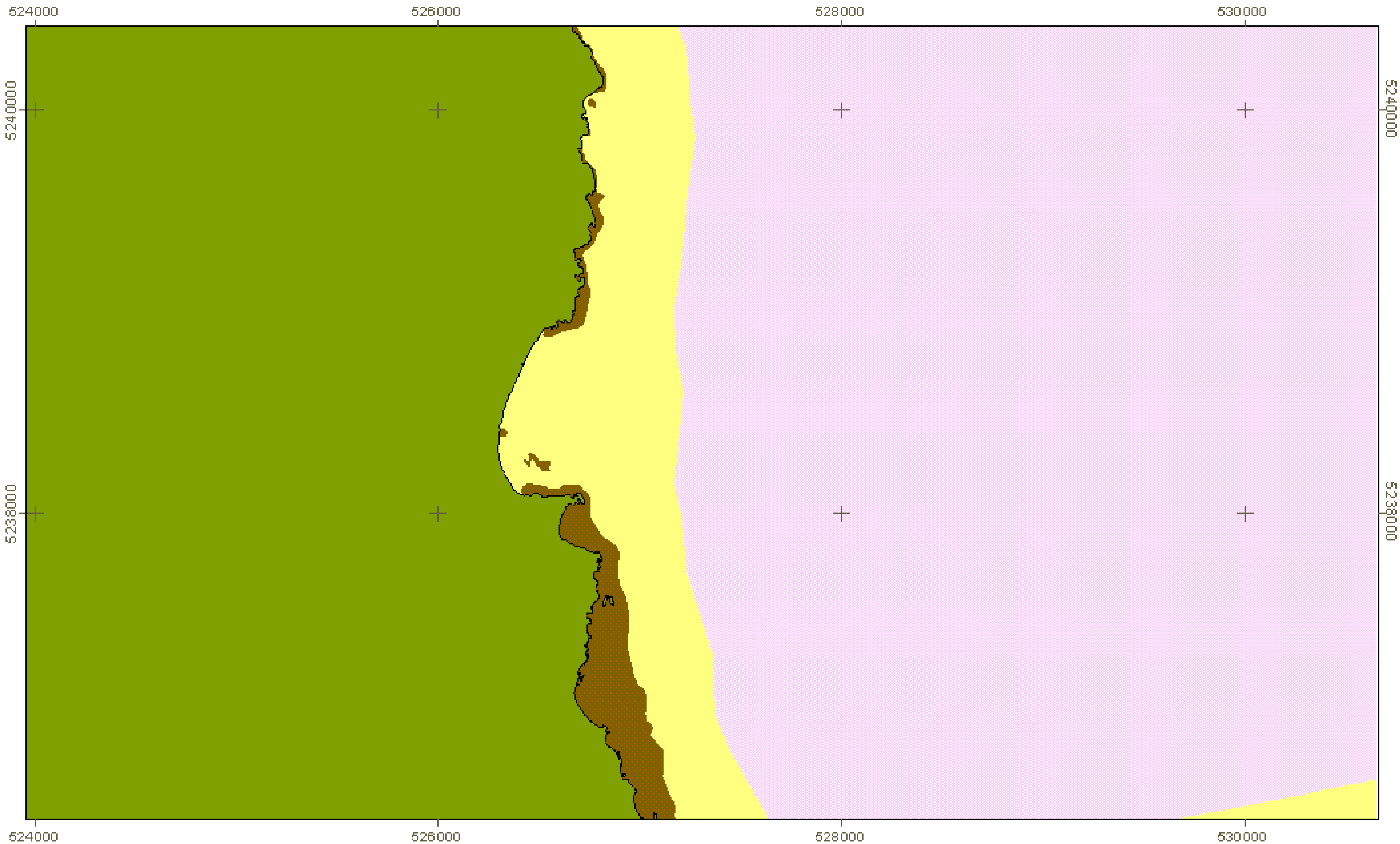
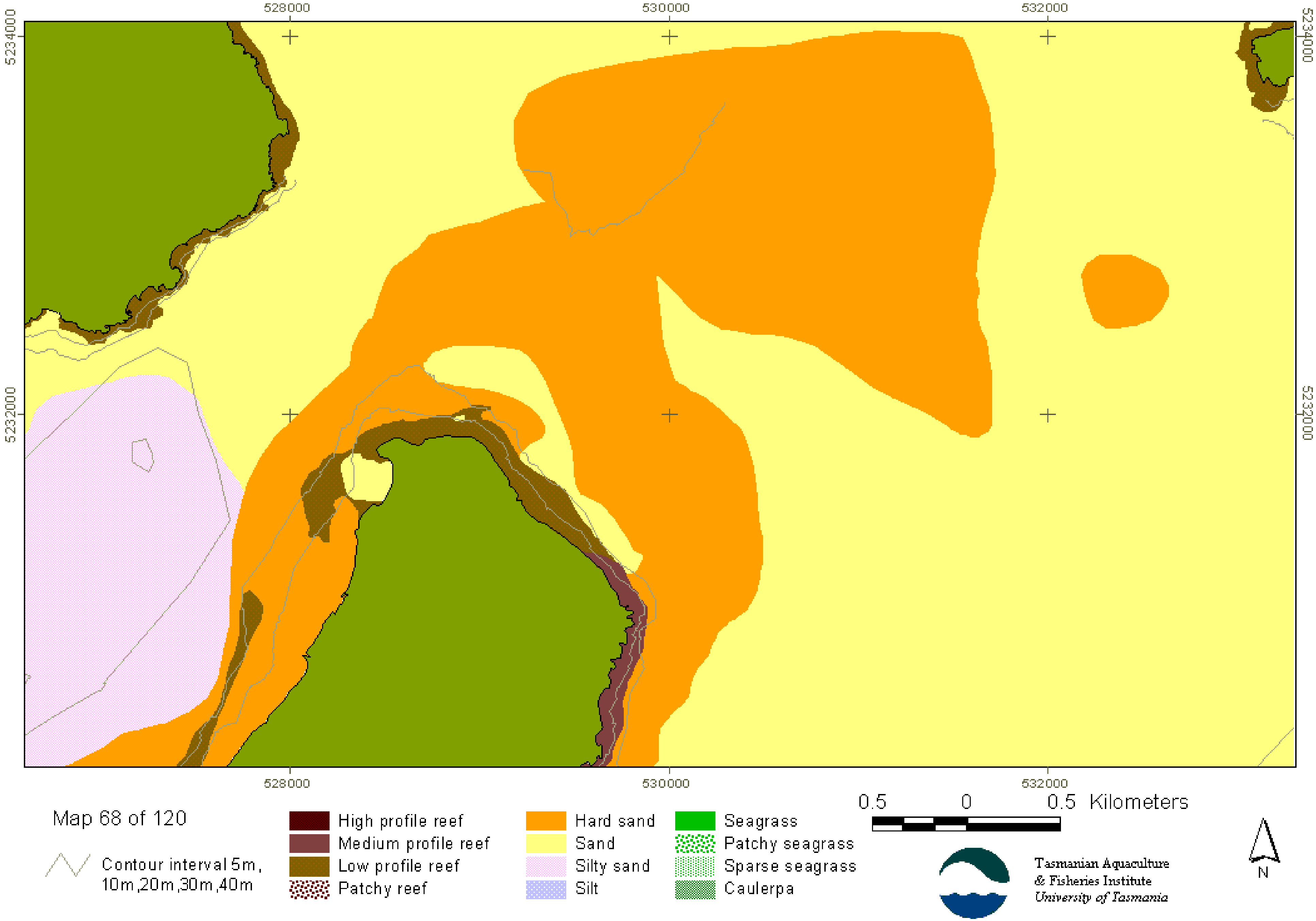


Map 67 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

Back


528000
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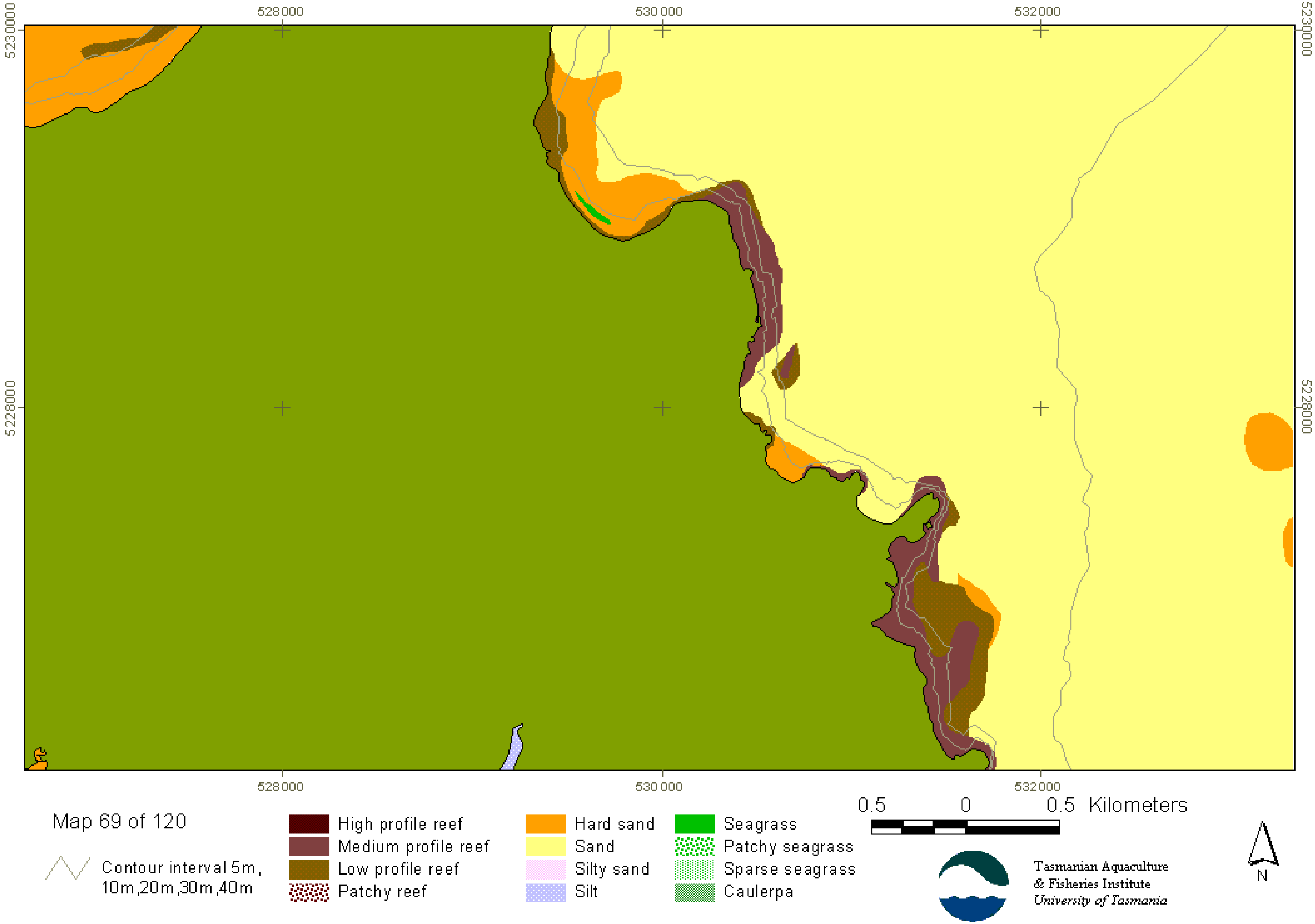
5232000
Map 68 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania

[Back]



528000
530000
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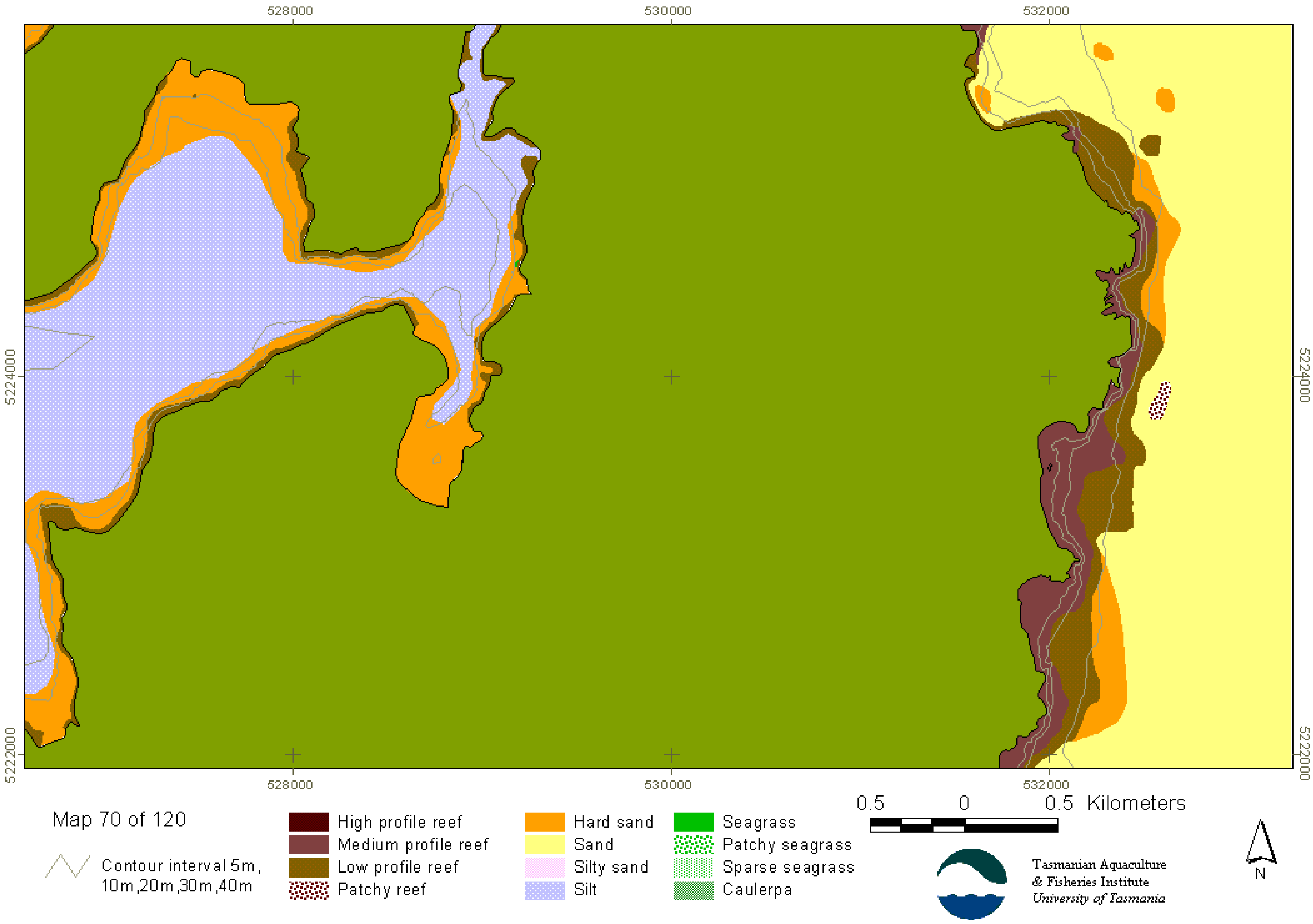
5228000
Map 69 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Contour interval 5m, 10m,20m,30m,40m
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back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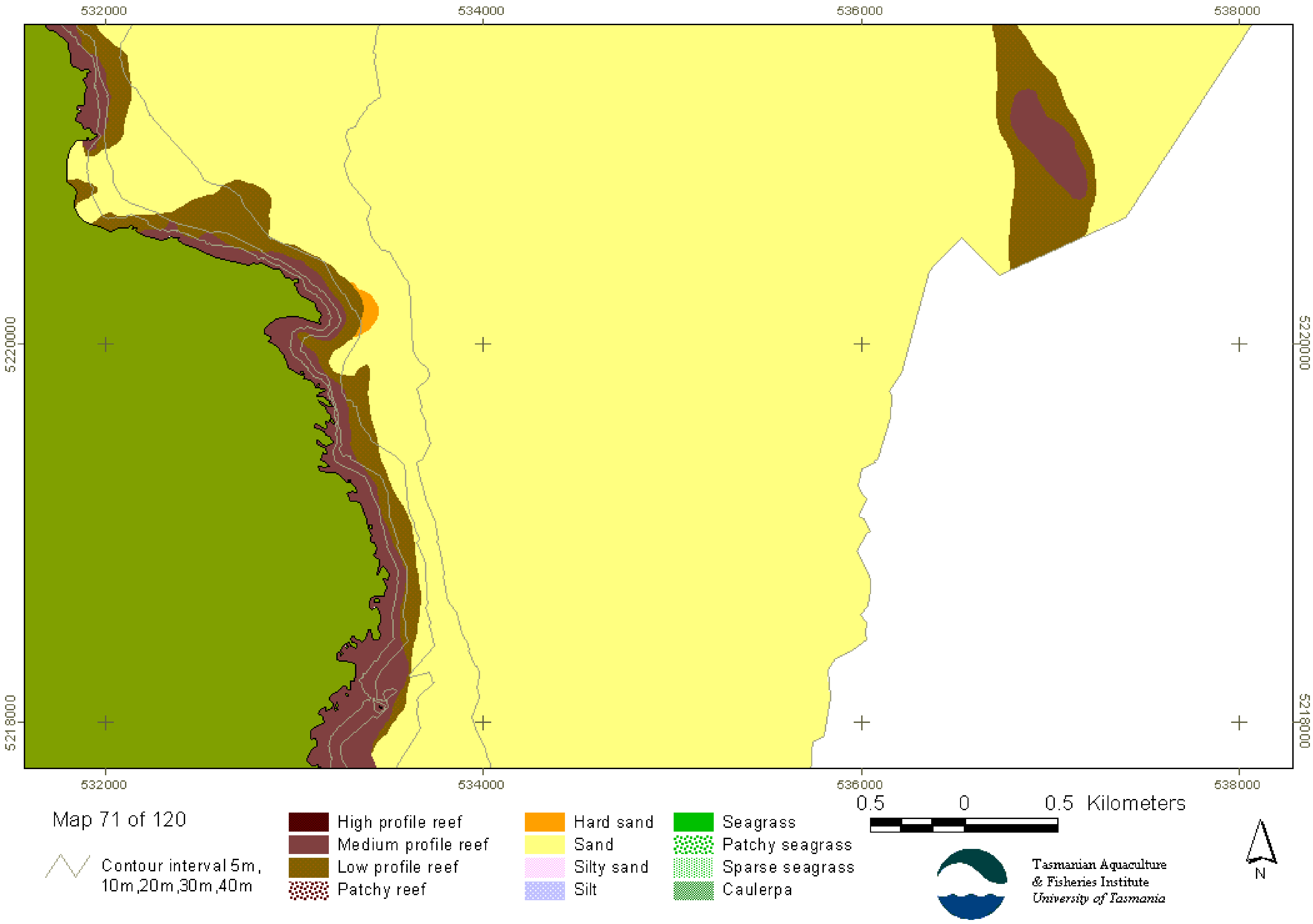
Map 70 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back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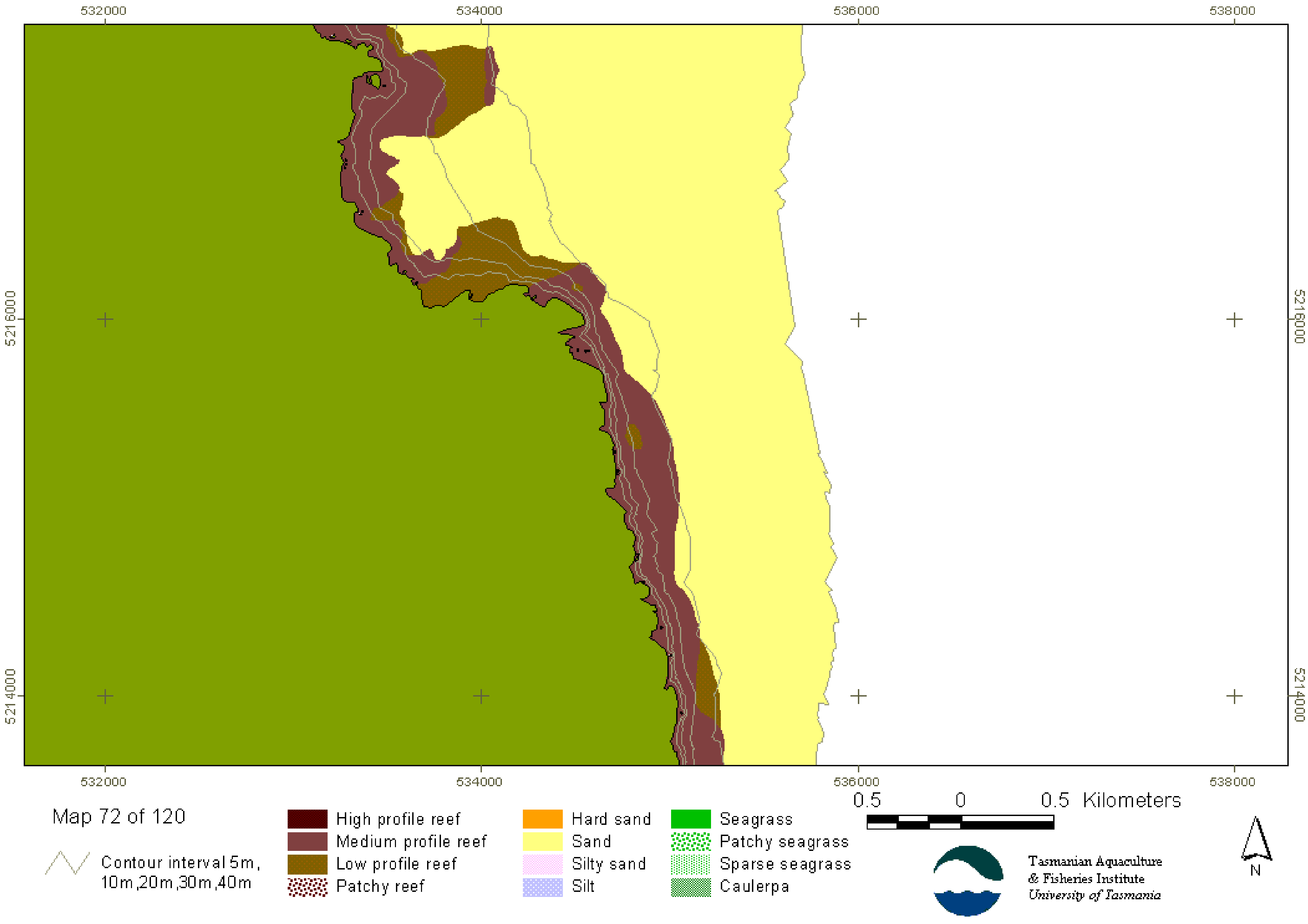
5218000
Map 71 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

[Back](#)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538000
5216000
5214000
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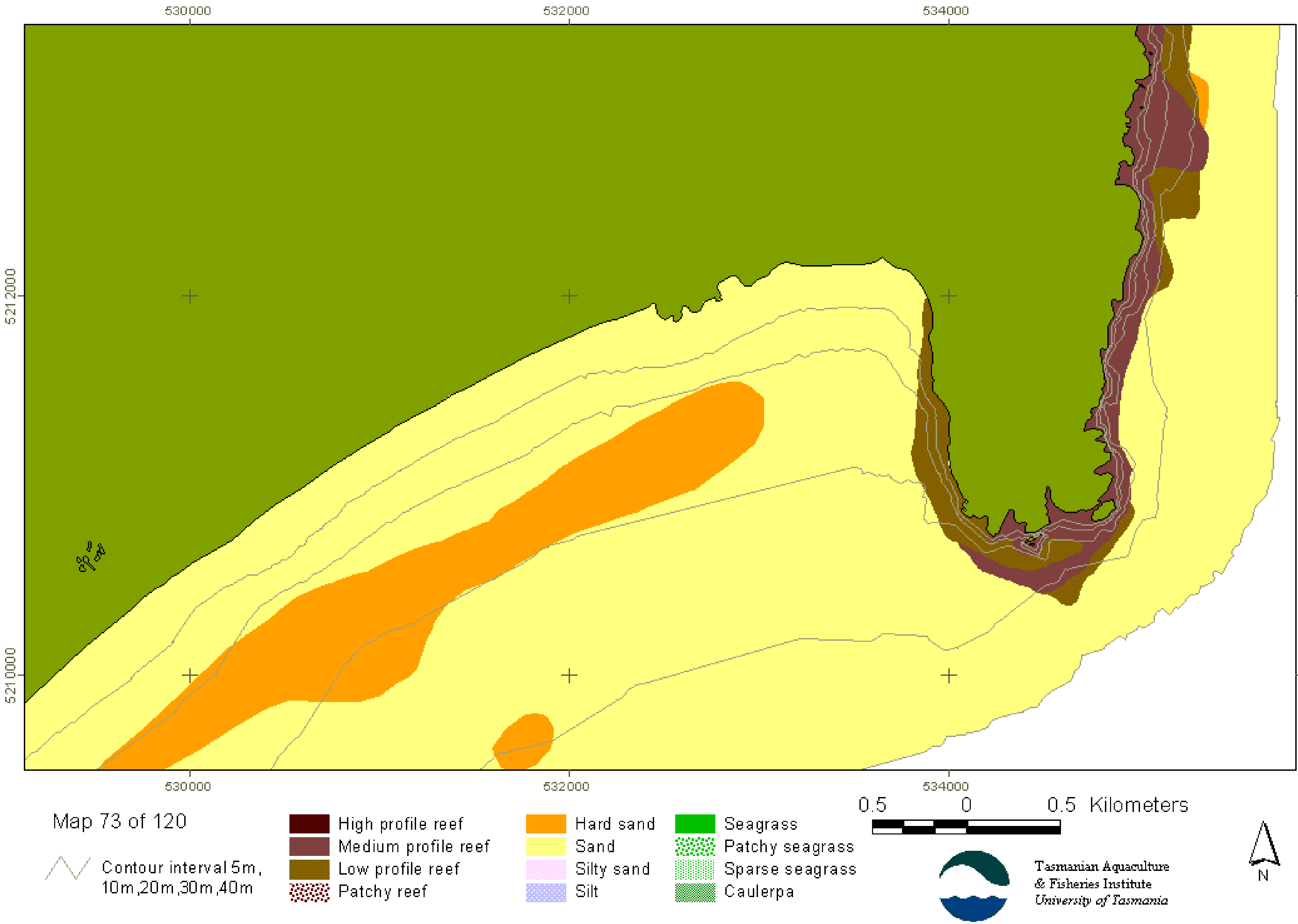
0
0.5 Kilometers
Map 72 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania
N

Back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5212000
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Map 73 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
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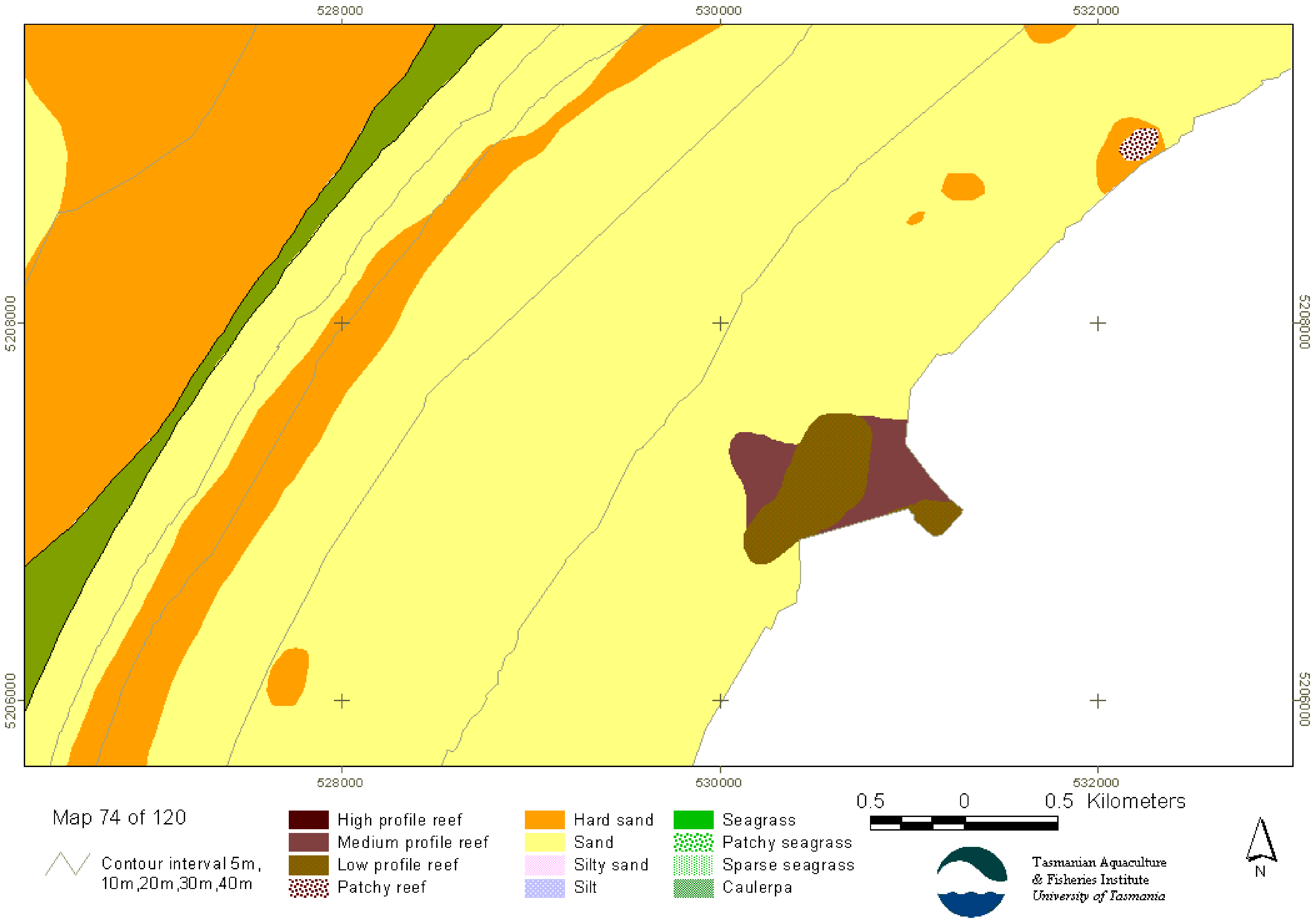

528000
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5208000
5206000
0.5 0 0.5 Kilometers
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Map 74 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute
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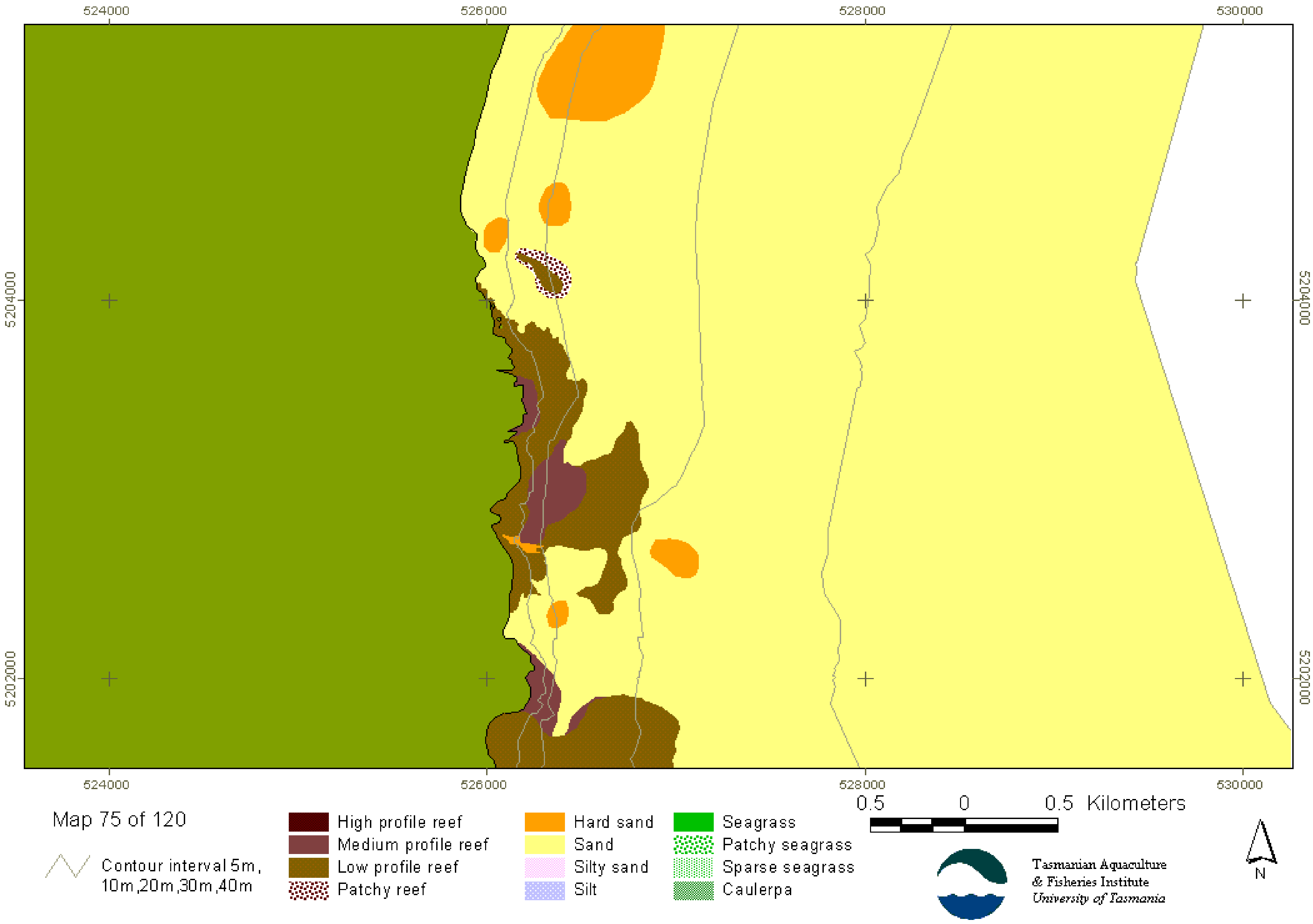
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5204000
5202000
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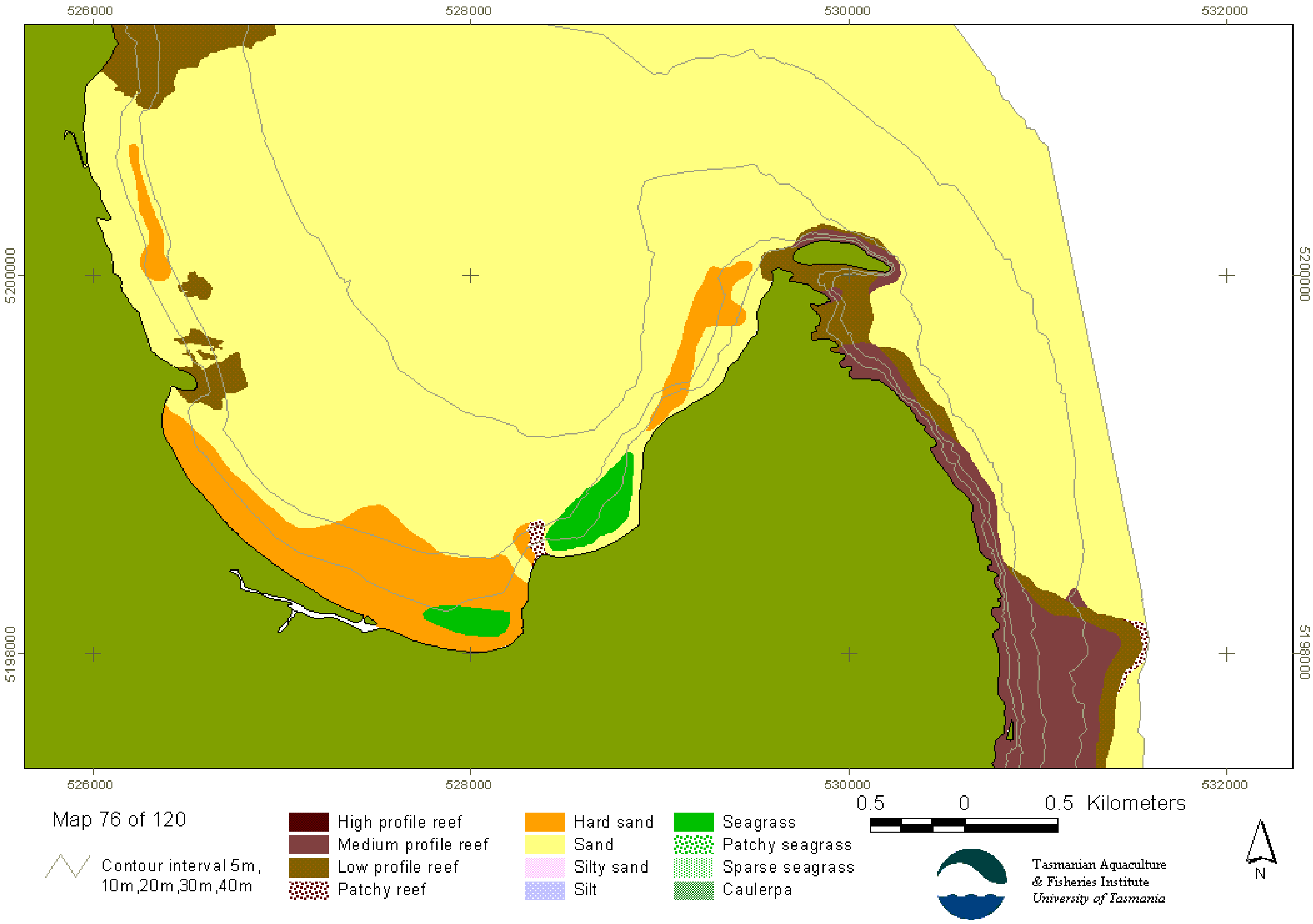
5204000
5202000
Map 75 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

[Back]



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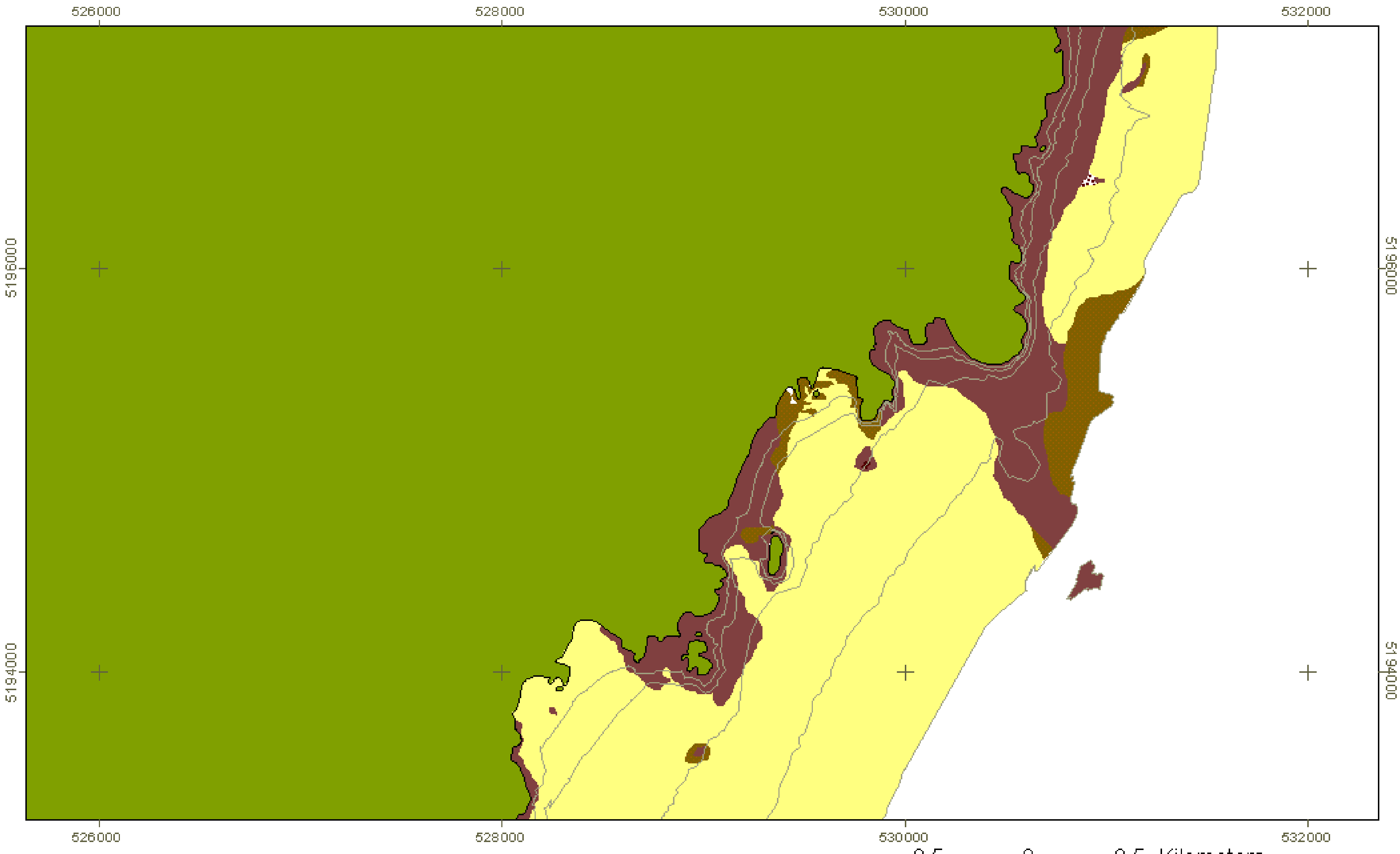
Map 76 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

[Back](#)



Map 77 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

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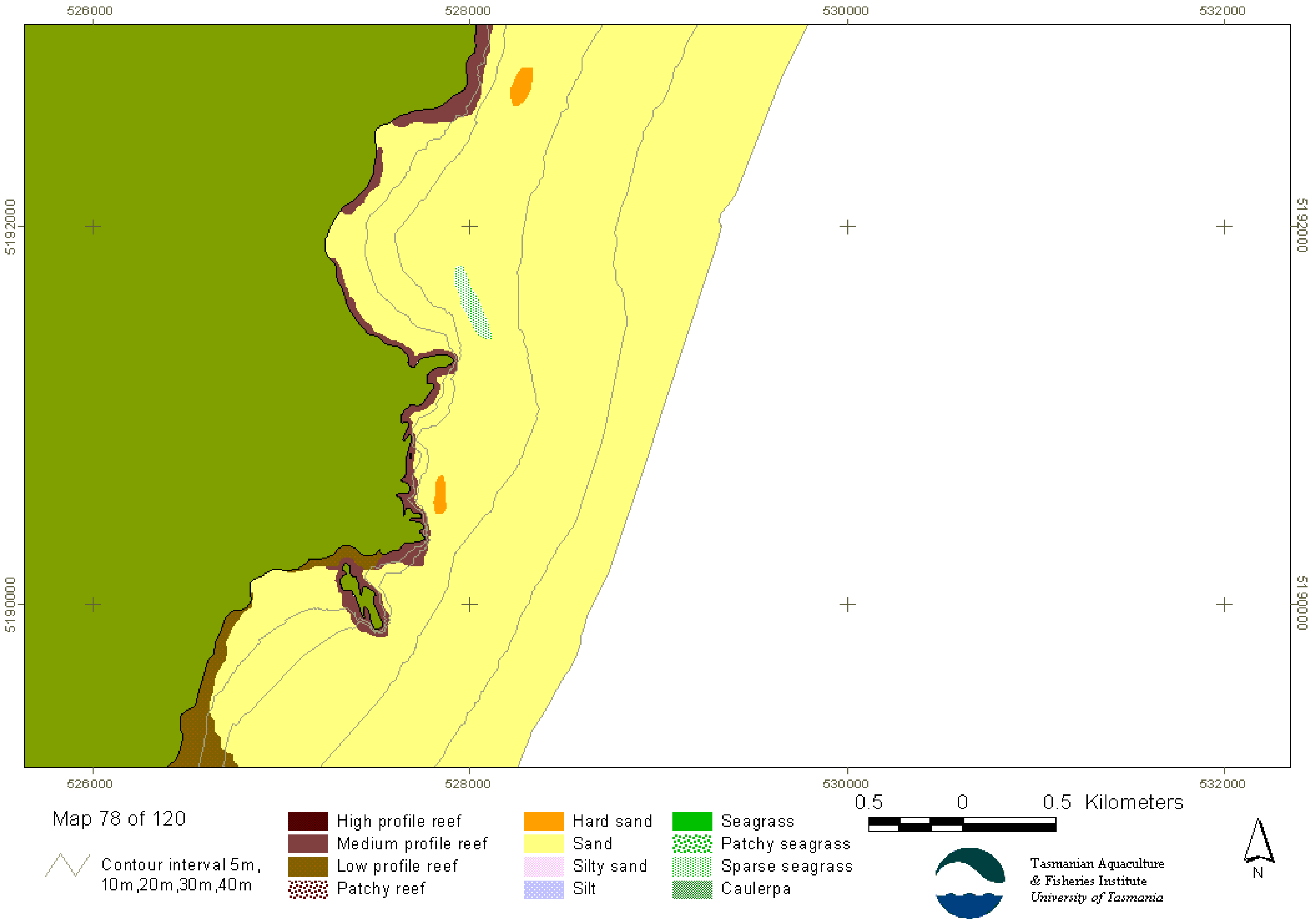
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528000
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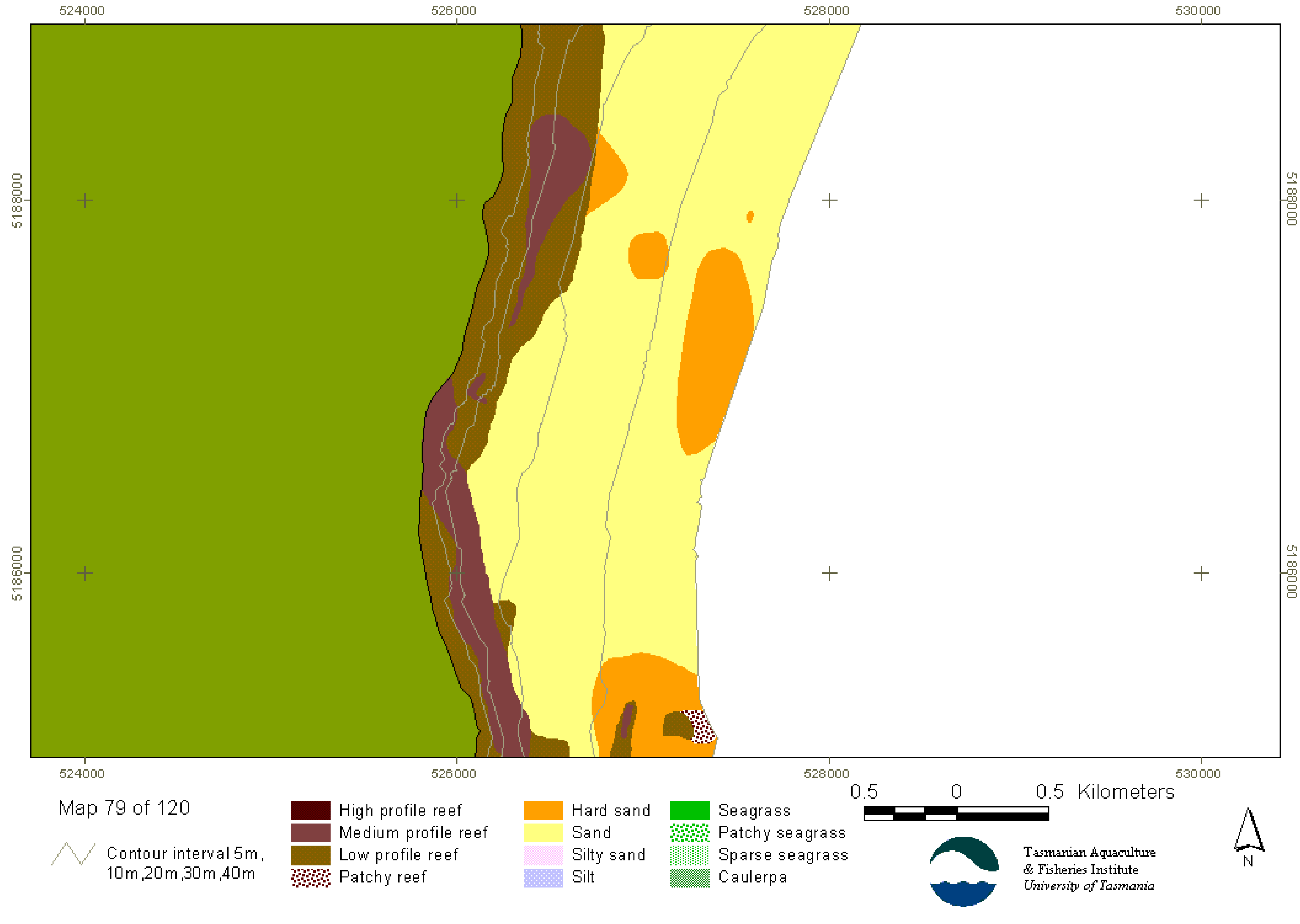
532000
5192000
5190000
0.5
0
0.5 Kilometers
Map 78 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back



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528000
530000
5188000
5186000
Map 79 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

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Map 80 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef

Hard sand
Sand
Silty sand
Silt

Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

0.5 0 0.5 Kilometers

N

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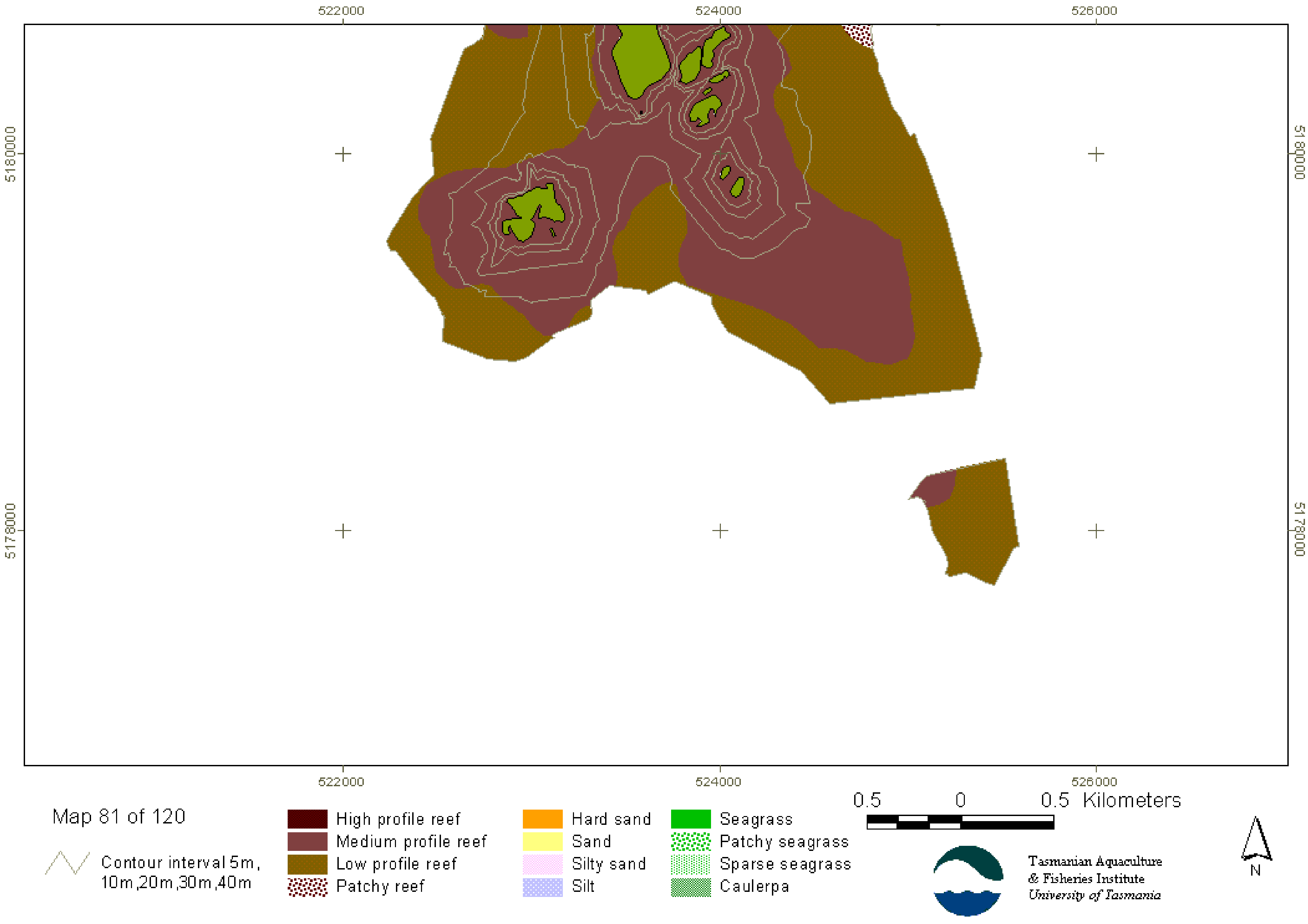

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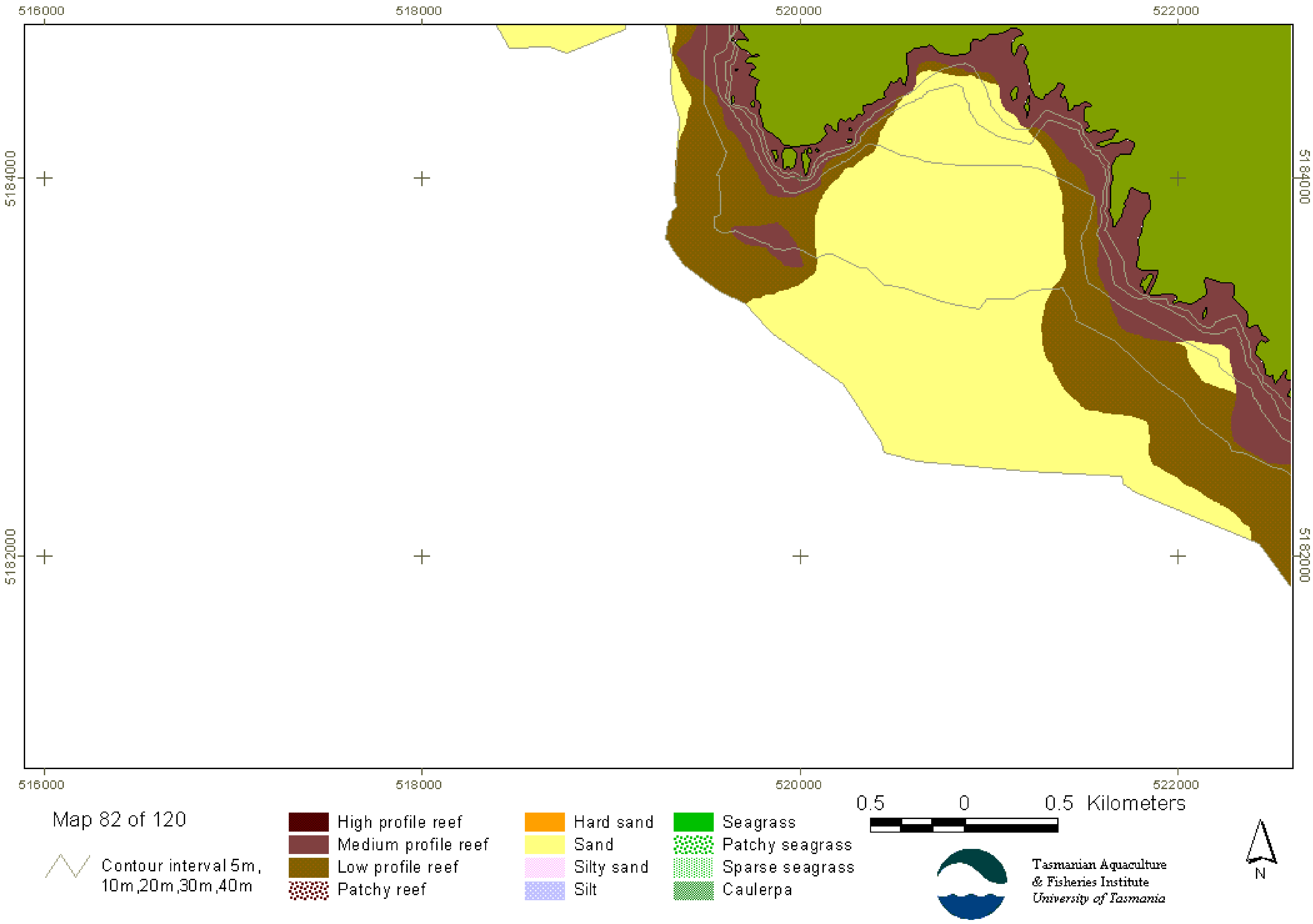
Map 81 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania
N

Back



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Map 82 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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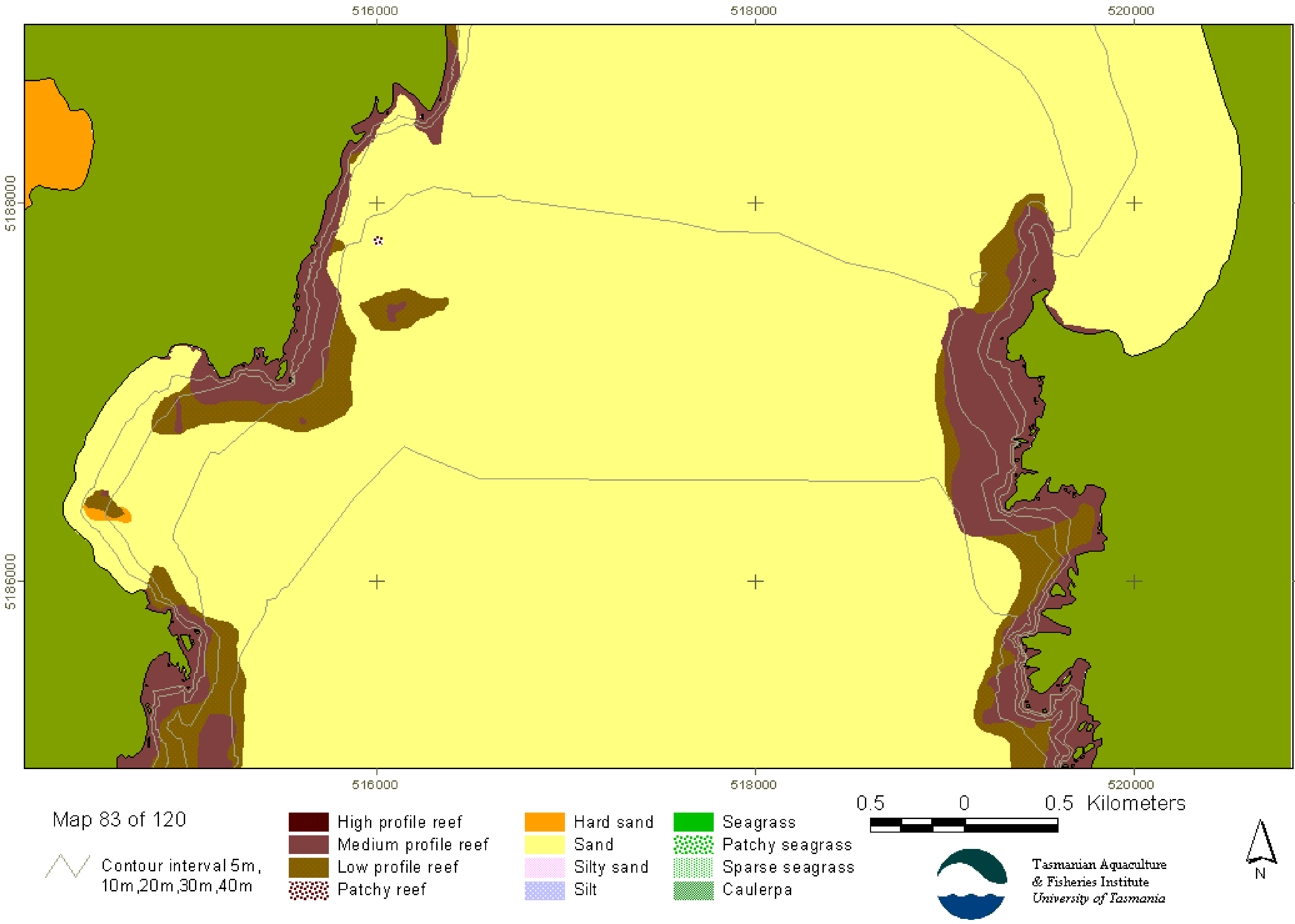
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5188000
5186000
Map 83 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute
University of Tasmania
N

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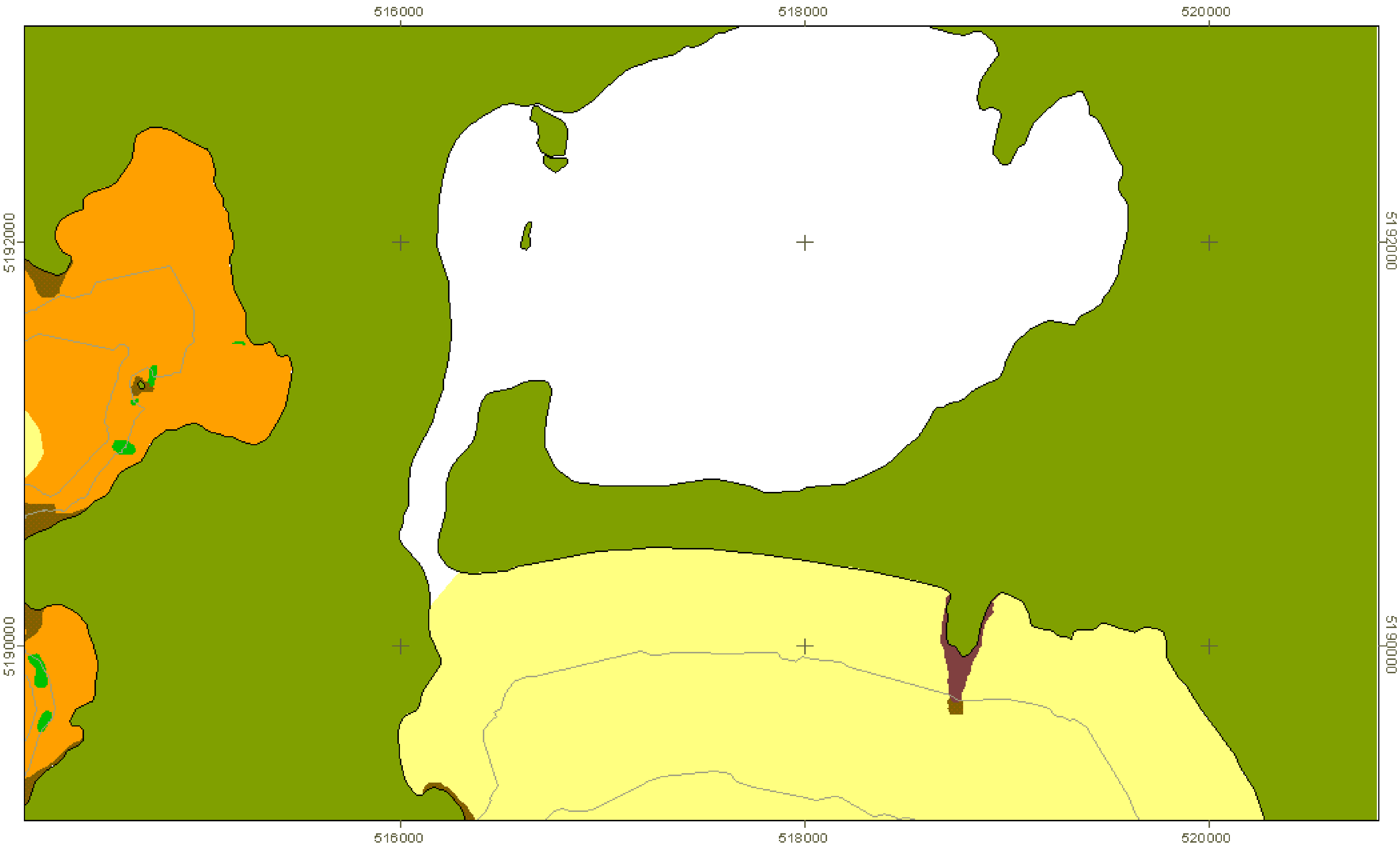

Map 84 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

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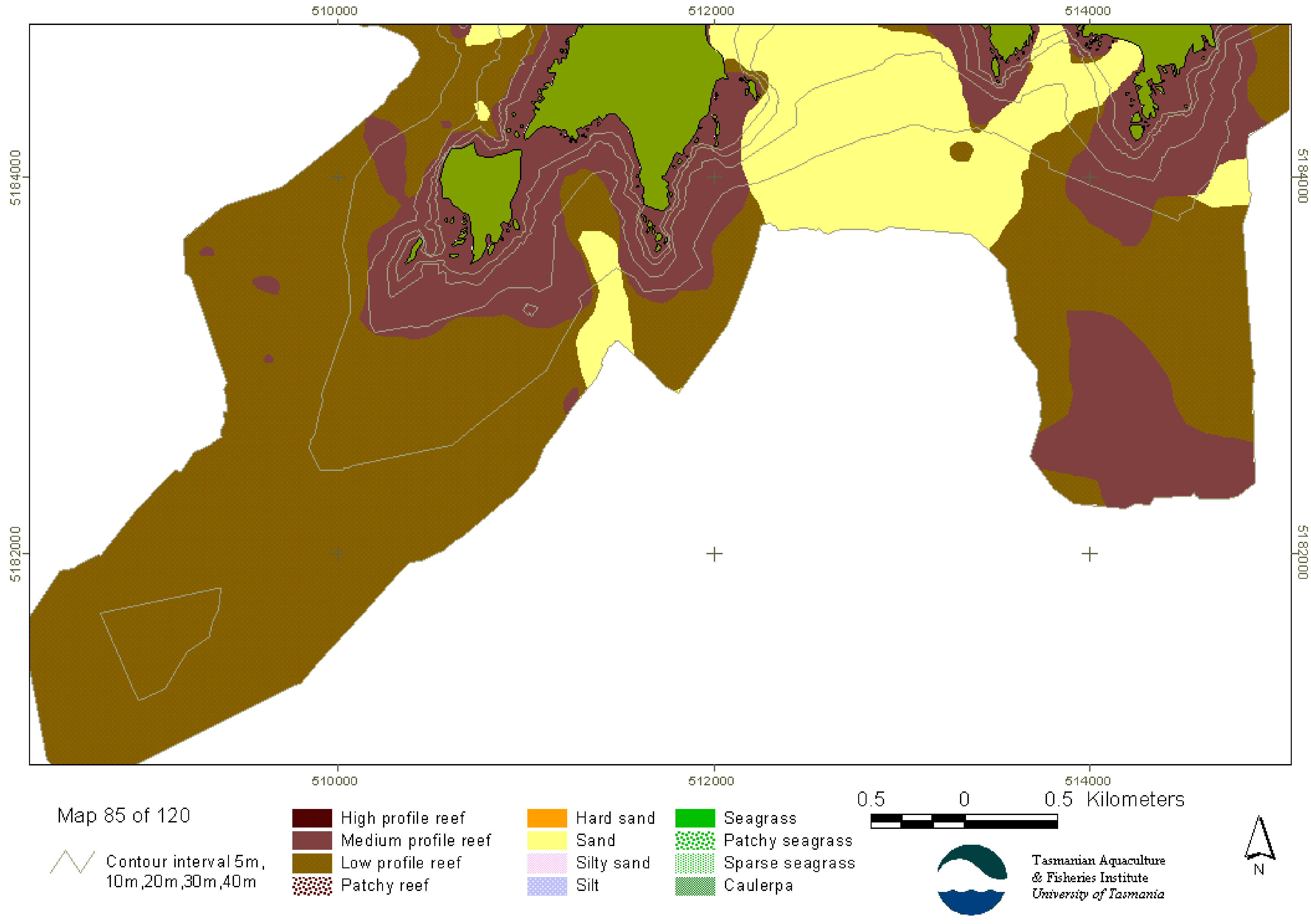
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5184000
5182000
Map 85 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania
N

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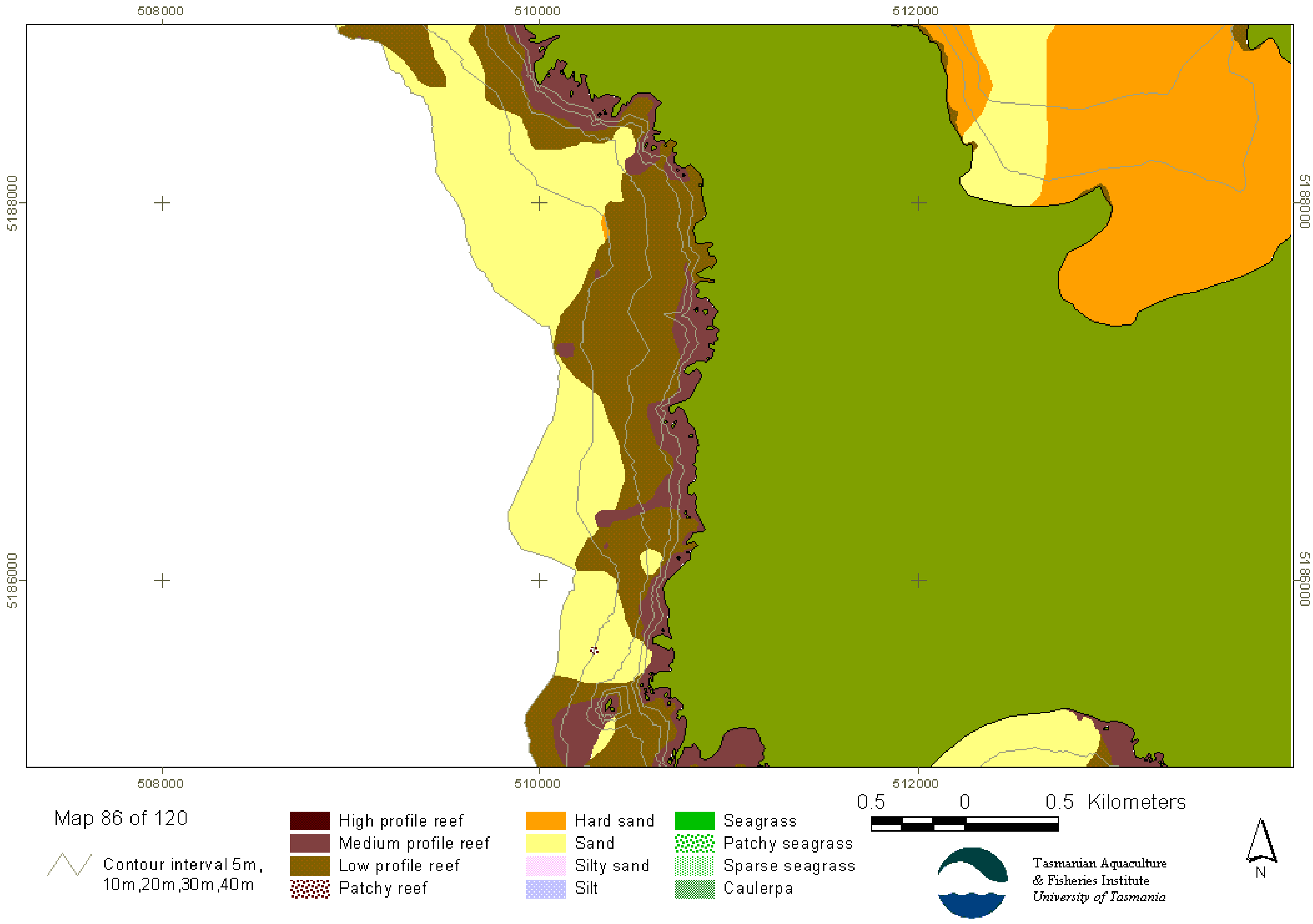
508000
510000
512000
5188000
5186000
Map 86 of 120
Contour interval 5m,
10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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University of Tasmania

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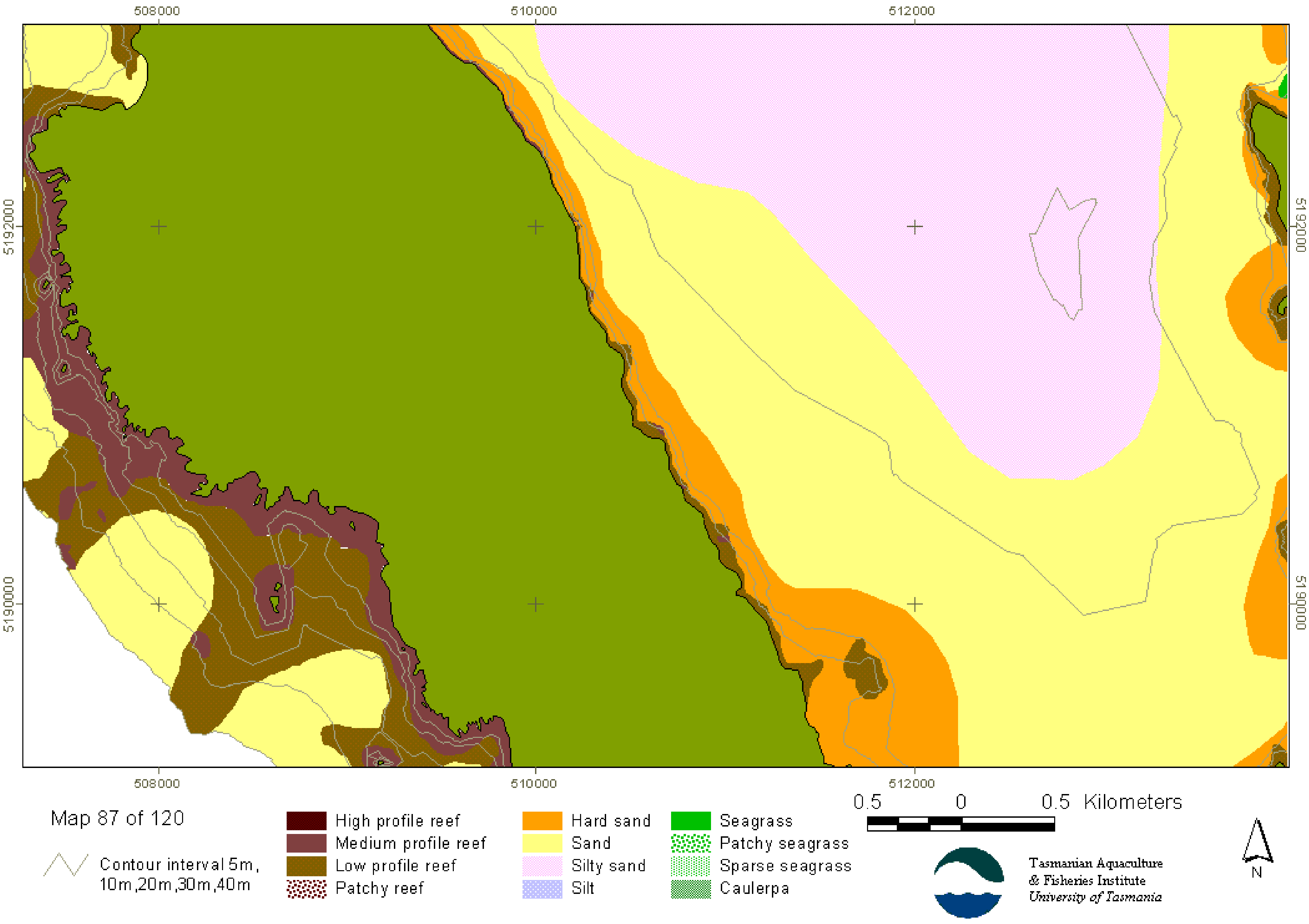
508000
510000
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5192000
5190000
0.5
0
0.5 Kilometers
N
Map 87 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute
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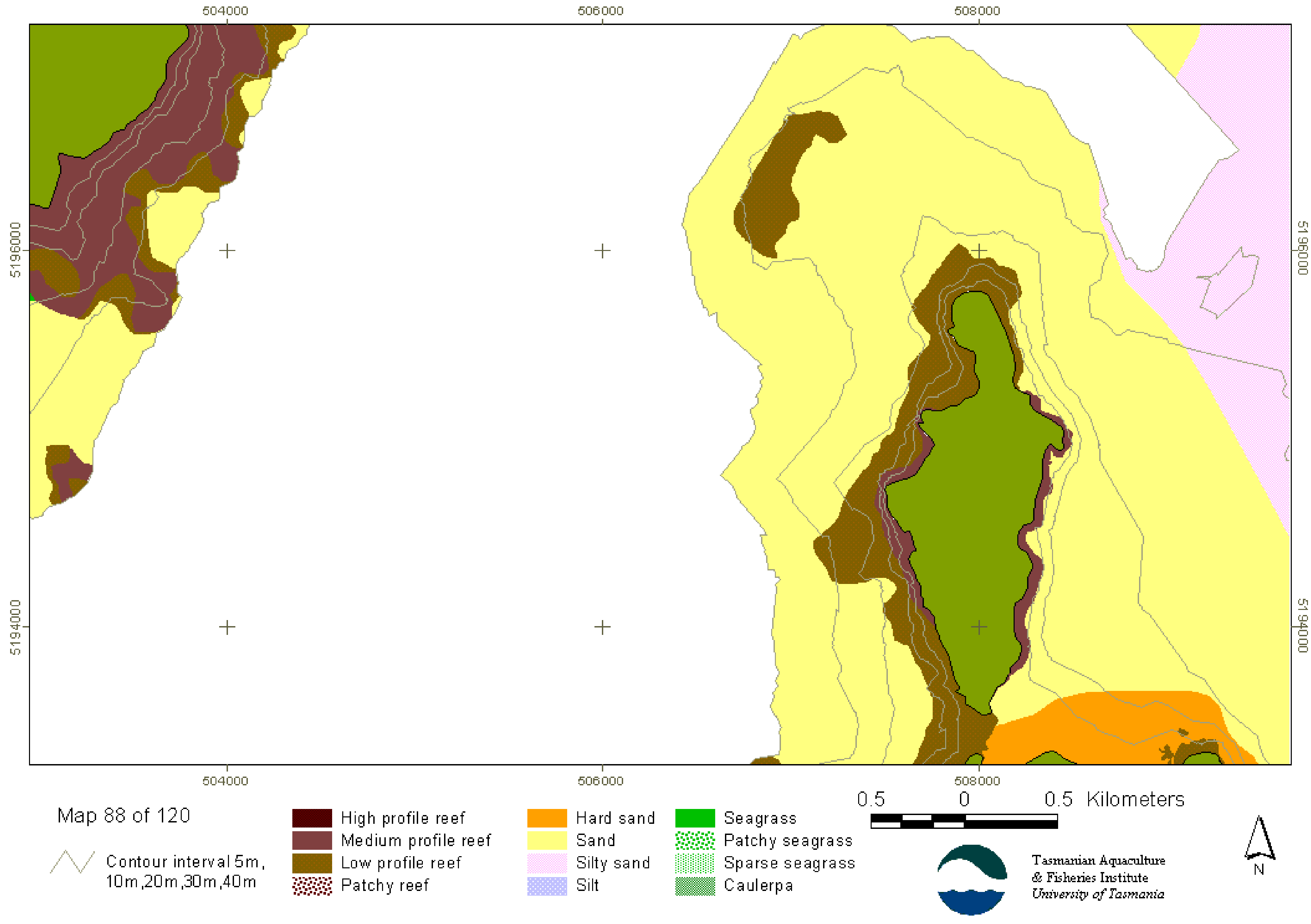
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Map 88 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
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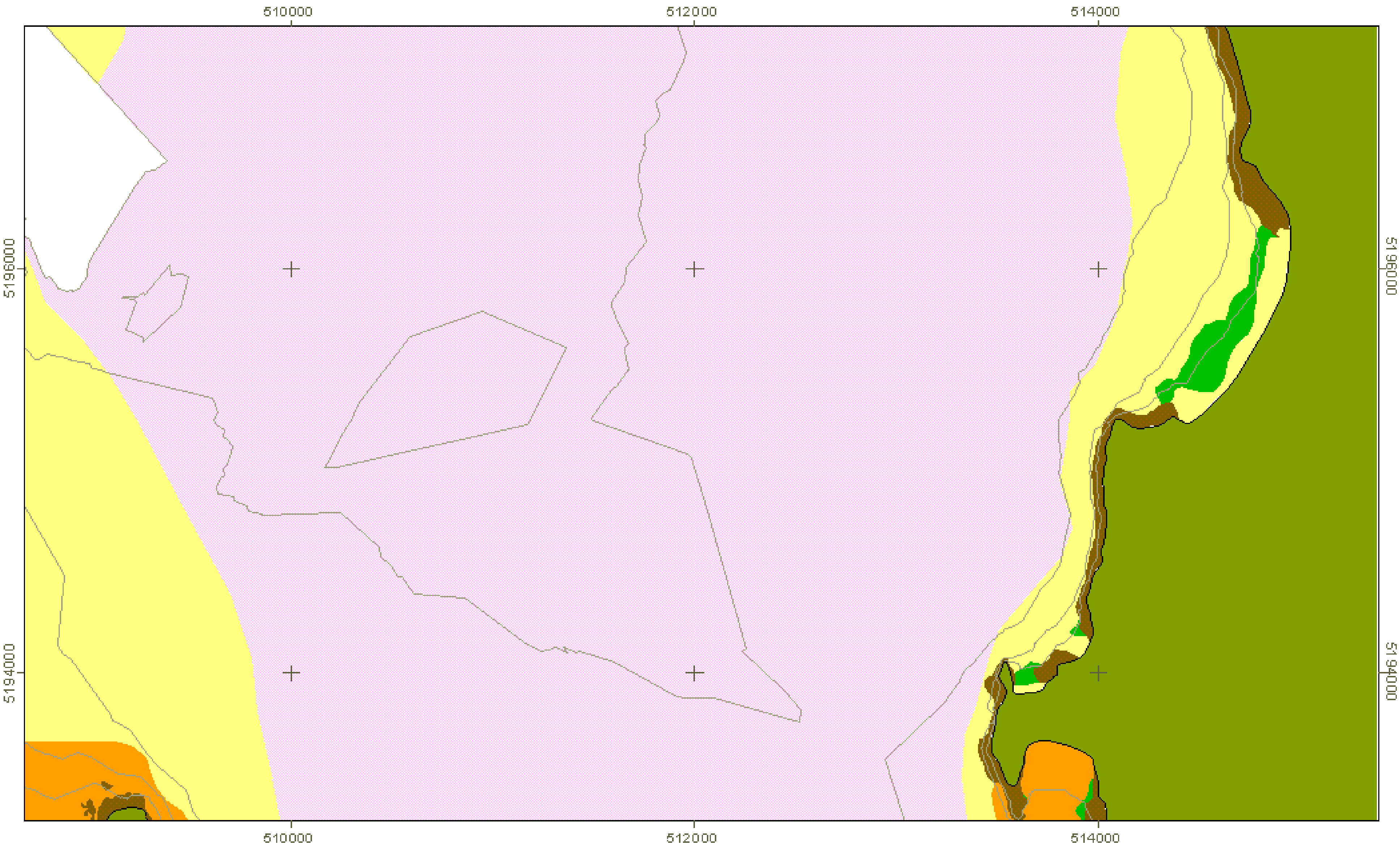

Map 89 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

0.5 0 0.5 Kilometers

N

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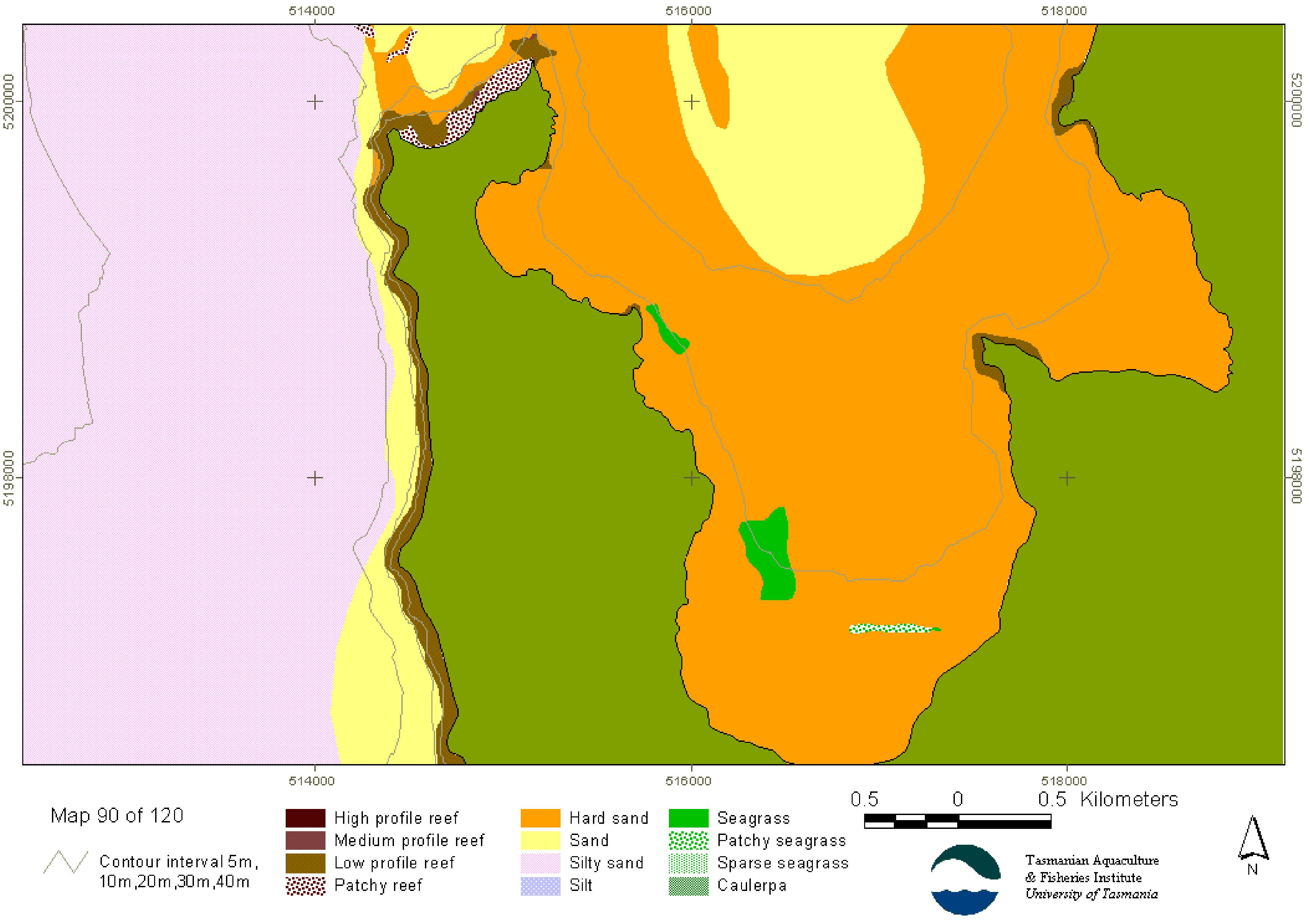
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Map 90 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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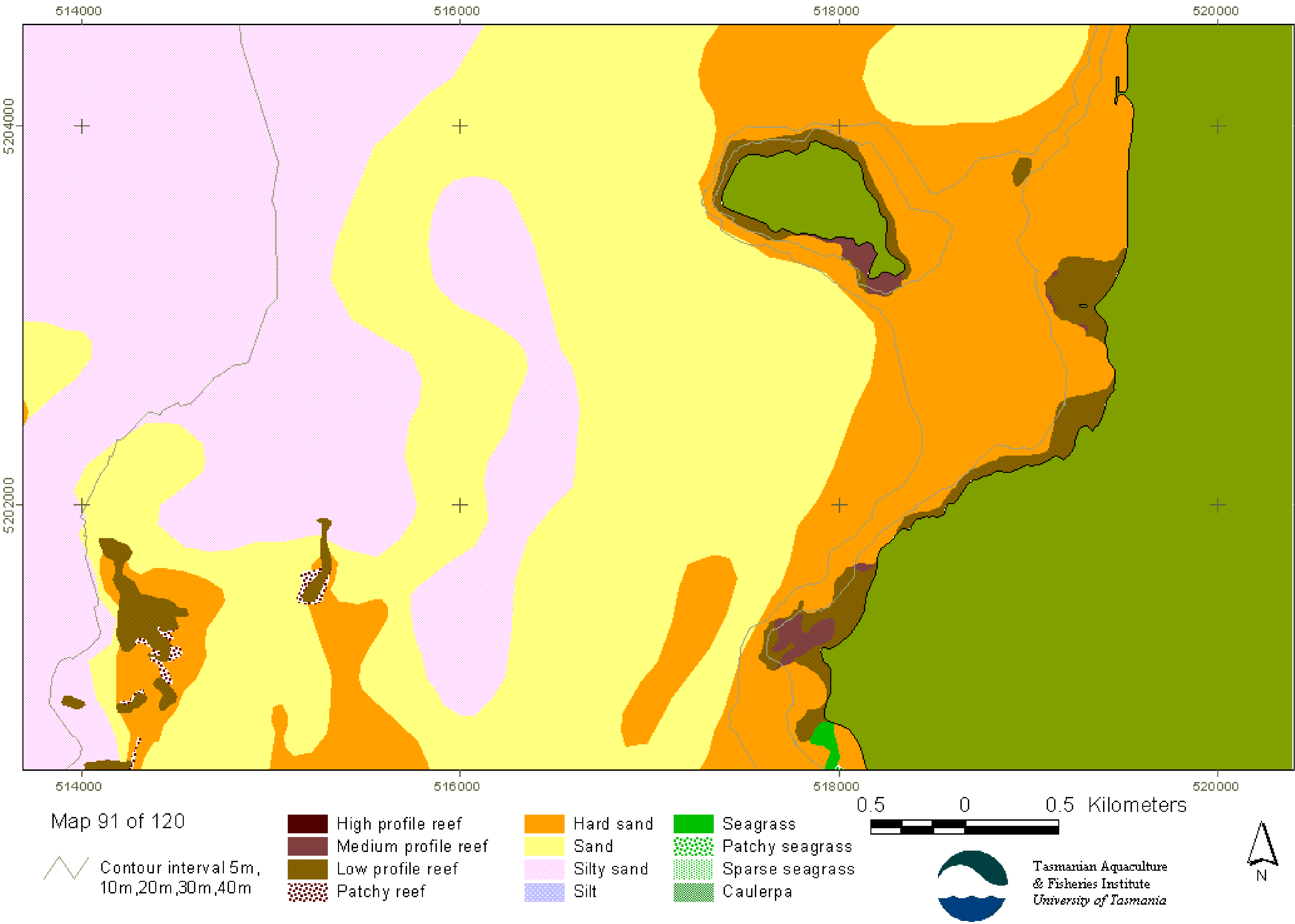

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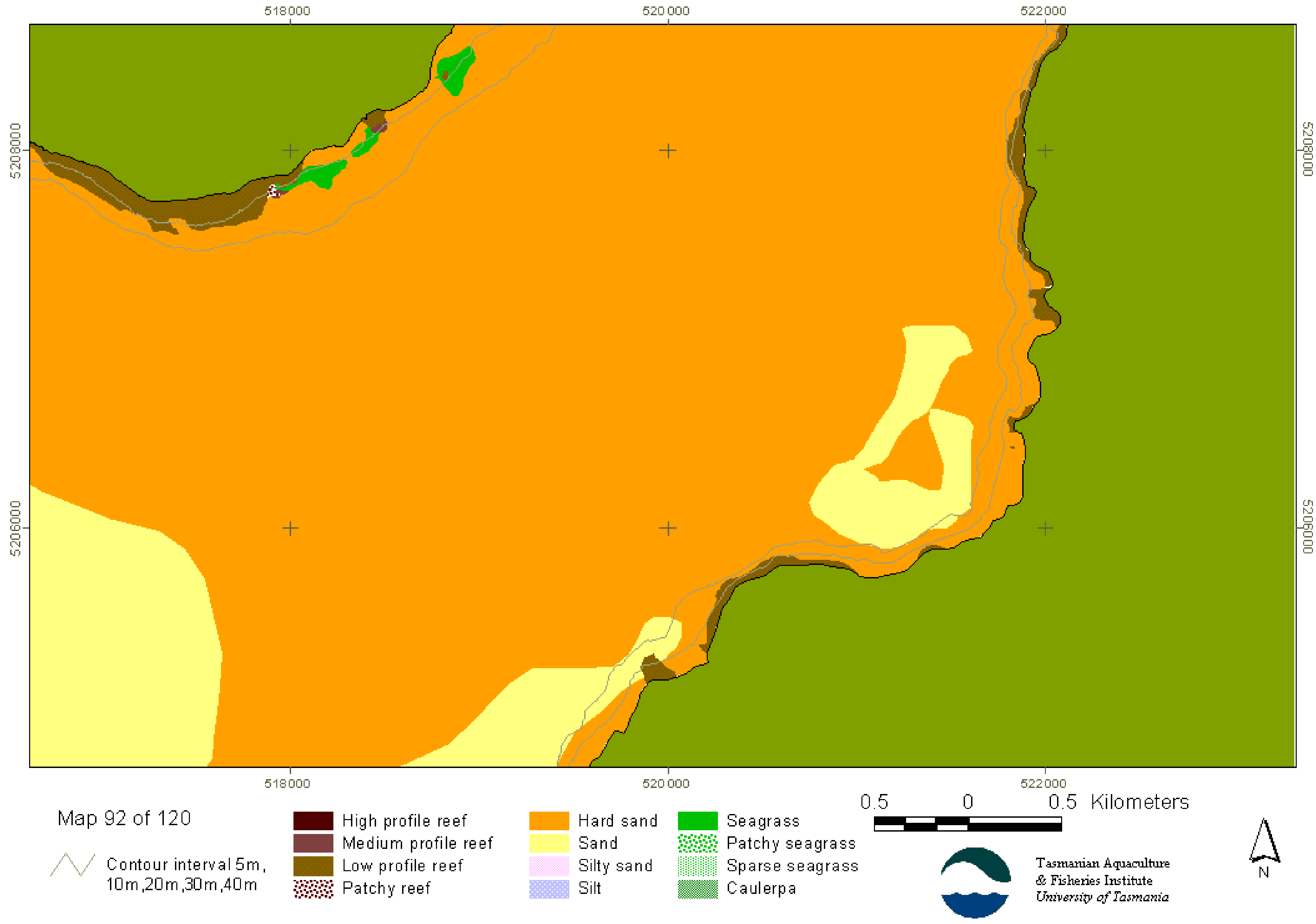
518000
520000
5204000
5202000
Map 91 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

Back



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5208000
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Map 92 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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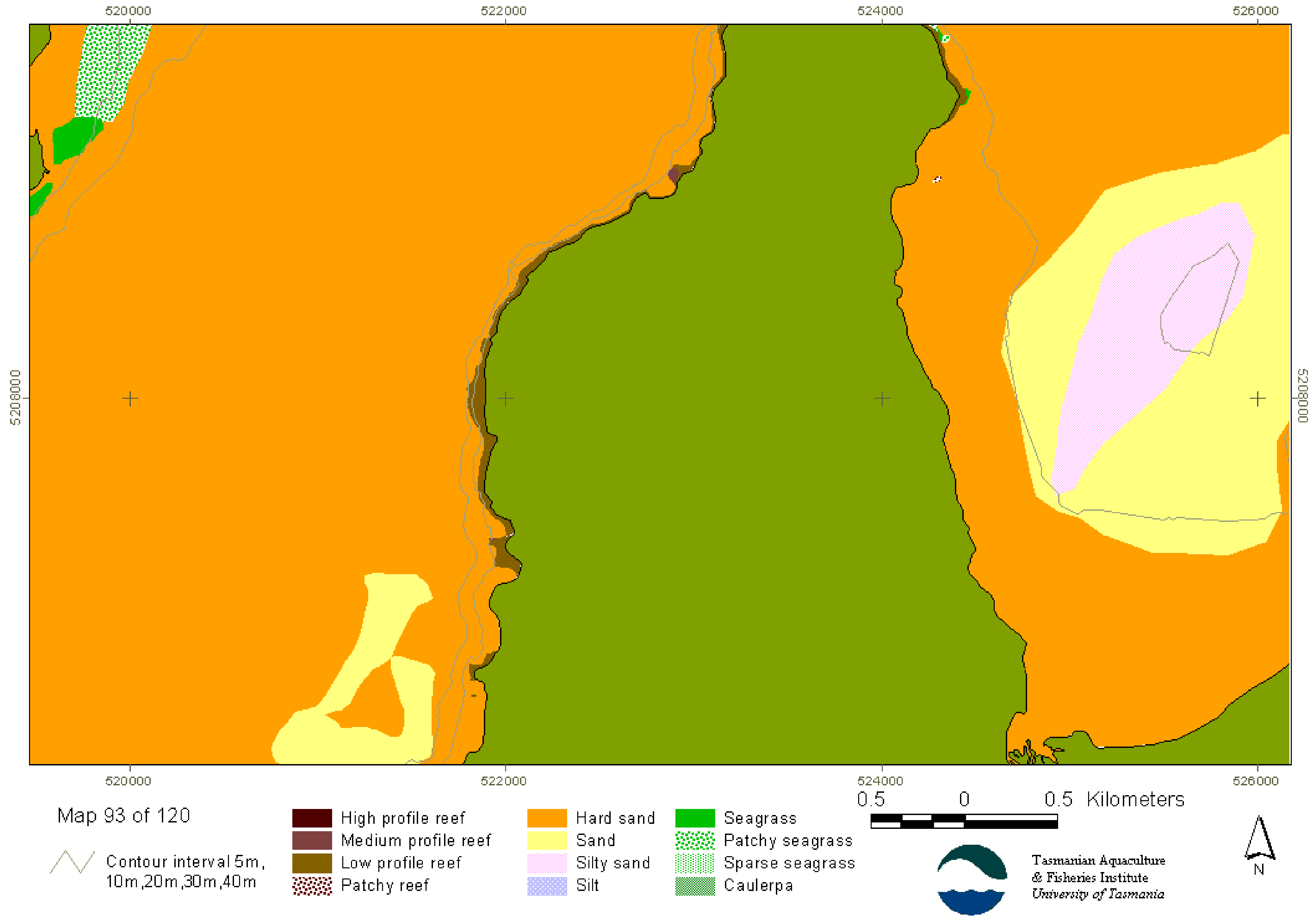
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Map 93 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5
0
0.5 Kilometers
N
Tasmanian Aquaculture
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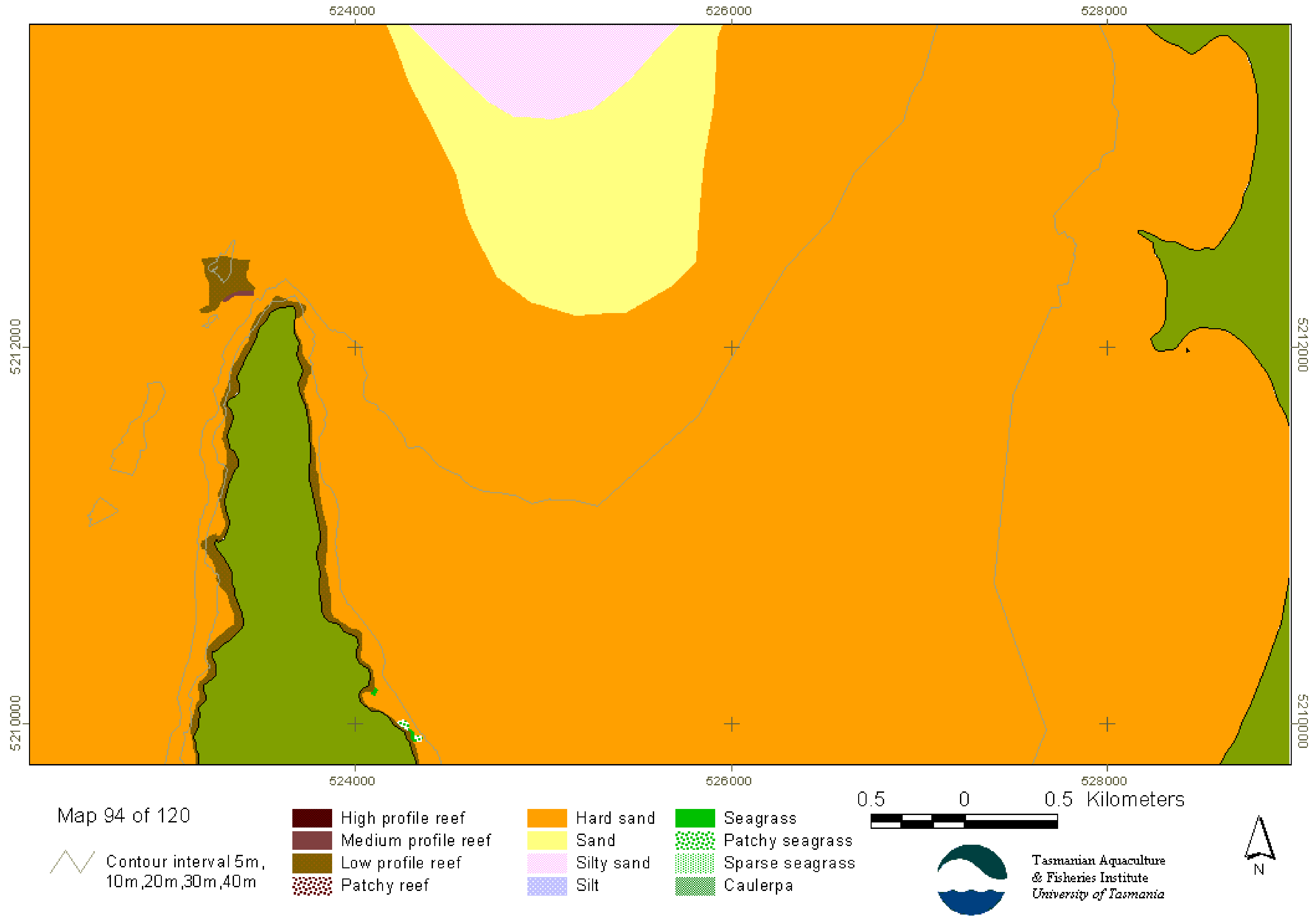
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Map 94 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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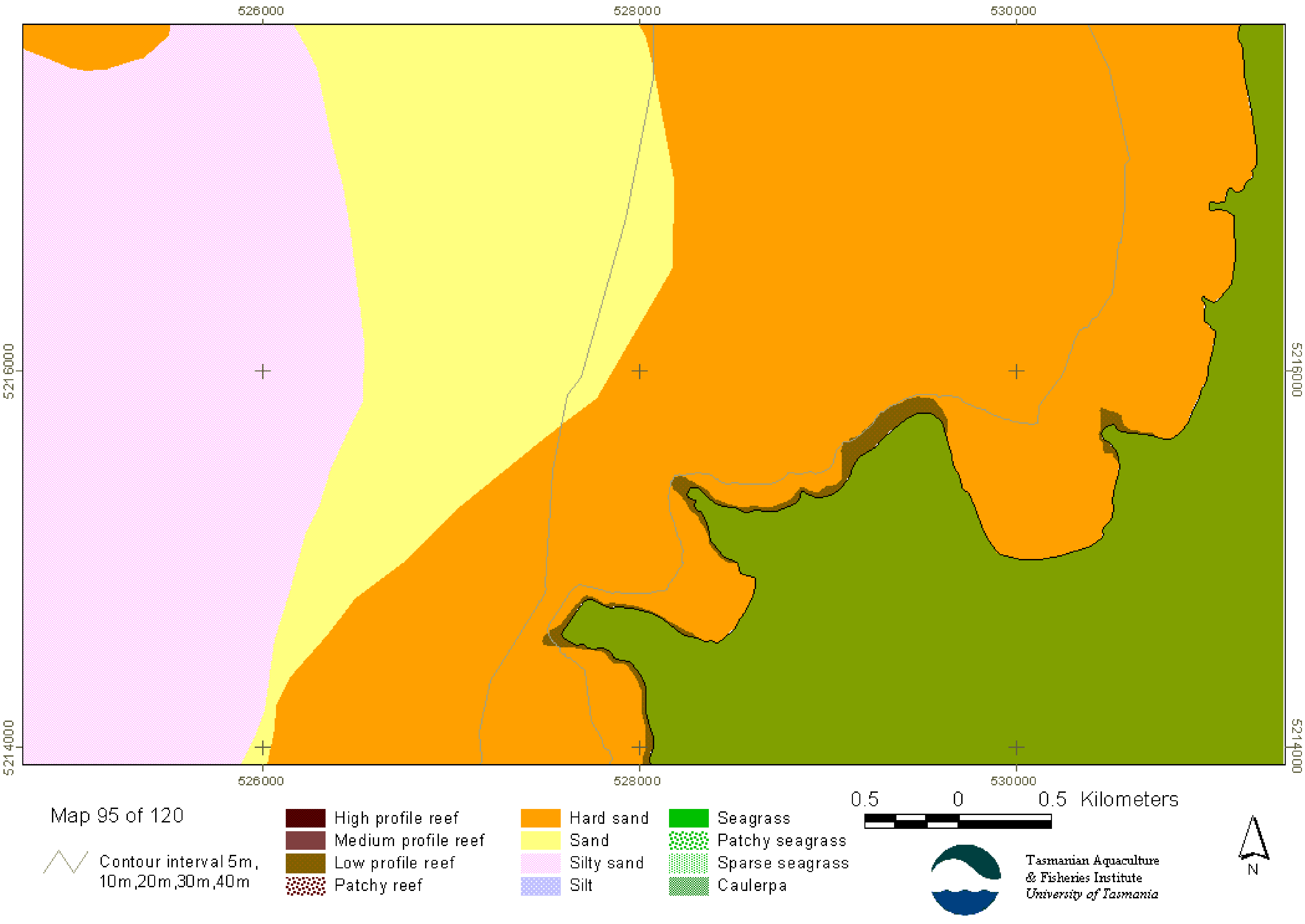
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5214000
Map 95 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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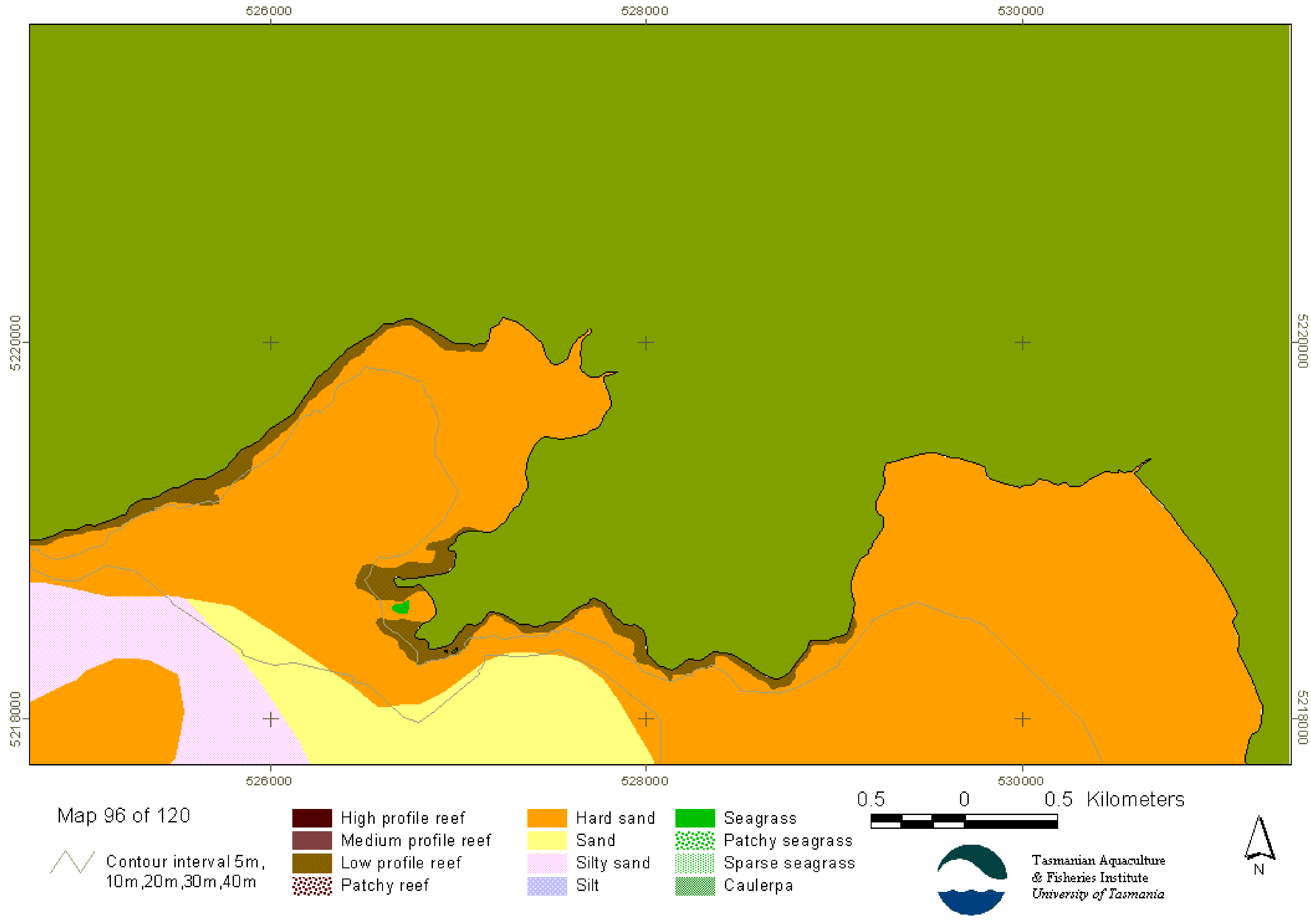
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Map 96 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture
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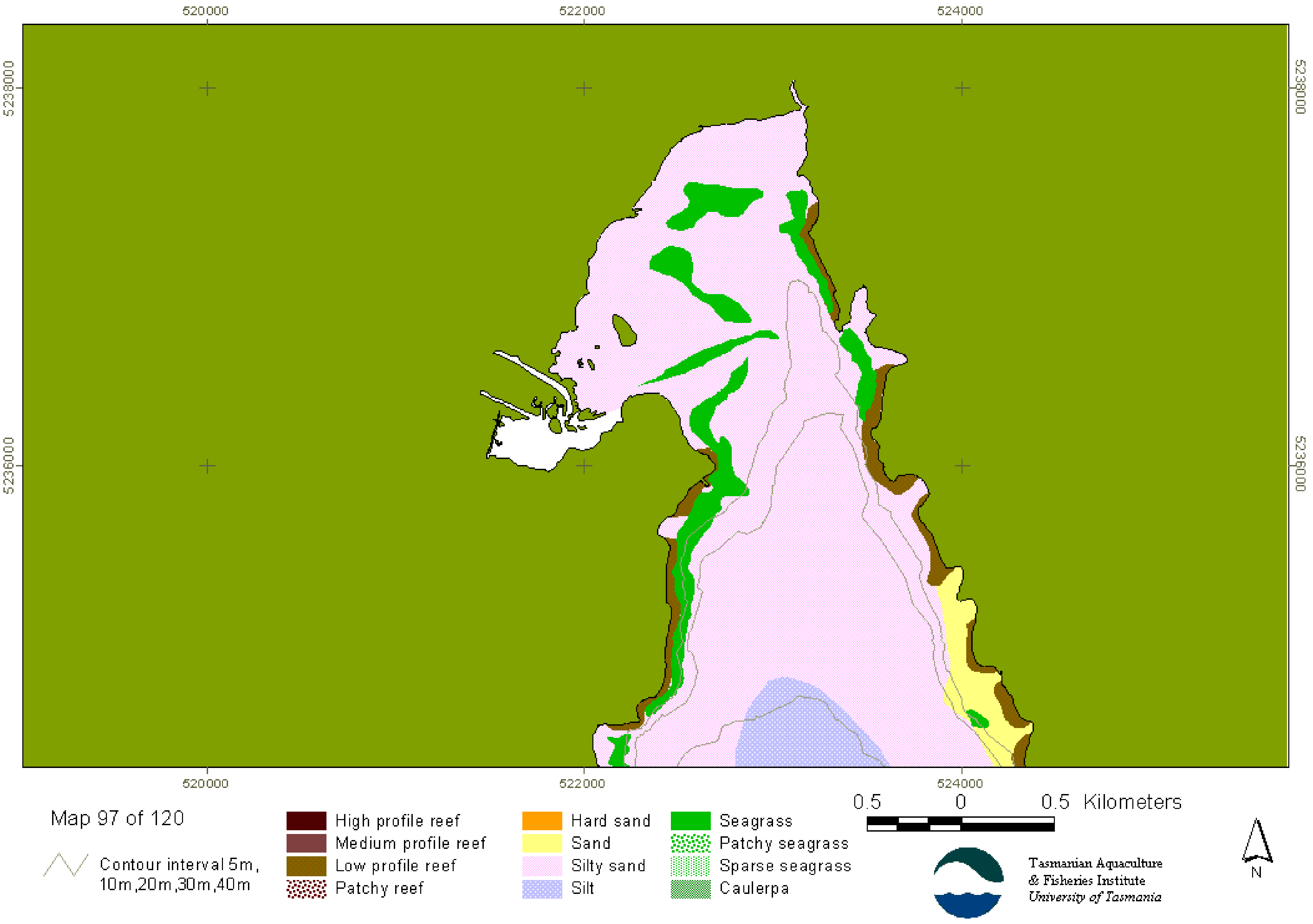
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Map 97 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture
& Fisheries Institute
University of Tasmania
N

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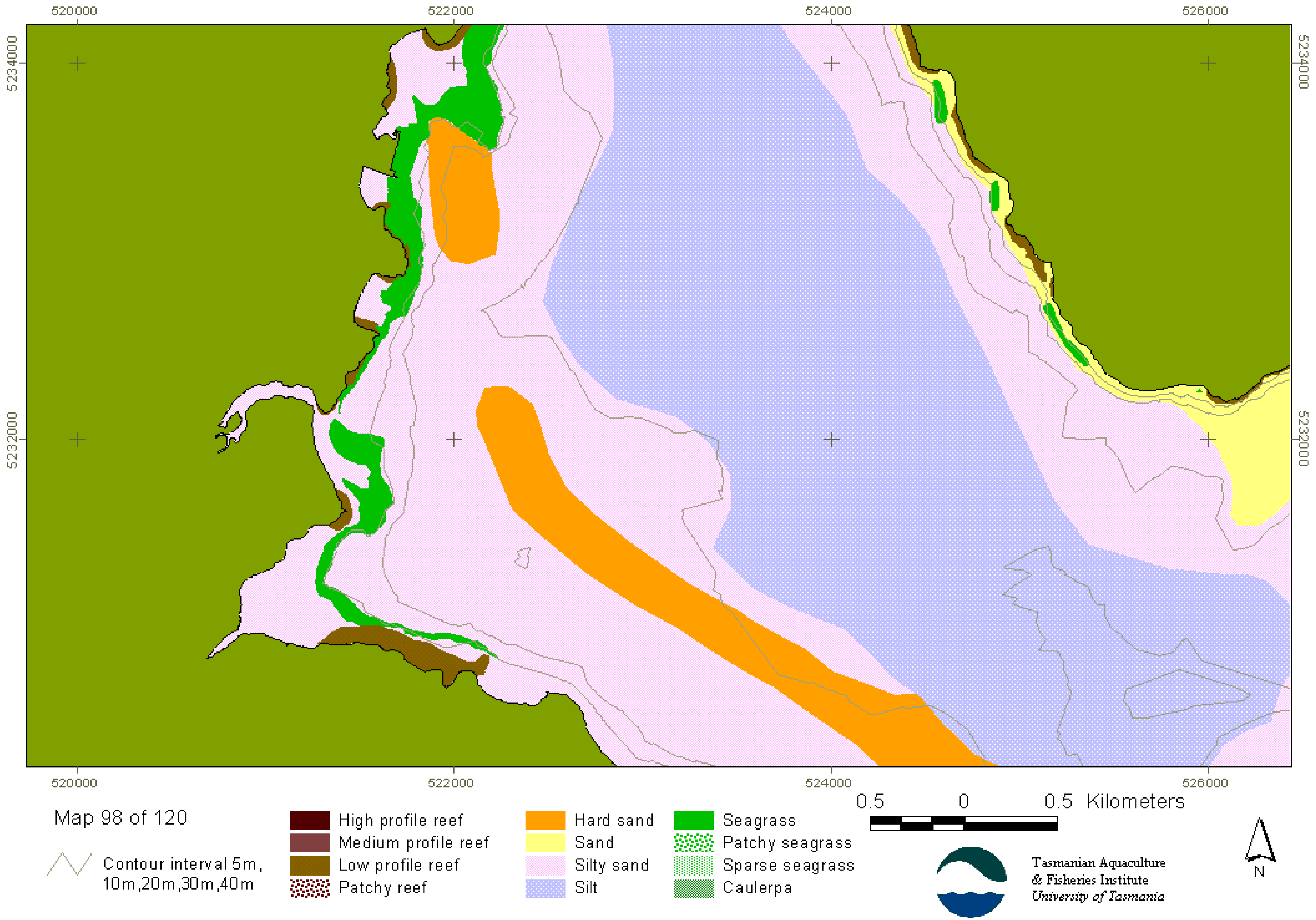

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Map 98 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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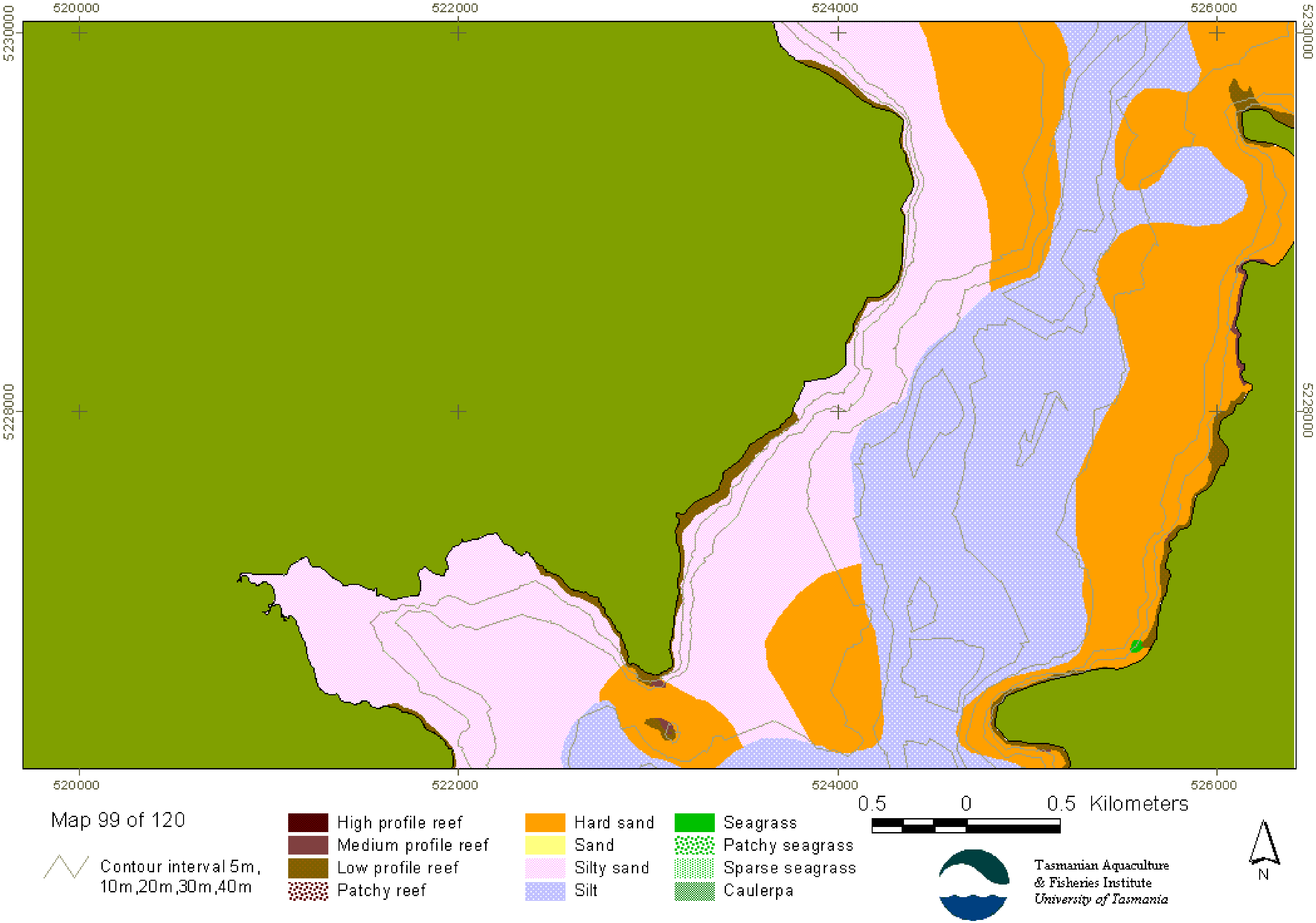

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Map 99 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
Tasmanian Aquaculture & Fisheries Institute
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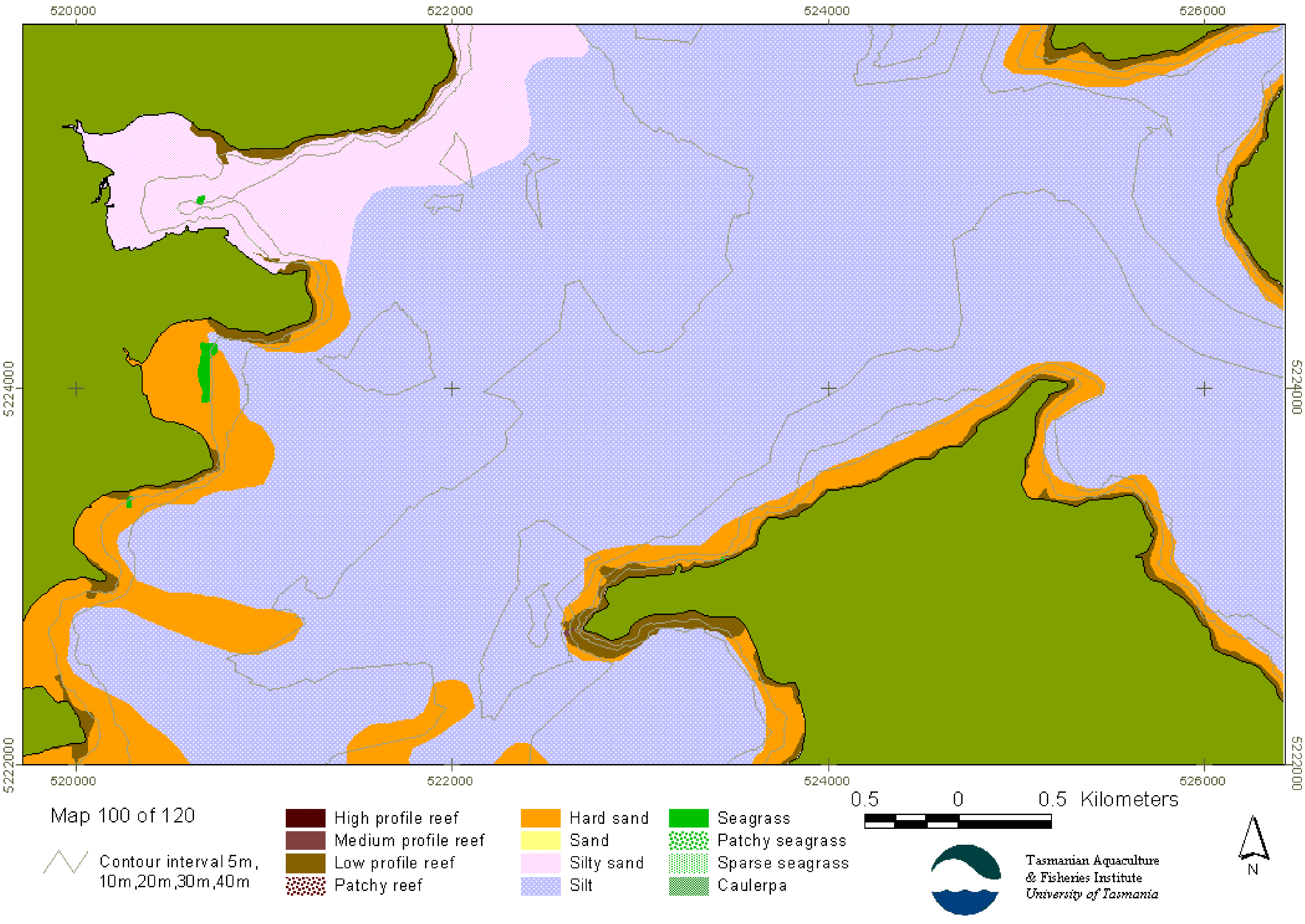
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Map 100 of 120
Contour interval 5m,
10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
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Tasmanian Aquaculture
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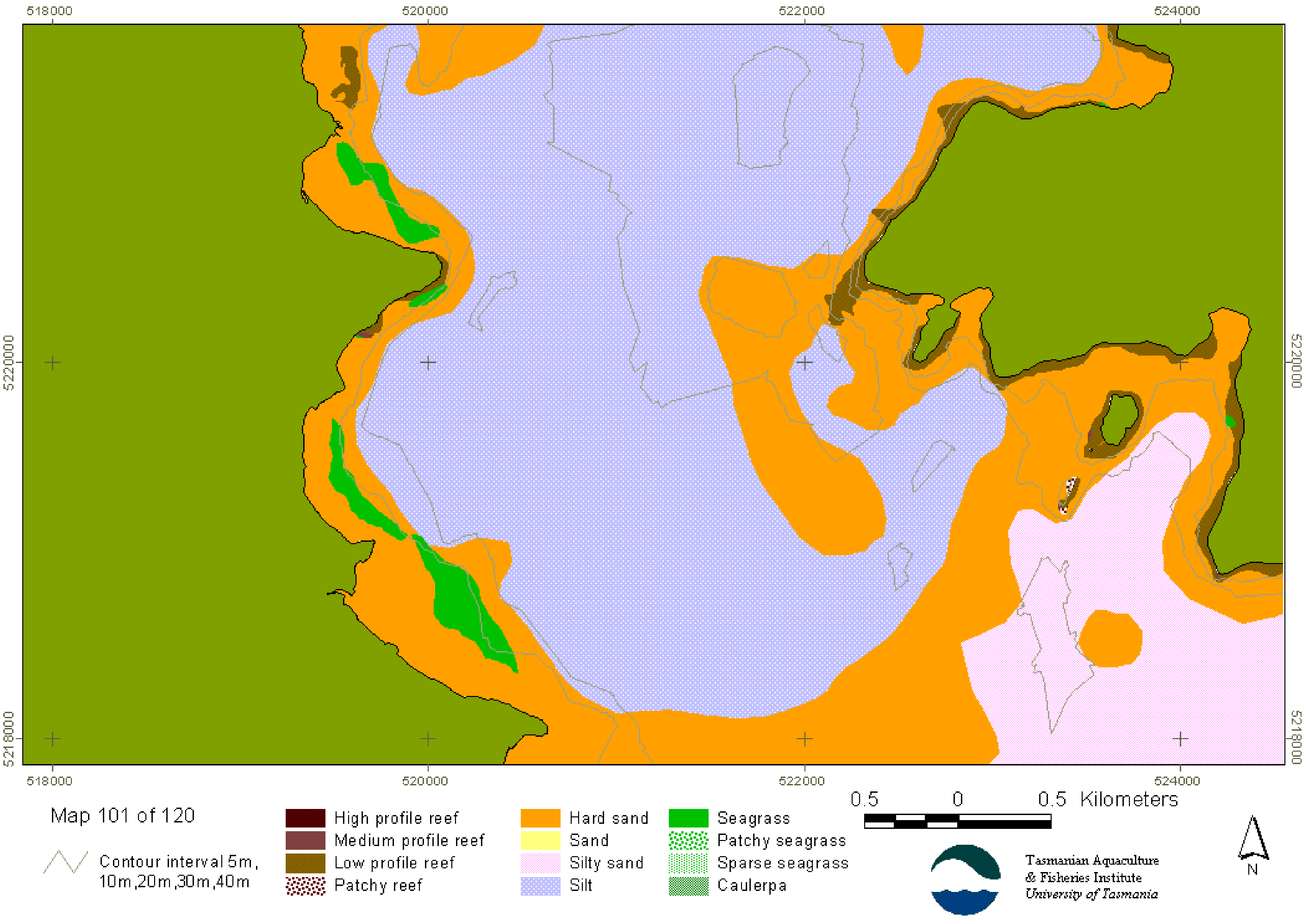

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5218000
Map 101 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5
0
0.5 Kilometers
N
Tasmanian Aquaculture
& Fisheries Institute
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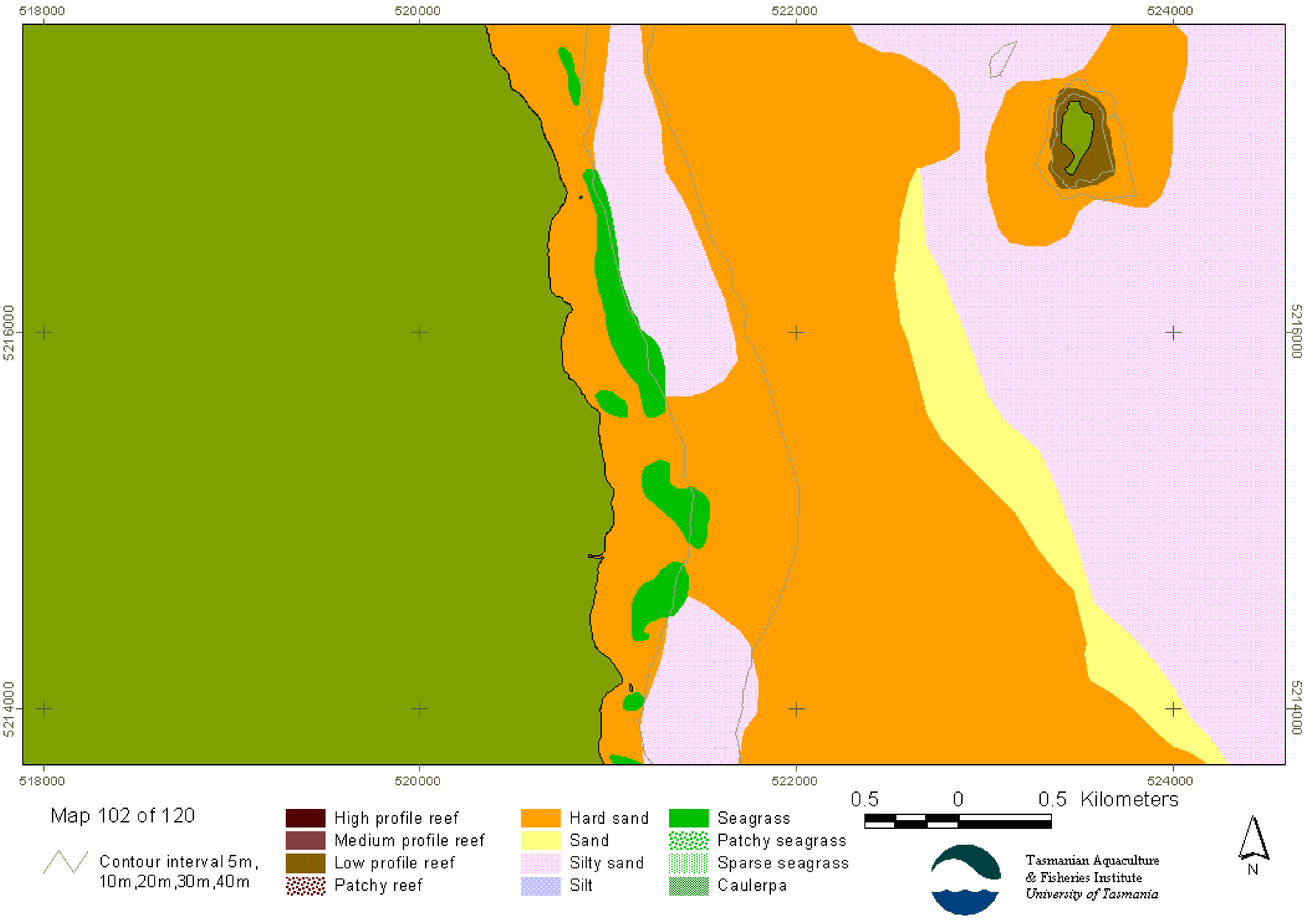
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Map 102 of 120
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Contour interval 5m, 10m,20m,30m,40m
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Tasmanian Aquaculture & Fisheries Institute University of Tasmania

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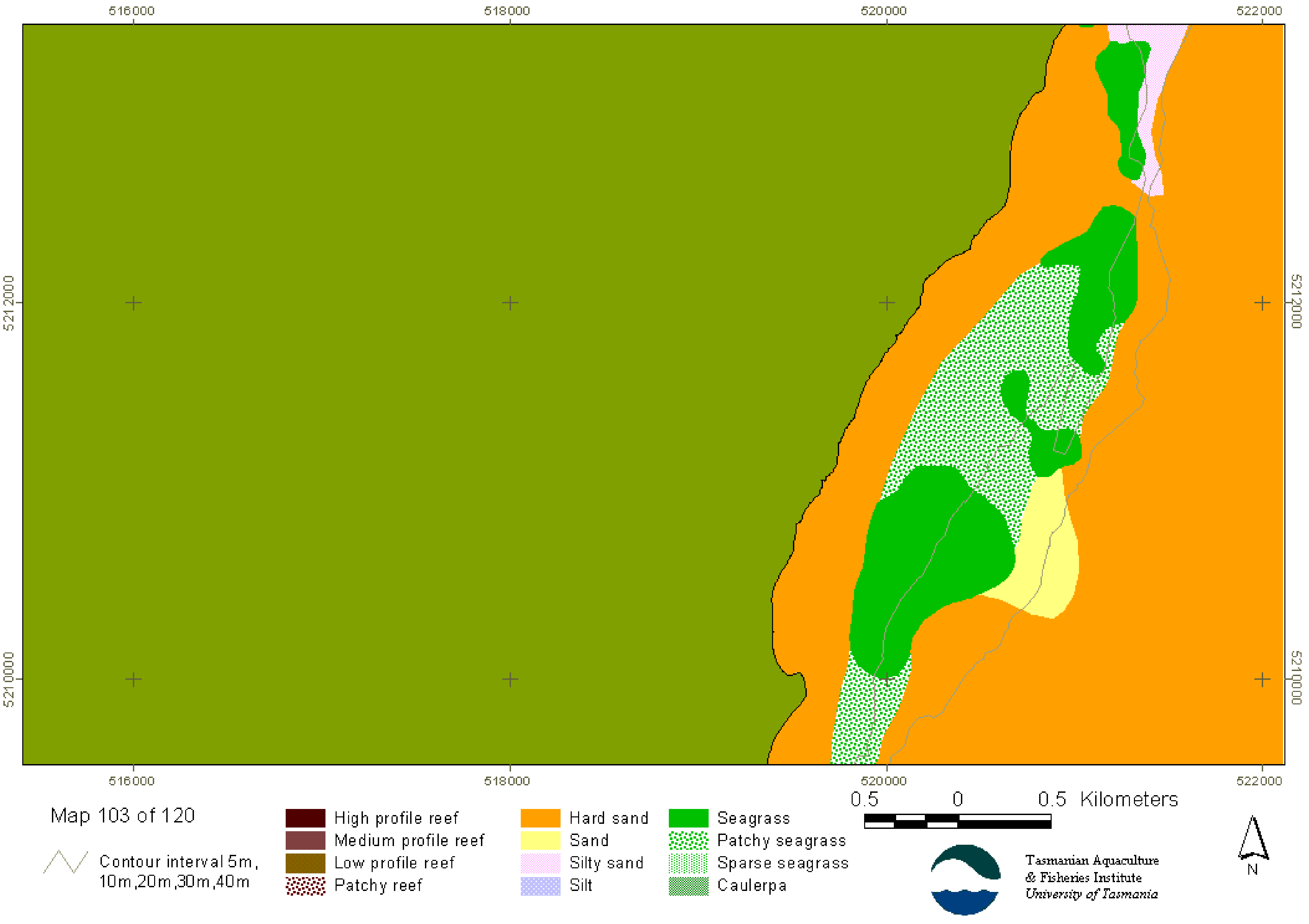
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5212000
5210000
0.5 0 0.5 Kilometers
N
Map 103 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute
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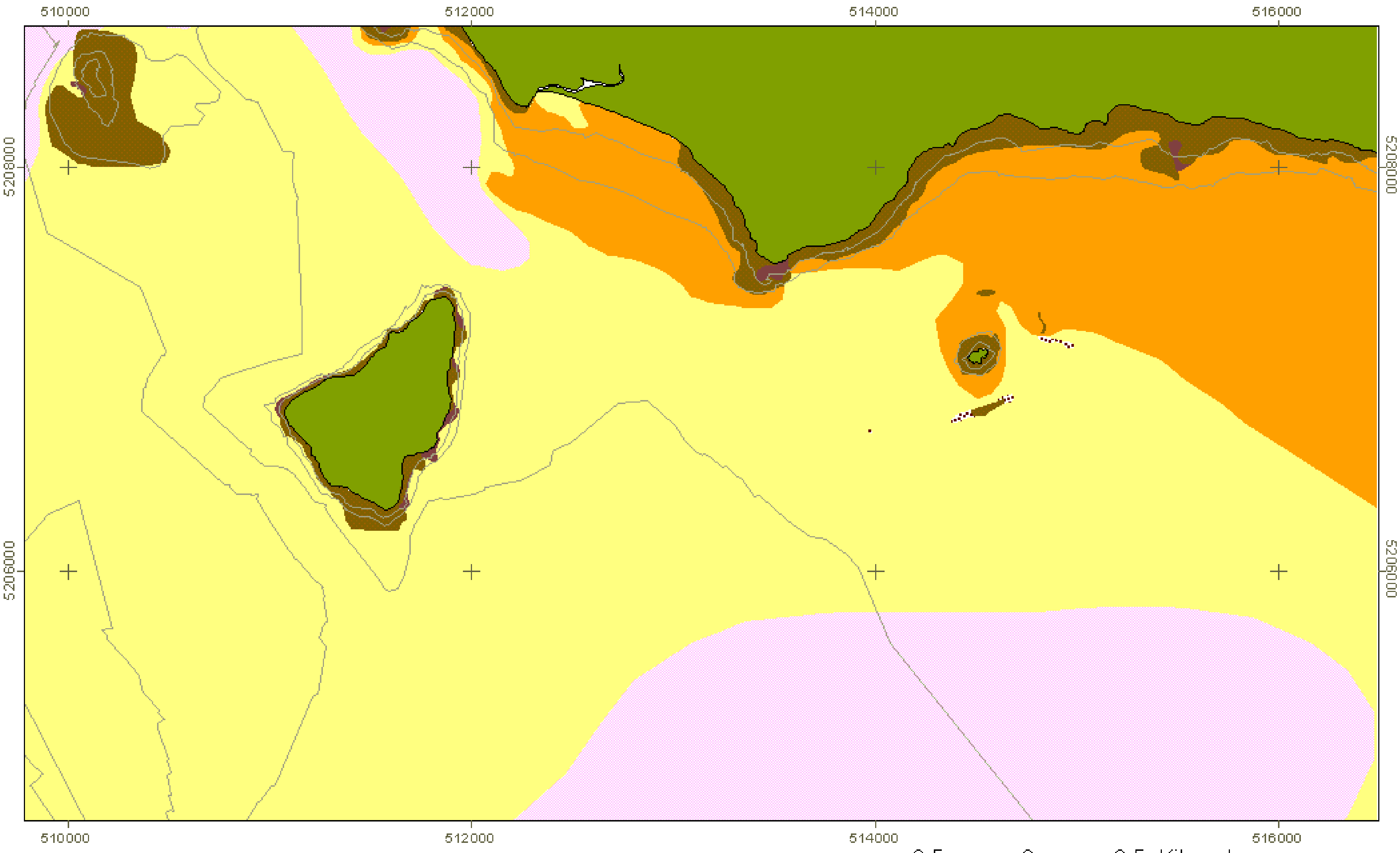

Map 104 of 120

Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

0.5 0 0.5 Kilometers

N

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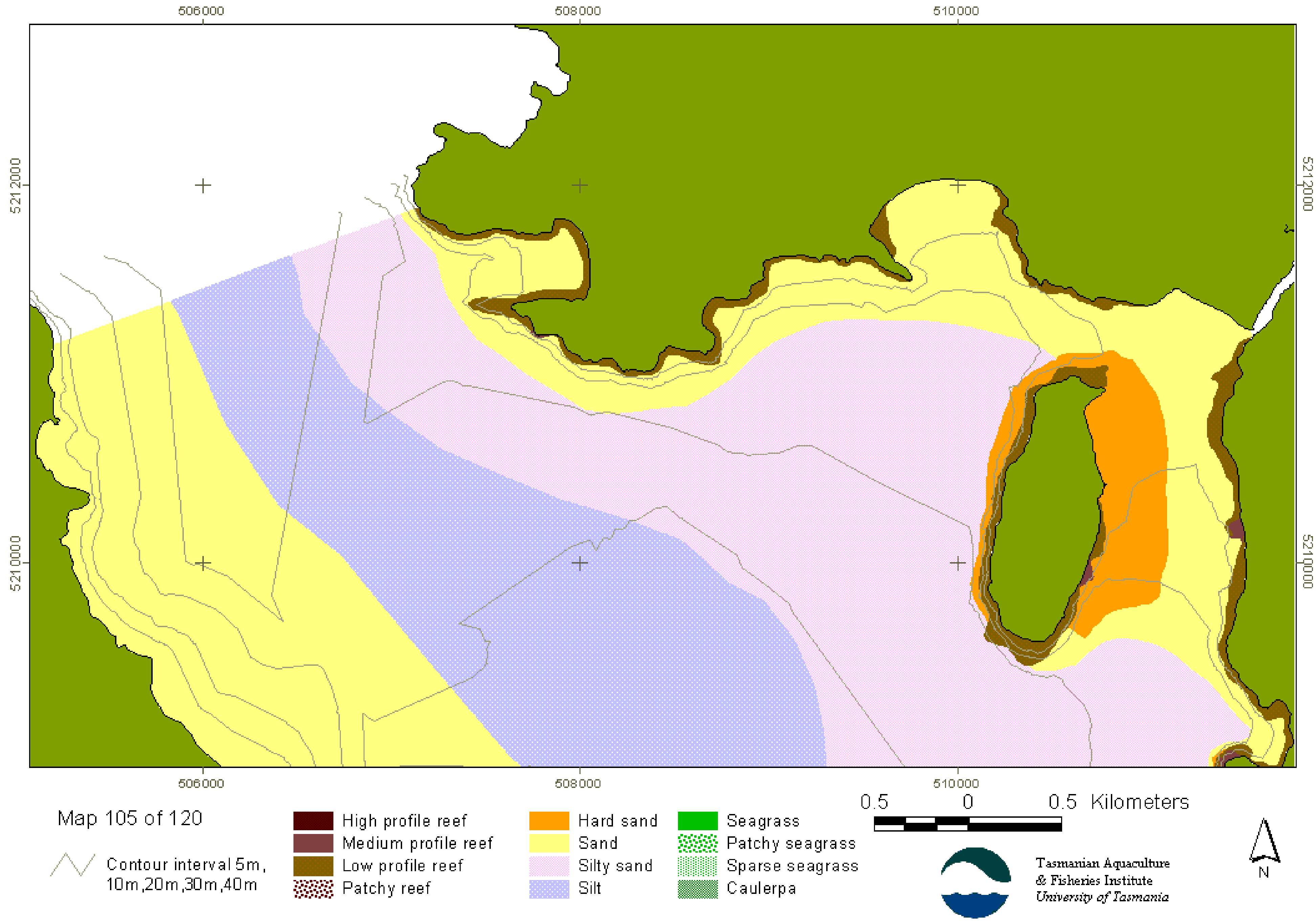
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Map 105 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
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Tasmanian Aquaculture & Fisheries Institute University of Tasmania
N

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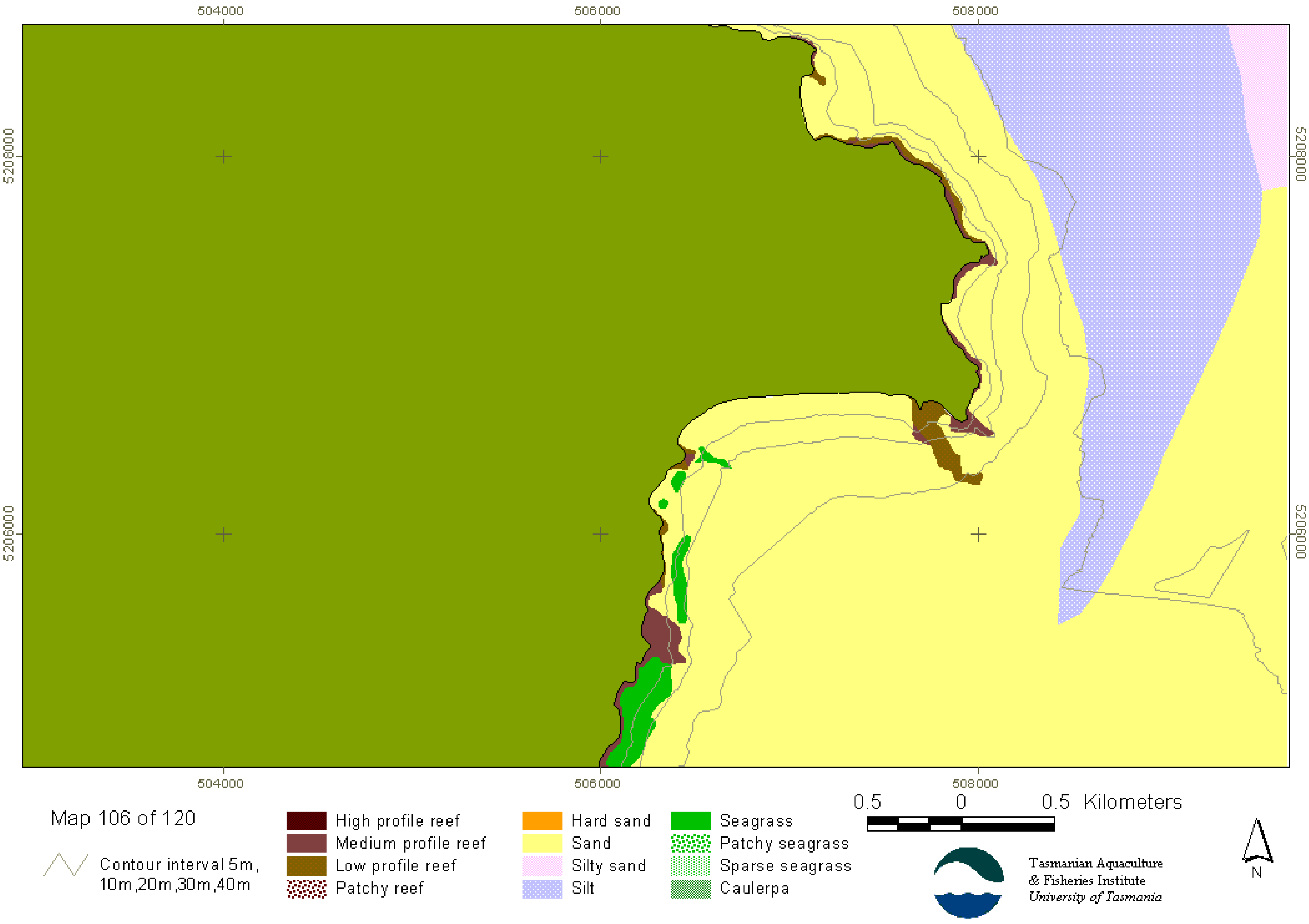
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Patchy reef
Hard sand
Sand
Silty sand
Silt
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Sparse seagrass
Caulerpa
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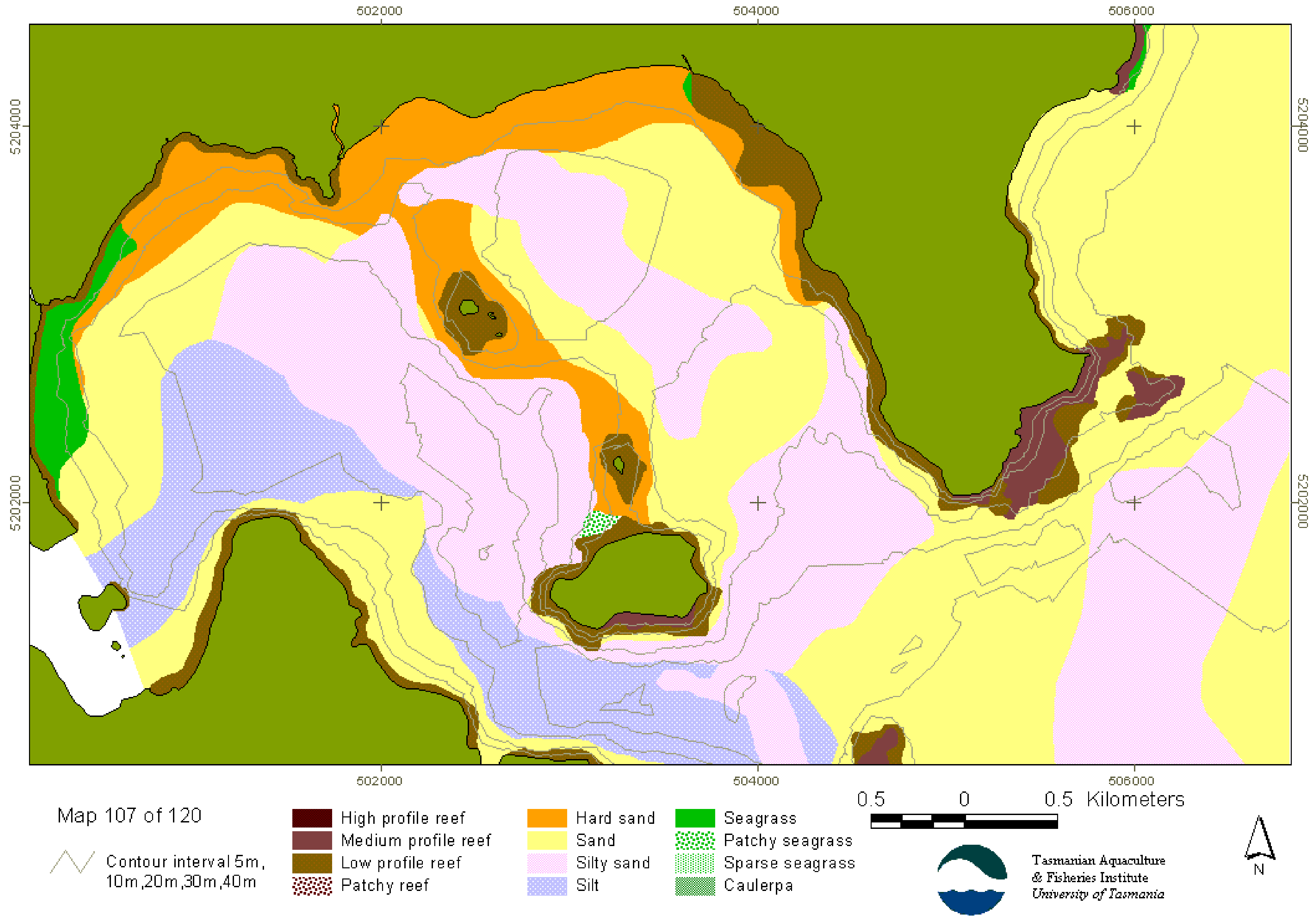
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Contour interval 5m, 10m,20m,30m,40m
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Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
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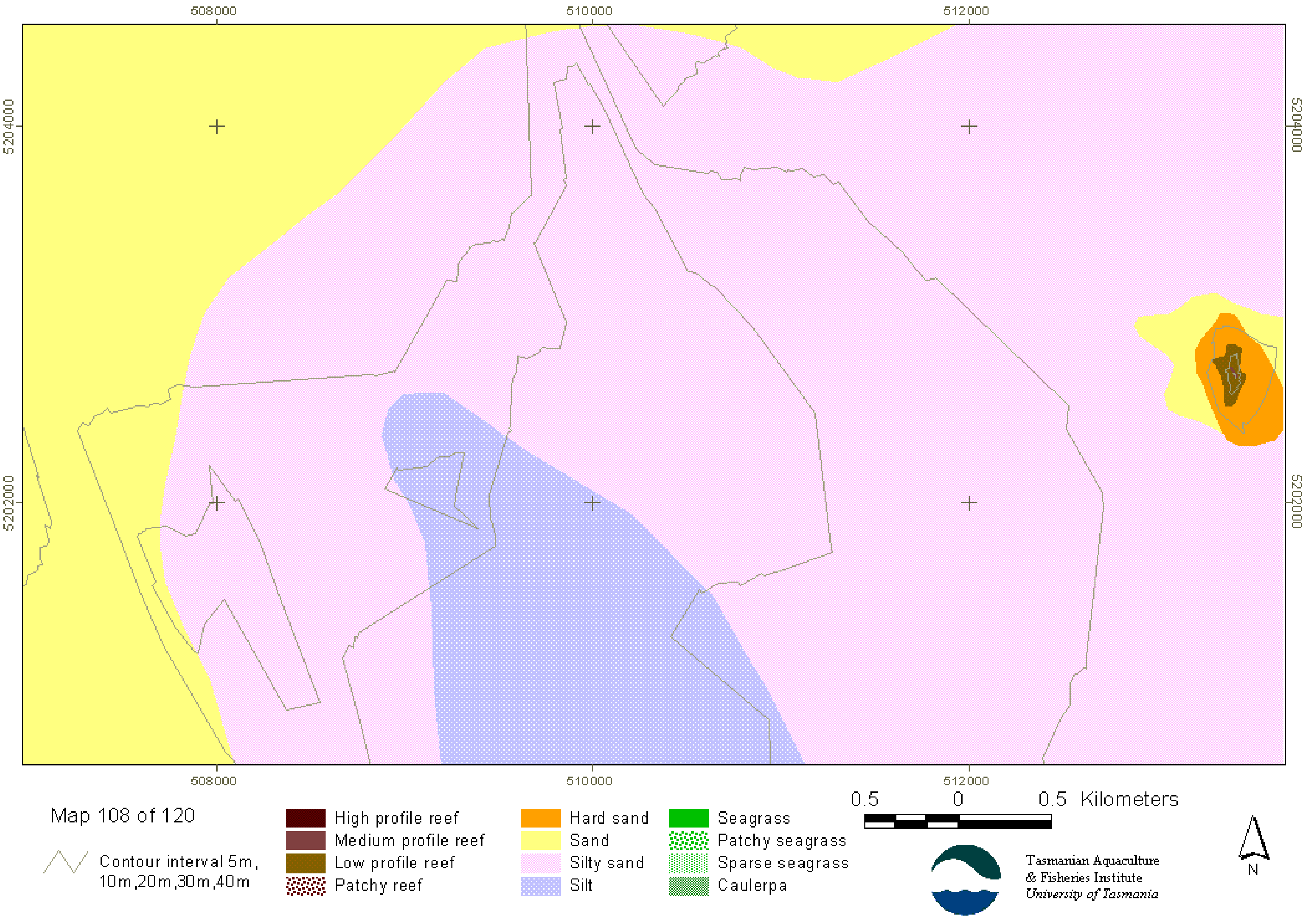

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Map 108 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
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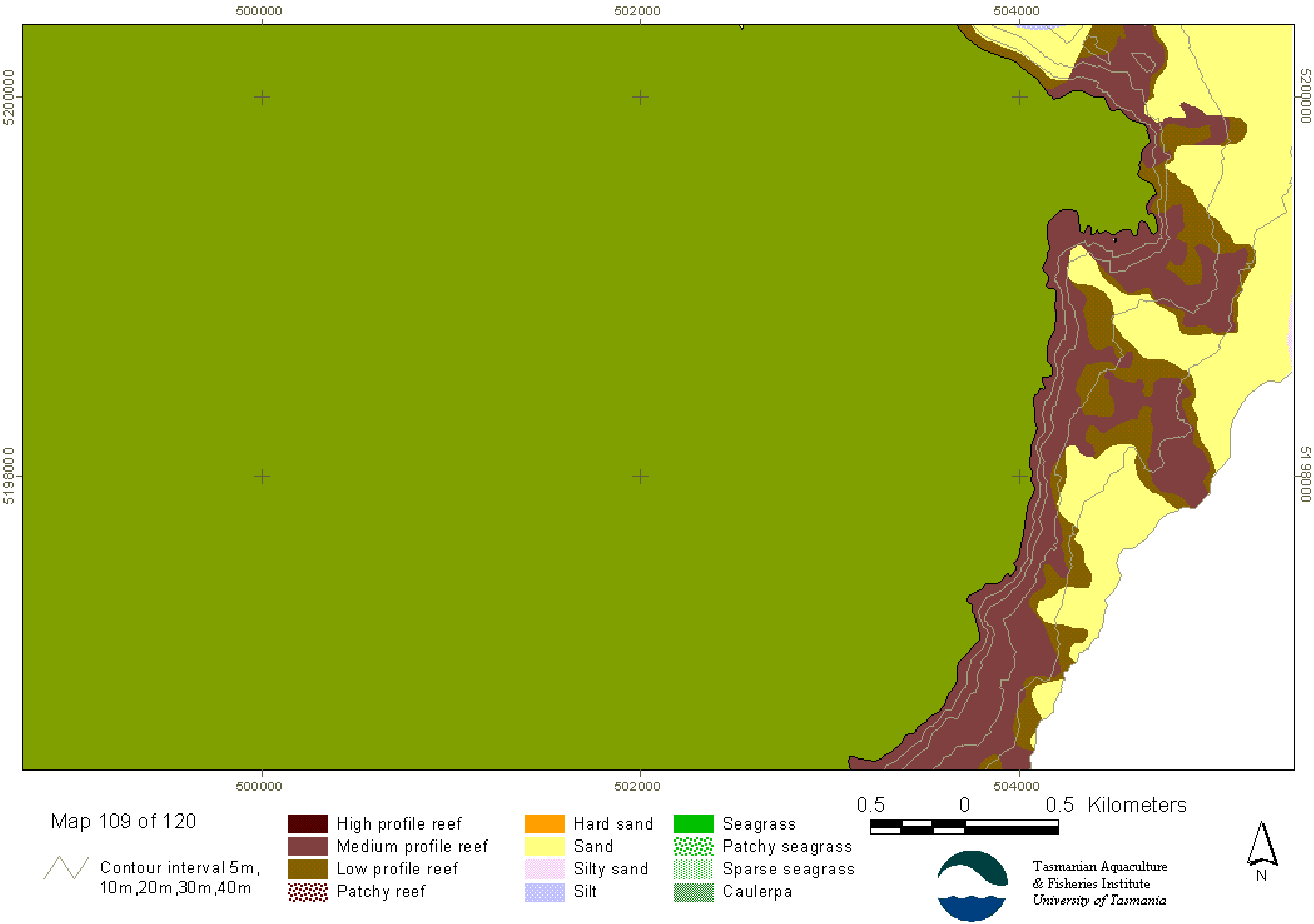
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Map 109 of 120
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Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
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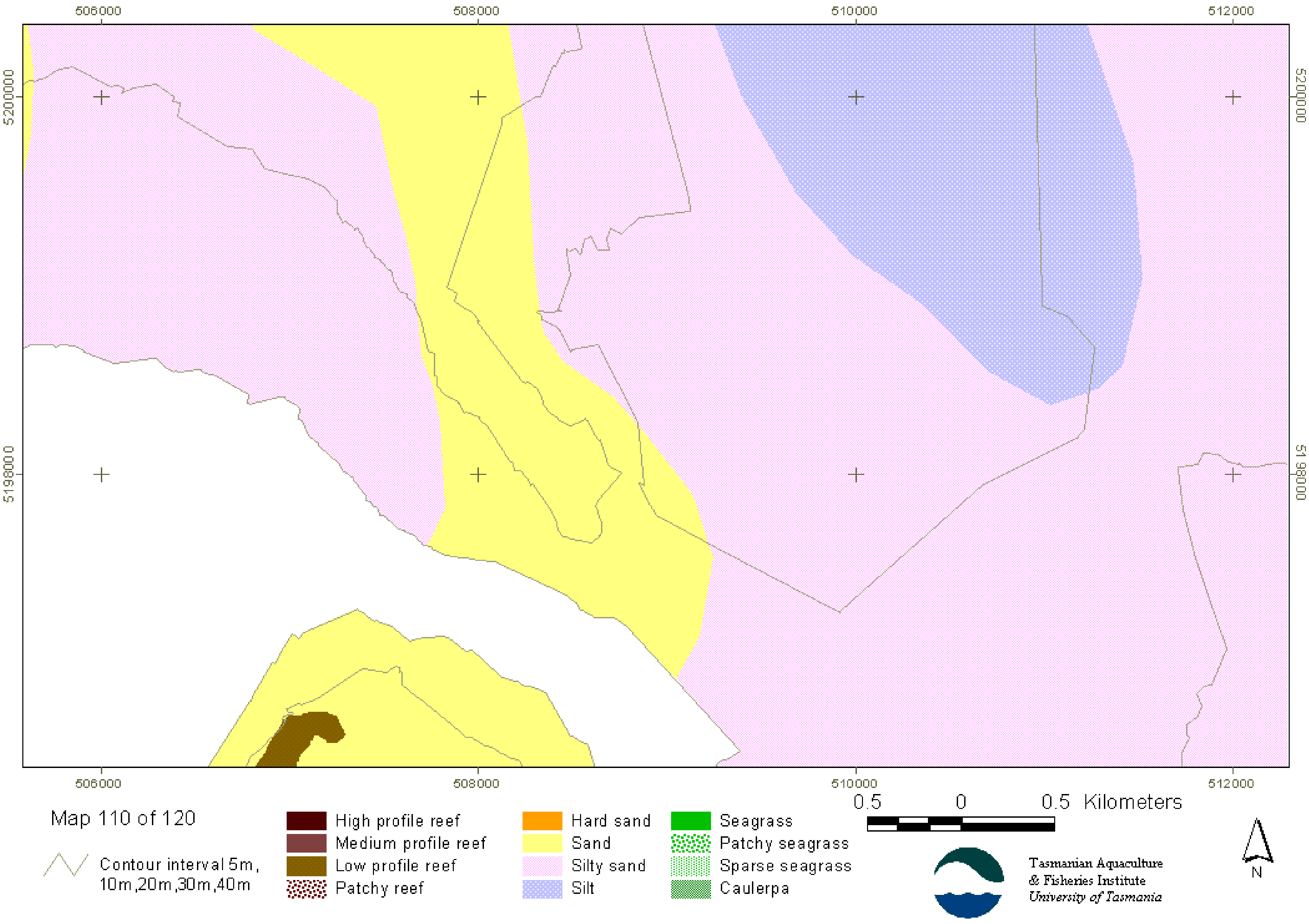
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0.5 Kilometers
Map 110 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
Tasmanian Aquaculture & Fisheries Institute University of Tasmania
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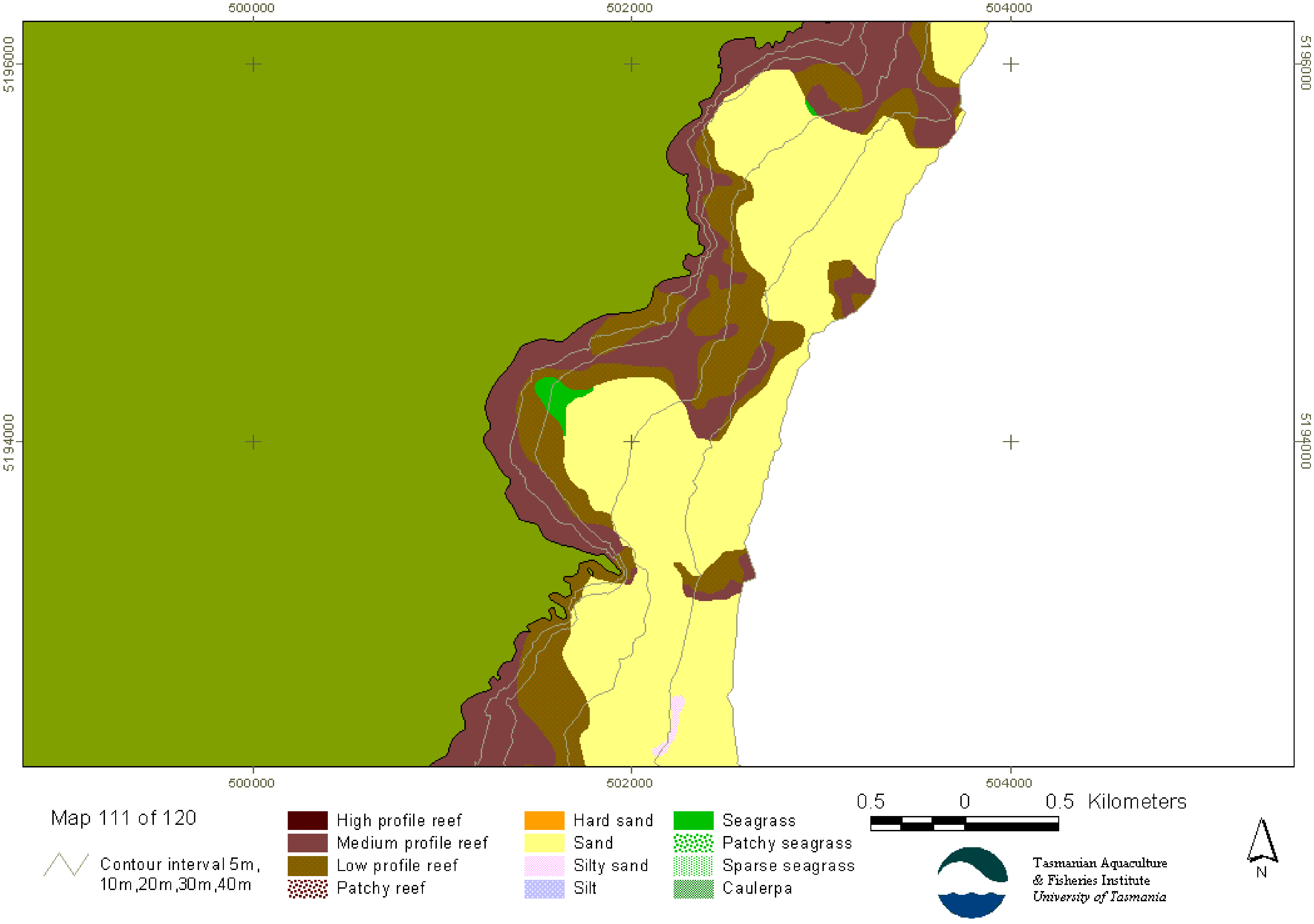
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Map 111 of 120
Contour interval 5m, 10m,20m,30m,40m
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Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
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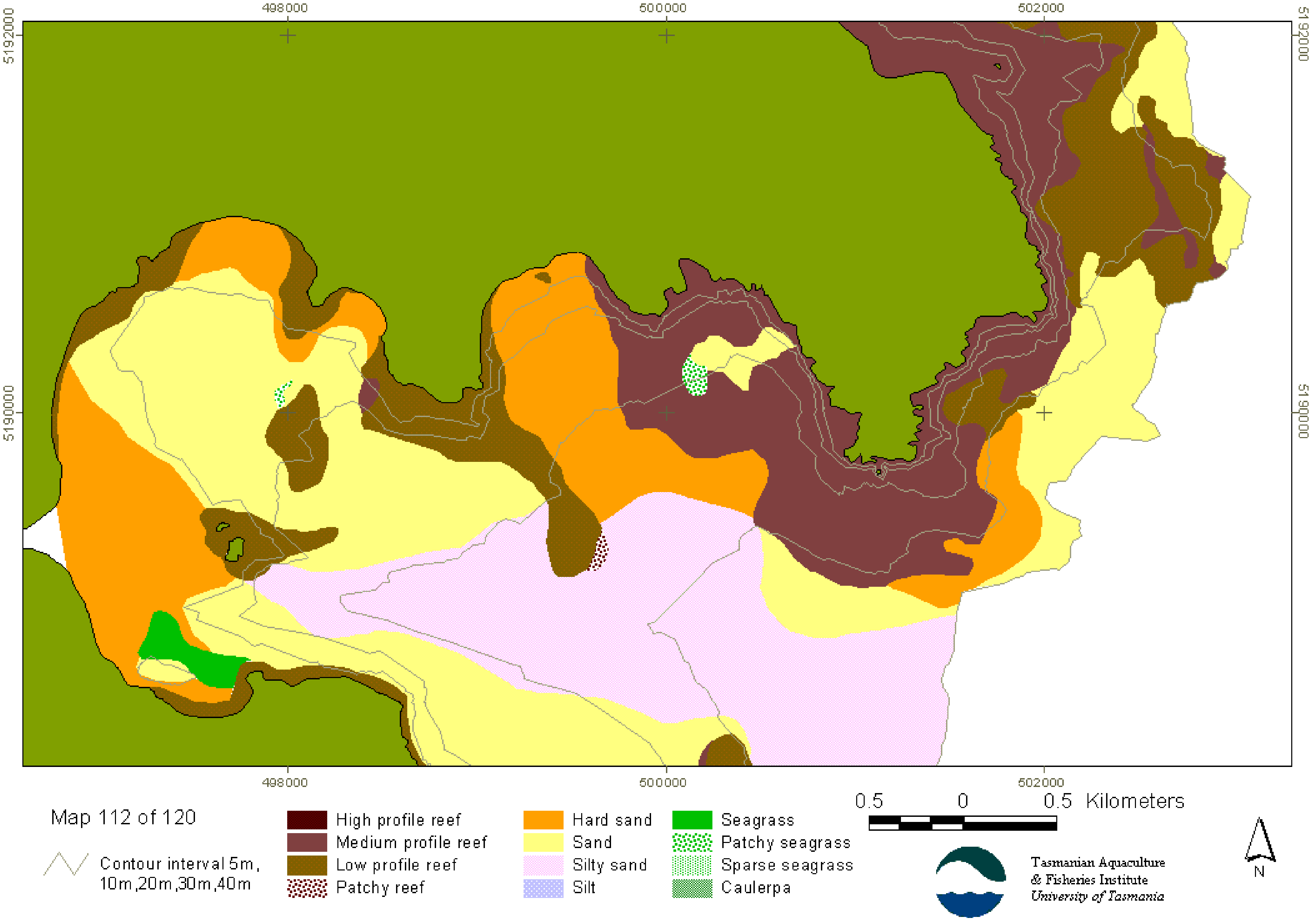

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Map 112 of 120
Contour interval 5m, 10m,20m,30m,40m
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Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
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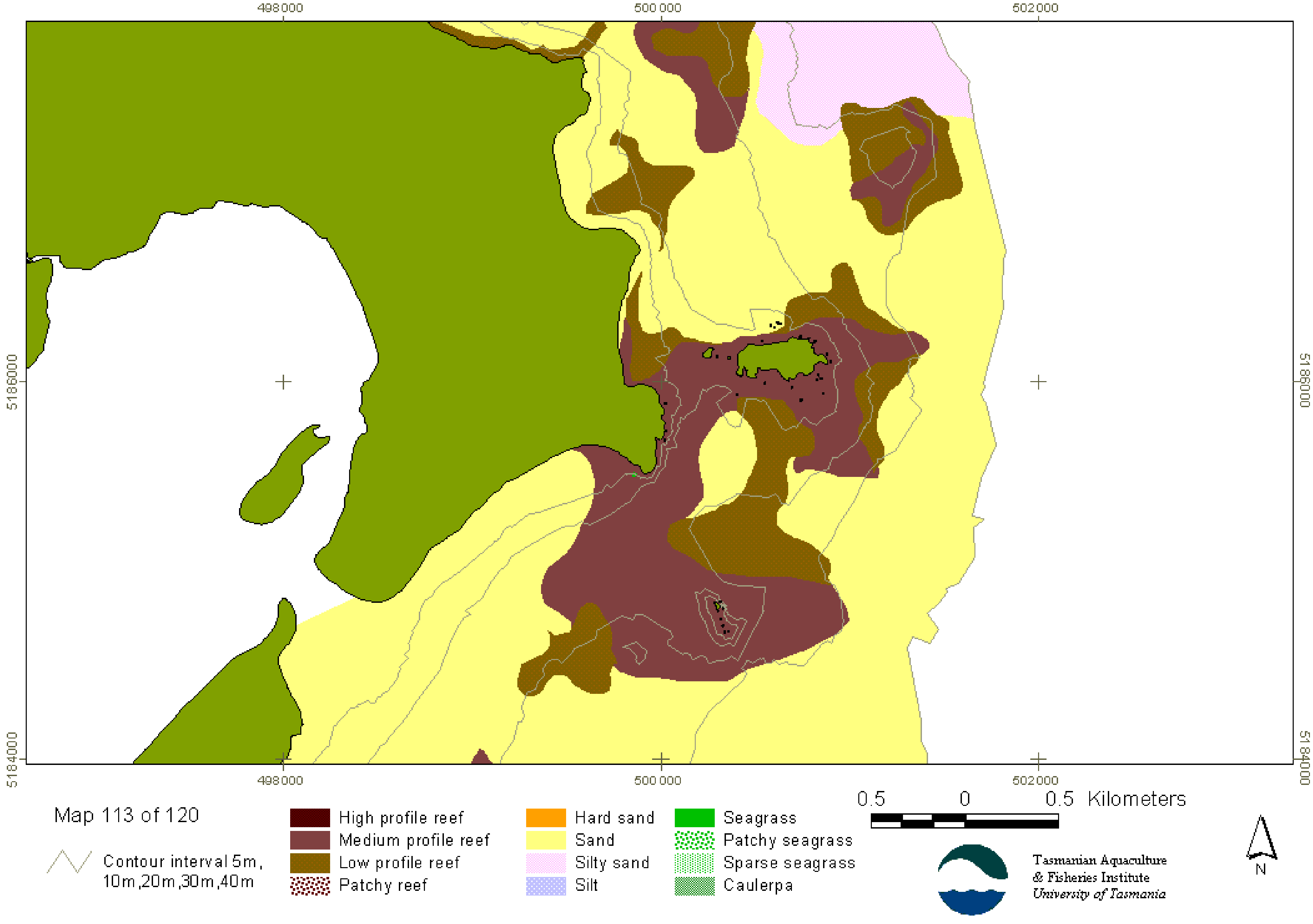
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Map 113 of 120
Contour interval 5m, 10m, 20m, 30m, 40m
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Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
N
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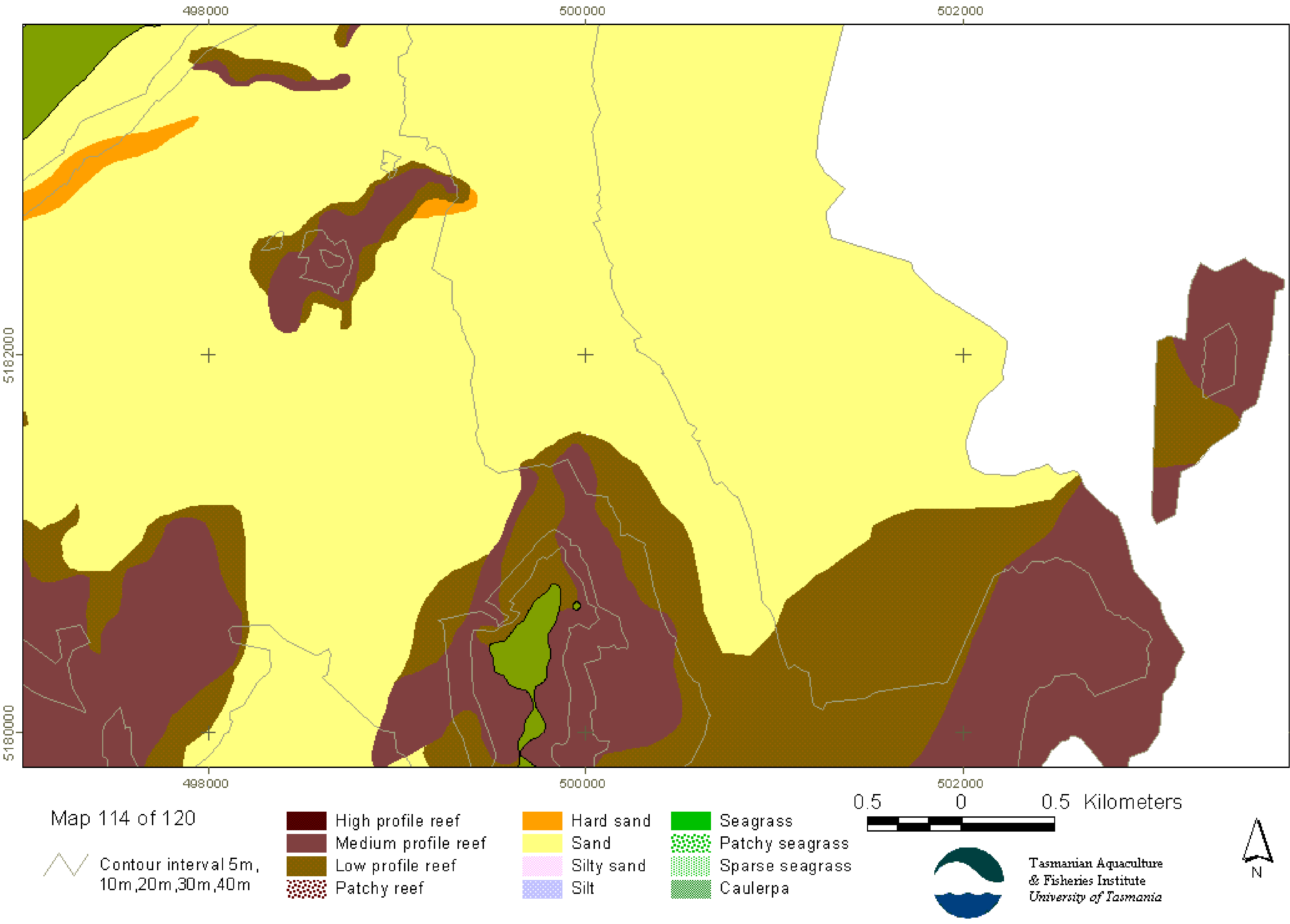
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Map 114 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa
0.5 0 0.5 Kilometers
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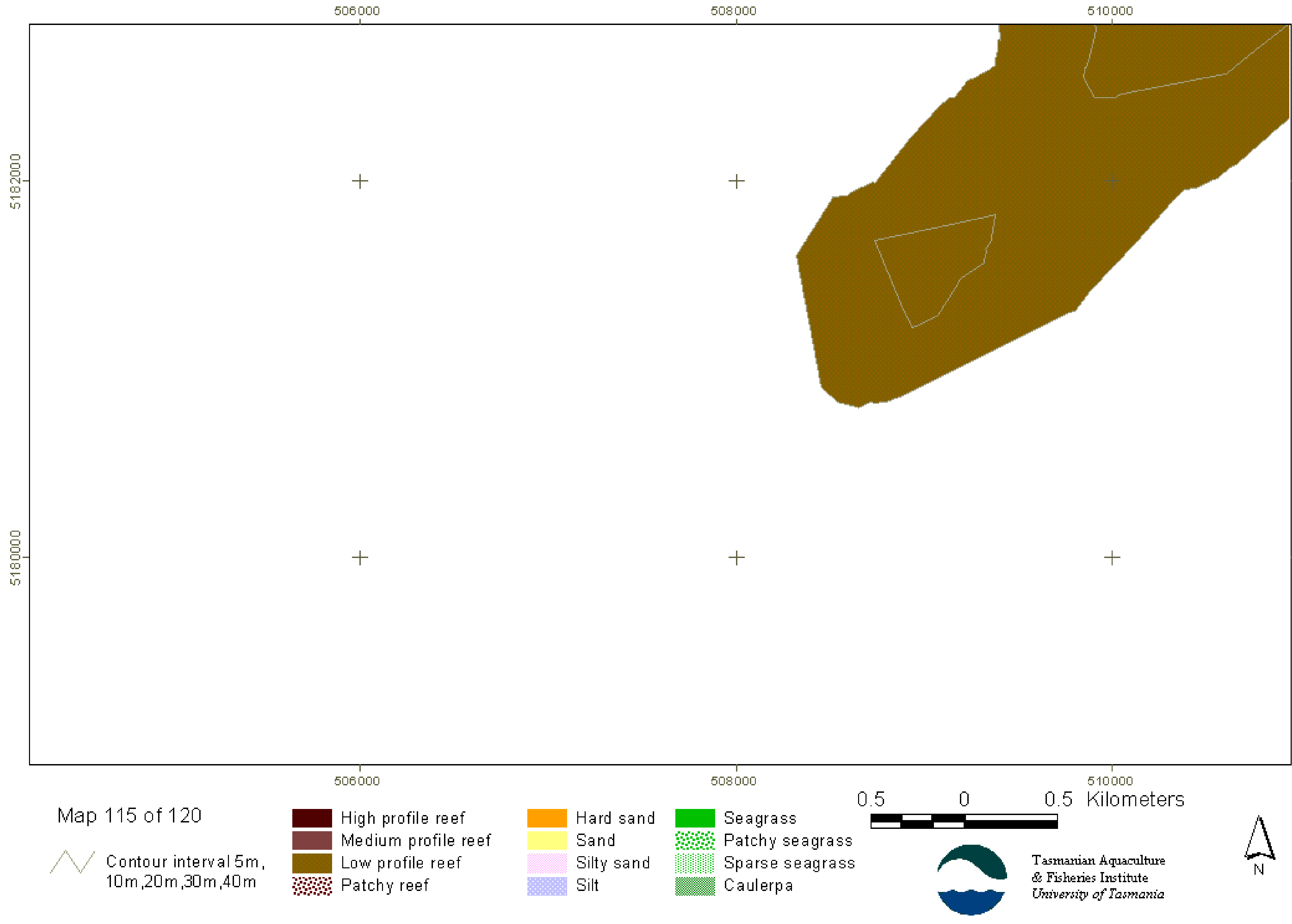
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Map 115 of 120
Contour interval 5m, 10m,20m,30m,40m
High profile reef
Medium profile reef
Low profile reef
Patchy reef
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Seagrass
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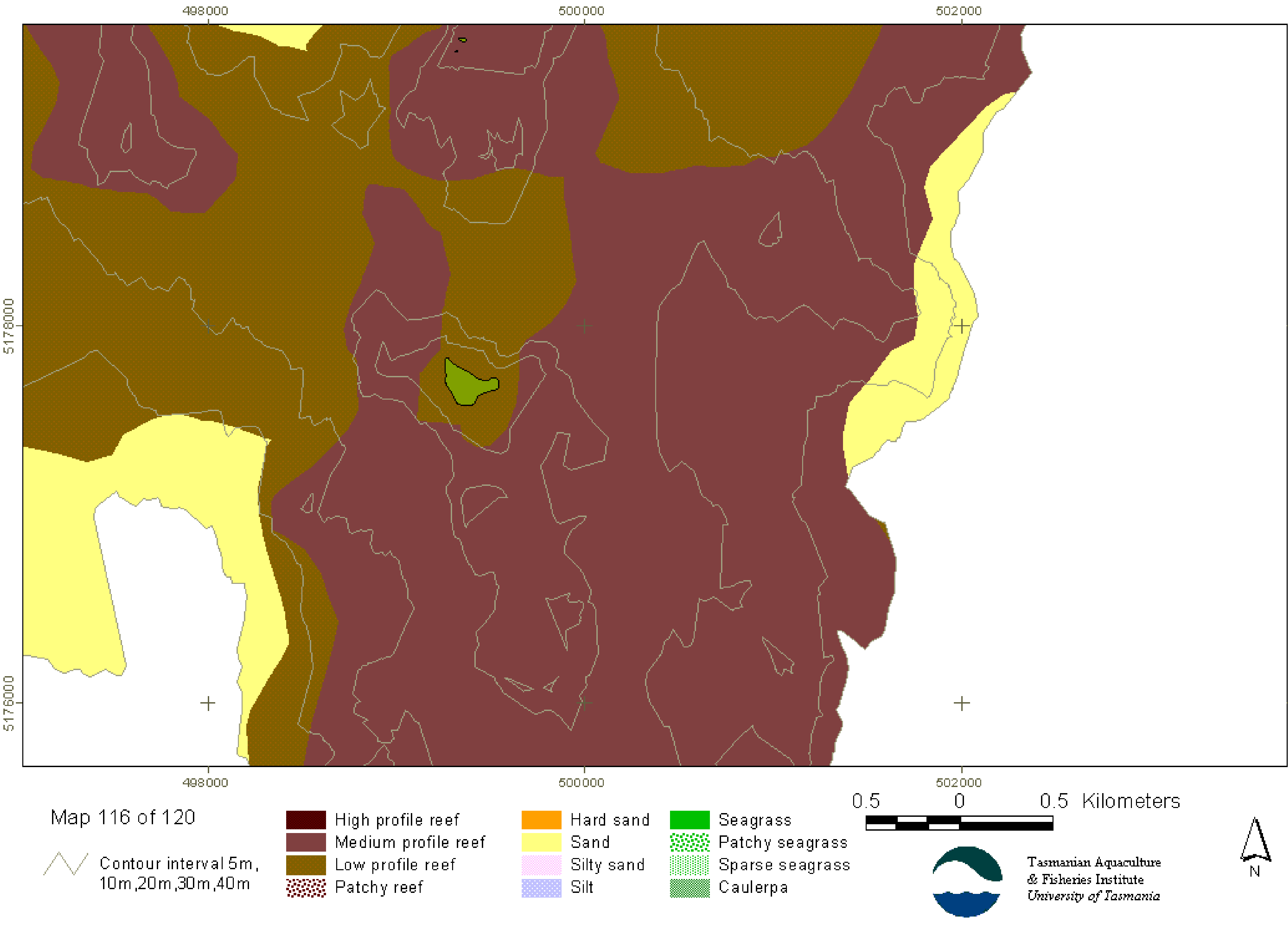
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Map 116 of 120
Contour interval 5m, 10m,20m,30m,40m
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Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
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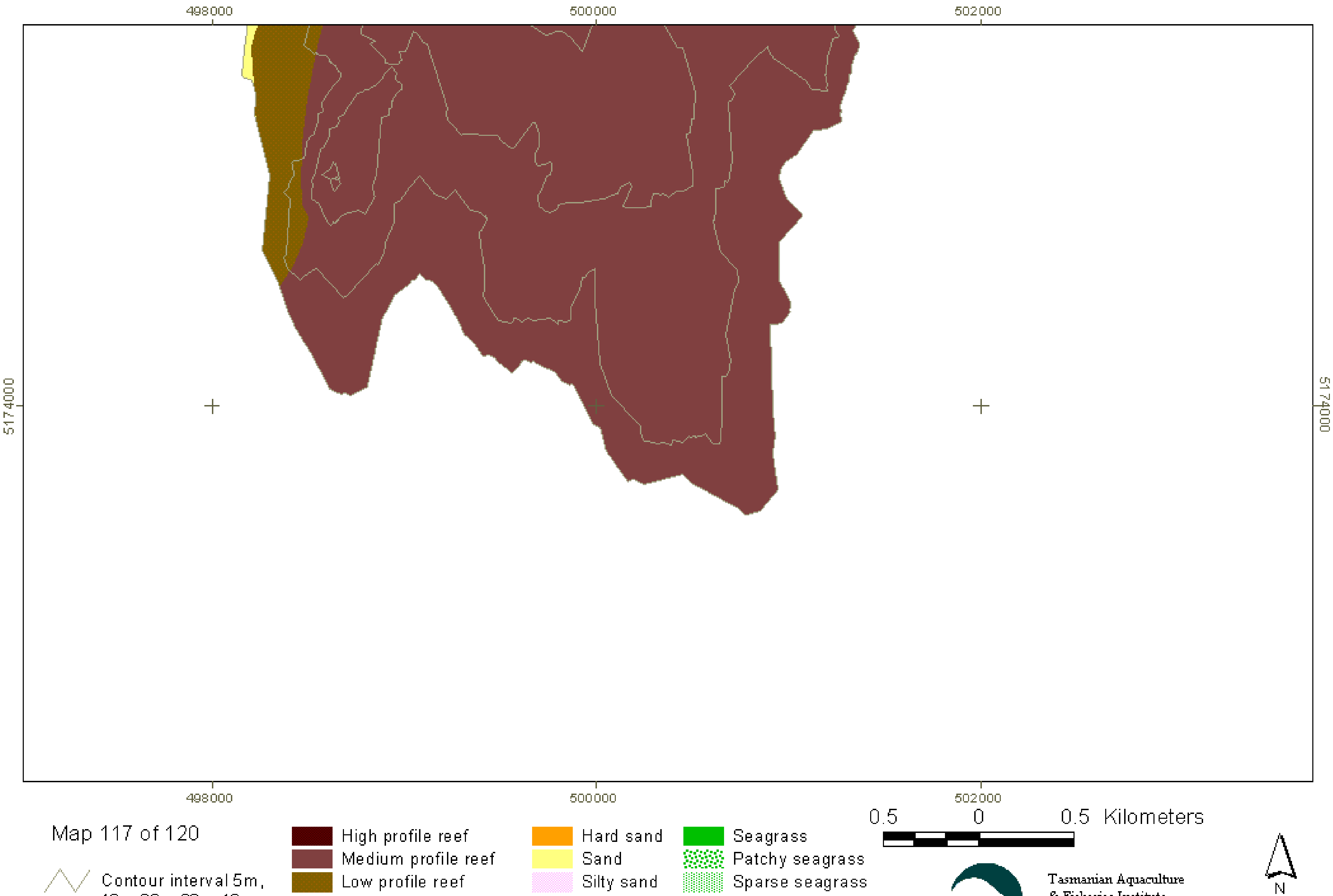

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Contour interval 5m, 10m,20m,30m,40m

High profile reef
Medium profile reef
Low profile reef
Patchy reef
Hard sand
Sand
Silty sand
Silt
Seagrass
Patchy seagrass
Sparse seagrass
Caulerpa

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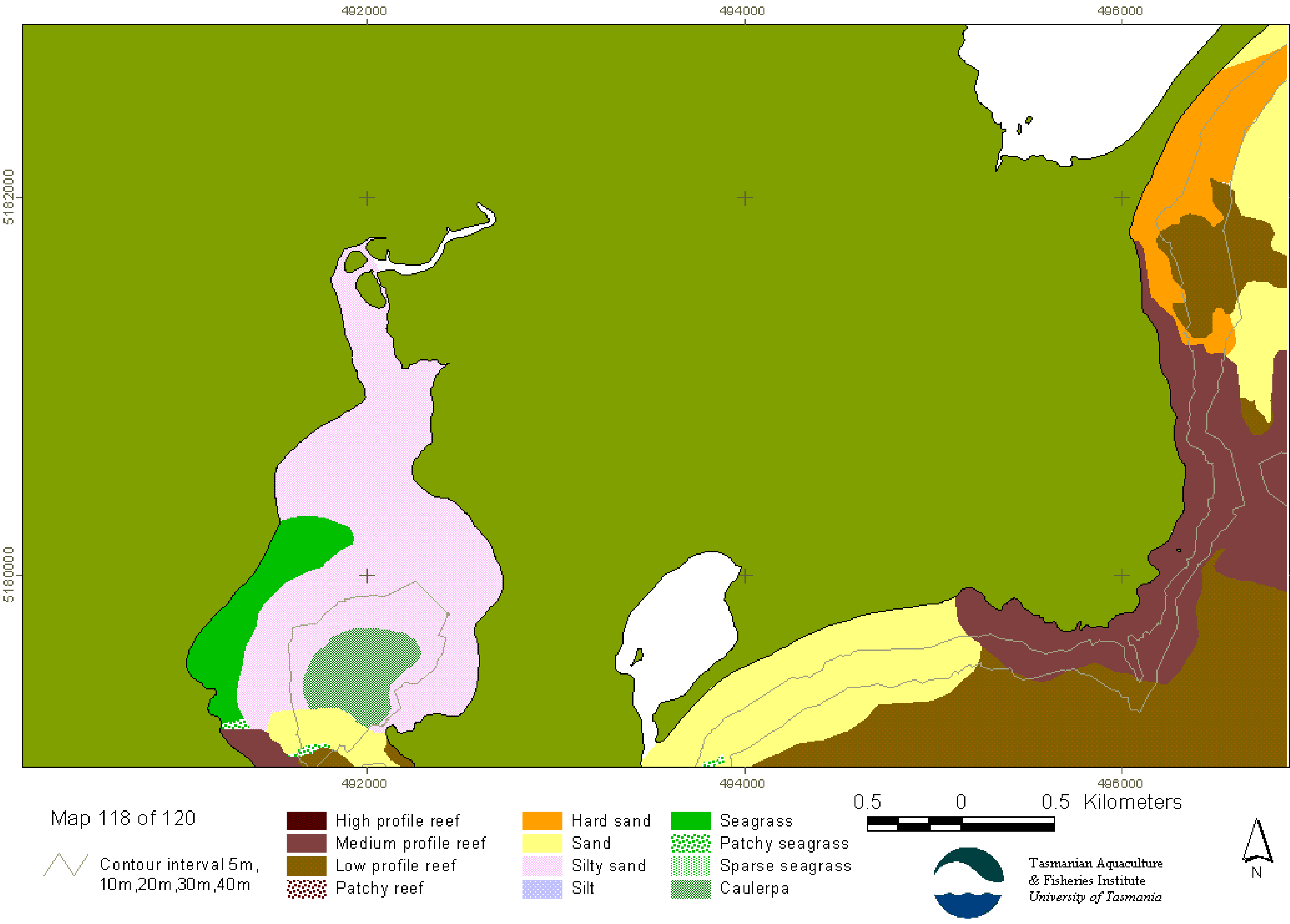
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Map 118 of 120
Contour interval 5m, 10m,20m,30m,40m
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Medium profile reef
Low profile reef
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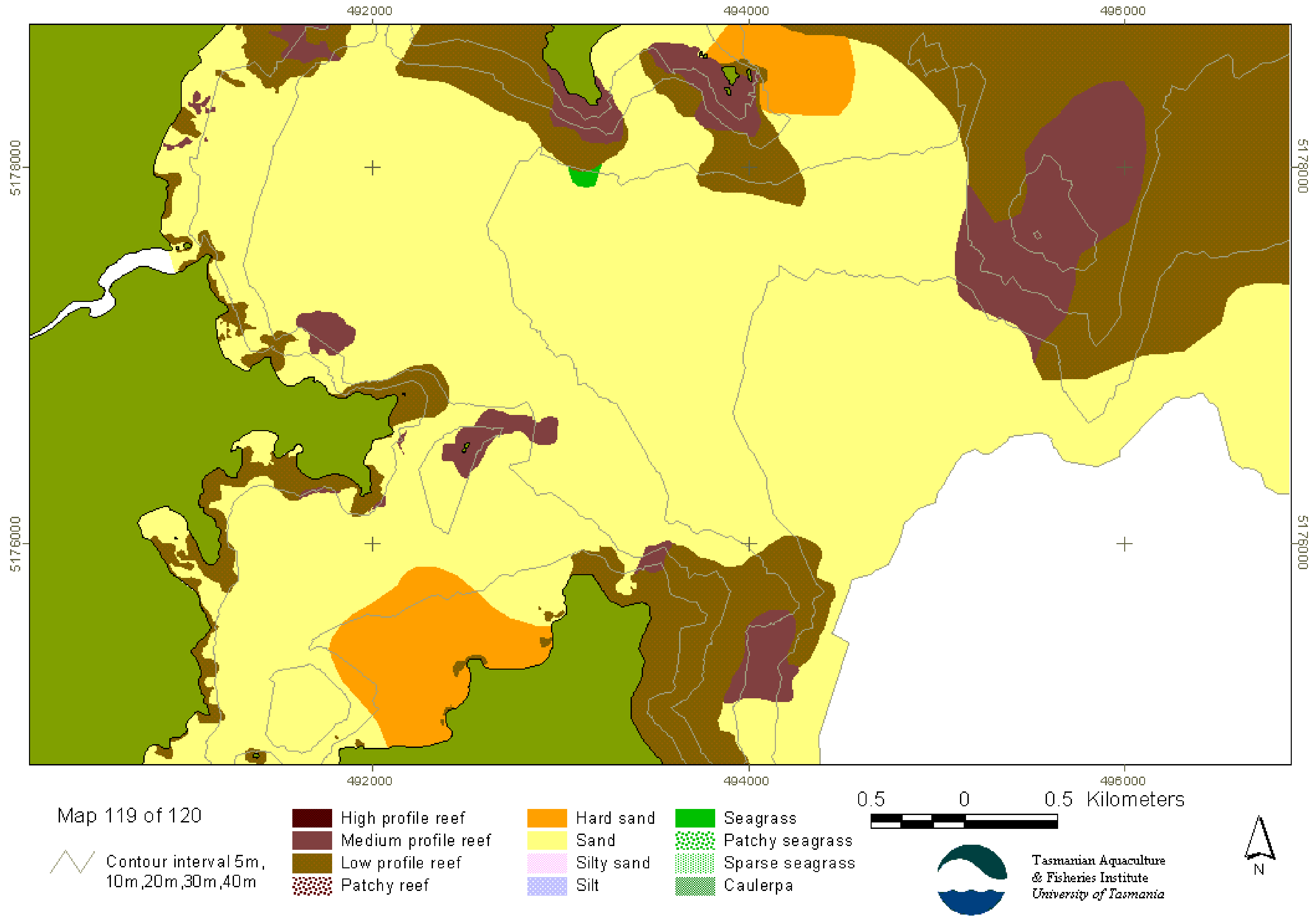
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Map 119 of 120
Contour interval 5m, 10m,20m,30m,40m
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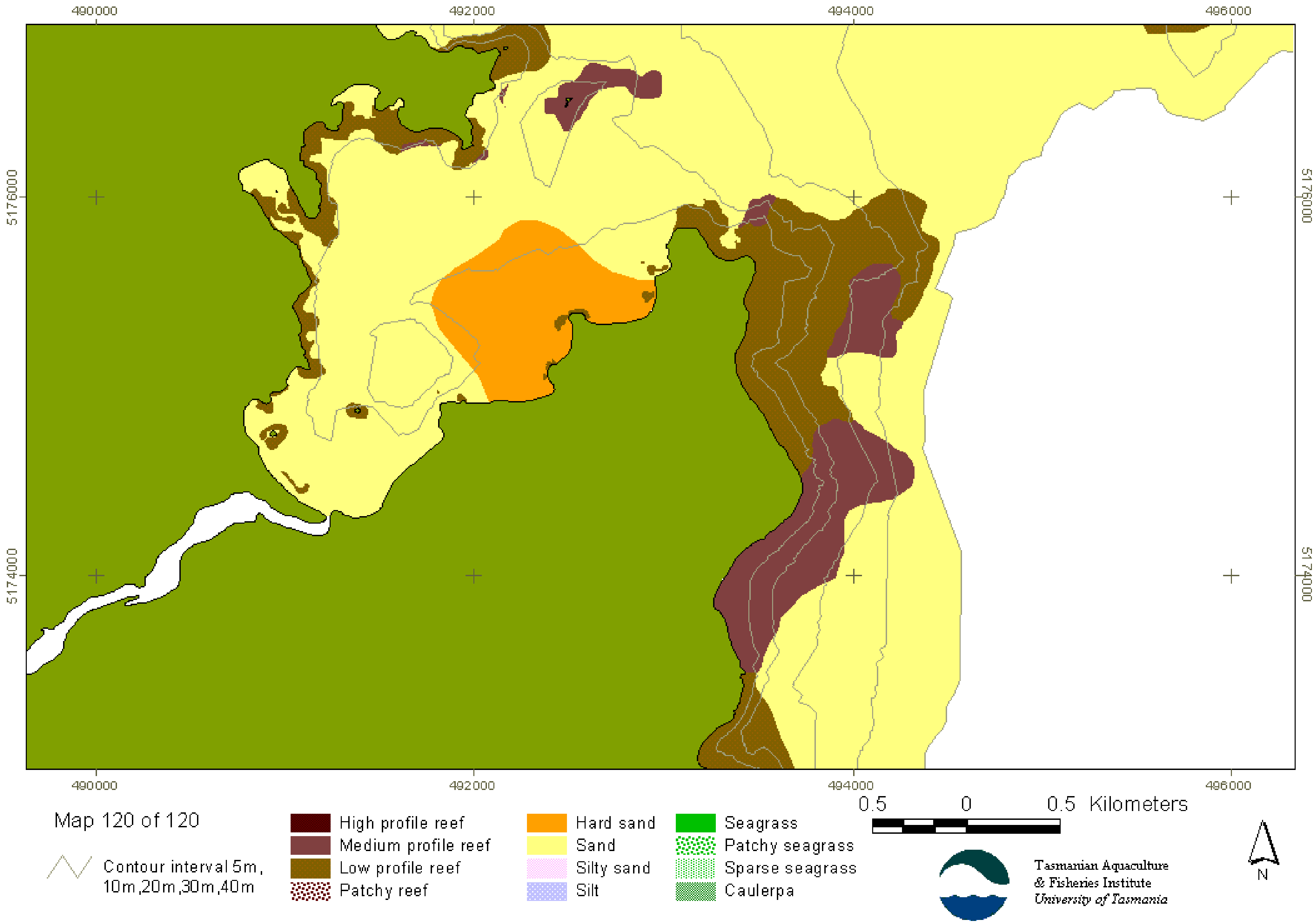
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Map 120 of 120
Contour interval 5m, 10m,20m,30m,40m
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Medium profile reef
Low profile reef
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