FINAL REPORT TO NHT

MAPPING OF ESTUARINE AND MARINE HABITATS IN THE SOUTHERN NRM REGION

Richard Mount, Vanessa Lucieer, Miles Lawler and Alan Jordan

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NHT46937 (04/NHTGFS04/102507NHT)

Natural Heritage Trust

Helping Communities Helping Australia

An Australian Government Initiative

Mapping of Estuarine and Marine Habitats in the Southern NRM Region

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Executive 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 2001 a baseline survey of marine habitats was conducted within the Bruny Bioregion. The study presented the first inventory of maps of marine habitats in Tasmanian waters. While there are nine bioregions in Tasmanian coastal waters, the Bruny region was identified as the priority for mapping due to it 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. This study builds onto the knowledge of this initial mapping completed by SeaMap Tasmania providing information on habitat extent and condition within key estuarine areas within the Bruny Bioregion.

Maps of eleven estuaries were produced including; Bryans Lagoon, Catamaran River, Cloudy Bay Lagoon, D'Entrecasteaux River, Great Swanport, Little Swanport, Pipeclay Lagoon, Pitt Water, Southport Lagoon, Little Swanport and Upper Pitt Water. The marine area of Great Oyster Bay was mapped to 1.5 km from shore. The production of maps involved extensive field surveys and purpose flown aerial photography. Information on bottom type was recorded either using acoustic sounders or in more shallower areas using an underwater viewer, coupled with a GPS. The information was collated and maps were produced using ArcGIS (v 9.0) allowing detailed spatial analysis of habitat distribution. The maps are available at; http://www.utas.edu.au/tafi/seamap/ .

The estuaries are found to vary substantially both in their physical form and the processes that are acting upon them. However, some similarities occur, including:

- The Catamaran River and D'Entrecasteaux River estuaries both exhibit narrow cobbled channels with high fluvial discharge rates and a lack of a distinct central basin. They also have little seagrass.
- Cloudy Bay Lagoon and Southport Lagoon share many characteristics, such as low fluvial inputs, similar amounts of seagrass, and broad shallow central basins with extensive macroalgal beds on unconsolidated substrates.
- Great Swanport and Little Swanport have by far the greatest amount of seagrass, in proportion to their area and seagrass density. They also have high levels of fluvial inputs and extensive beds of the brackish water macrophyte *Ruppia megacarpa*.
- Pitt Water is 3.5 times larger than the next largest estuary (Great Swanport) and has the second highest amount of seagrass in absolute terms, mostly clustered around the end of the main entrance channel at the flood tide delta.
- Pipeclay Lagoon has an exceptionally high tidal exchange rate and is notable for its absence of virtually any seagrass.
- Bryans lagoon is a unique closed system with a clear split between the brackish water dominated reedy habitat in its upper reaches and the more saline (though still brackish) seagrass dominated lower reaches.

- The substrates of Great Oyster Bay within 1.5 km of the shore consist of sand (~680 km^2 or 90%), with ~62 km^2 of reef (8%) and balance in seagrass (2%).

This study provides natural resource managers, industry and the community with the information needed to contribute to biodiversity conservation and natural resource management in a large number of estuarine and marine areas. It provides further information needed to define and measure relevant targets for estuarine and marine habitat extent and condition and increases the focus on the impact of coastal developments on the health and importance of subtidal marine and estuarine habitats in the Southern NRM region.

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1. Introduction

This project builds on the existing mapping conducted in the Southern NRM region and fills a significant gap in the knowledge in habitat extent and condition in these selected areas. It is intended to contribute to the habitat mapping requirements and assessment of key estuarine and marine areas. These data are required by managers, industry and the community to contribute to sustainable natural resource management in the nearshore shallow marine waters of this region.

Nine estuarine areas were selected for this study including Catamaran, the D'Entrecasteaux, Southport Lagoon, Cloudy Bay Lagoon, Pipeclay Lagoon, Lower Pitt Water, Great Swanport, and Bryans Lagoon. Upper Pitt Water and Little Swanport were mapped externally to this project, and are included in this report. The additional area of Upper Pitt Water completes the entire extent of the Pitt Water estuary. The marine area completed in this project is Great Oyster Bay.

Until now, estuaries and lagoons have not been the focus of habitats data collected in the Southern NRM region. The major effort to date has focused on mapping the open coast and bays from the shore to forty meters depth. Most of Tasmania's estuaries have recently been assessed for their conservation significance and assigned to five classes ranging from Class A (Critical conservation significance) to Class E (Low conservation significance – severely degraded) based on the level of anthropogenic impacts and species diversity (Edgar *et al*. 1999). The Southern Region contains five Class A estuaries and nine Class B estuaries (High conservation significance), none of which have baseline data on habitat extent and condition; information essential to the effective on-going management of these areas. The selected estuaries are from the southeast and eastern parts of the Southern Region, rather than the south coast, as this is where the major human impacts occur. The Class A estuaries mapped for this report are Bryans Lagoon and Southport Lagoon and the Class B estuaries are Great Swanport, Cloudy Bay Lagoon, Catamaran River and D'Entrecasteaux River. Apart from Freshwater Lagoon, all the Class A and B estuaries within the southeast and eastern parts of the region are now mapped.

Little Swanport is a Class C estuary, that is, of moderate conservation significance. It is included here as there is a large amount of work being conducted to establish an integrated understanding of the biological and physical processes operating within the catchment and the estuary and, in addition, the interactions of these processes with the economic productivity of the system (Crawford *et al*., 2005). Pipeclay Lagoon and Pitt Water are Class D (degraded) estuaries of low conservation significance but are included as they are under increasing pressure from catchment, coastal and aquaculture development, as is the marine area of Great Oyster Bay.

Previous studies in the region have either focussed on assessing specific areas for marine farm development (eg. Mitchell, 1999), potential Marine Protected Area (MPA) locations (Barrett and Wilcox 2001), the distribution of selected seagrass beds (Rees, 1993), and have been completed at a very coarse scale (Edyvane *et al.*, 2000). This mapping project builds upon the data collected under the SEAMAP Tasmania project and significantly increases the breadth of knowledge regarding subtidal habitats in Tasmanian coastal waters.

Habitat has 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 that the important physical characters are known (e.g., wave energy, currents, nutrient load, 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 multiple depth transitions, this current study has used “indicator” physical characteristics for the identification of marine habitats. In order to identify the dominant marine and estuarine communities present, regular video surveying was conducted. The main physical characteristics used to identify key habitats were depth, sediment particle size and substrate type. A series of water column salinity profiles were collected in each estuary to assist with characterising the mixing regime of the water body (Please note, however, that caution should be exercised when interpreting the salinity results, as they only constitute a single “snapshot” of salinity at the time of collection, and salinity can vary with a large number of factors including rainfall and tide). Biotic factors were included for soft sediment areas where the presence of seagrass 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 seagrass communities has been mapped with a relatively high degree of accuracy.

The main objectives of this report are to:

- Provide detailed marine habitat mapping and baseline physical data for the selected estuaries (Bryans Lagoon, Catamaran River, Cloudy Bay Lagoon, D’Entrecasteaux River, Great Swanport, Little Swanport, Pipeclay Lagoon, Pitt Water and Southport Lagoon) and Great Oyster Bay.

- Compile a spatial database for all the seagrass and adjacent habitat types and publish the maps on the Australian Coastal Atlas (now the Coastal Atlas category on the Land Information System Tasmania (LIST) web mapping site) and the SEAMAP Tasmania website.

- Identify representative habitat monitoring sites and protocols that would encourage community participation in future ongoing data collection.

- To provide crucial information to the relevant Councils to assist in land use decision-making within the relevant catchments.

- To communicate the findings to stakeholders and the community.

The outputs of the project include:

- The production of 1:25,000 estuarine and marine habitat maps in the identified areas published in hard copy form and on the Internet.

- Estimates of the extent and condition of specific habitat types for the above areas allowing an ongoing assessment of habitat change.
- Production of a report detailing the biological and physical structure within the mapping areas.
- Establishment of a baseline of estuarine and marine habitat distribution and selected sediment ands sediment quality parameters.
- Development of habitat monitoring protocols.

2. Methods

Between August 2004 and September 2005 the distribution of benthic habitats within nine estuaries and Great Oyster Bay were mapped. Within each of the estuaries information on the salinity, sediment particle size and habitat condition was also collected (Table 1). Information on the distribution of benthic habitats was colleted through a combination of aerial photography (both archival and via aerial survey), satellite remote sensing, acoustic surveys, underwater video and visual observations. Different methods were used for mapping the estuaries compared to Great Oyster Bay due to the difference in size, exposure and depth of these areas. The estuaries, which are generally shallow and small in size, were mapped primarily based on interpretation of aerial photography and in some cases satellite remote sensing data (Quickbird). Field surveys were used to ground truth these interpretations, collect bathymetric information and collect a suite of biological and physical information. In Great Oyster Bay the majority of the benthic habitats were too deep to detect using optical remote sensing techniques, for this reason the aera was comprehensively mapped with acoustic surveys. Existing aerial photography was used to supplement the mapping process for the shallow habitats within the 0-10 m depth range.

For both the estuaries and Great Oyster Bay, the mapping process consisted of obtaining aerial photography; either from Information and Land Services (ILS), Department of Primary Industries, Water and Environment (DPIWE) archives; or with targeted flights conducted by TAFI. The photographs were scanned into a GIS platform and polygons digitised around features of contrasting colour and/or texture. Field surveys were conducted to confirm the identification of these polygons, refine their boundaries and fill in areas where the photo coverage was poor, especially due to deep water. During these field surveys additional information on the sediment particle size, salinity, and habitat condition for selected habitats was collected. A full description of each of the components of the mapping process is outlined below.

Table 1. Summary of field sampling in the nine estuaries

Estuary	Substrate	Bathymetry	Temp/ Salinity	Sediment Core	Seagrass	Benthic Video
Little Swanport	Yes	Yes	Yes	Yes	Yes	No
Great Swanport	Yes	Yes	Yes	Yes	Yes	Yes
D'Entrecasteaux River	Yes	Yes	Yes	Yes	n.a.	No
Catamaran River	Yes	No	Yes	Yes	n.a.	No
Cloudy Bay Lagoon	Yes	Yes	Yes	Yes	Yes	Yes
Pitt Water	Yes	Yes	Yes	Yes	Yes	Yes
Pipeclay Lagoon	Yes	Yes	Yes	Yes	n.a.	No
Bryans Lagoon	Yes	No	Yes	Yes	Yes	Yes
Southport Lagoon	Yes	Yes	Yes	Yes	Yes	Yes

2.1 Capture and preparation of aerial photographs

The aerial photography archives of ILS, DPIWE were searched to identify photographs that covered the selected Southern NRM estuaries. Nineteen 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 1:24,000 to 1:52,000 and the most recent images were chosen to reflect current habitat extents. The final set spanned a period from 1988 through to 2004, with most from 2003 and 2004.

Cloudy Bay Lagoon and Southport Lagoon did not have suitable recent imagery, so a flight capturing small-format photography was conducted on the 26th of November 2004 in the Tasair twin engine AeroCommander. Methods and techniques developed jointly at TAFI and the Centre for Spatial Information Science (CenSIS), University of Tasmania were employed to ensure high quality imagery (Mount, 2003, 2005a). Imagery of Cloudy Bay Lagoon, Southport Lagoon, Catamaran estuary and the D'Entrecasteaux River estuary from a height of 7,500 ft (~2,300 m) was collected. The imagery collected included vertical and oblique RGB digital stills captured with a SLR Canon 300D and a SLR Nikon 1D. Infrared and RGB video was also collected to assist with habitat discrimination.

Appendix 1 lists the aerial photographs selected and their coverage.

2.1.1 Scanning

The selected archival aerial photographs were captured with a A3 flat bed colour scanner at 600 DPI (dots per inch). The scanned images were stored as 24 bit colour TIFF images and viewed in the field as MrSID wavelet compressed images.

2.1.2 Registering, Rectifying and Mosaicing of Aerial Photographs:

Each image was georectified using ArcGIS 9.0 (Environmental Systems Research Institute (ESRI)) to the LIST (Land Information Services Tasmania) coastline coverage in GDA94. 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 ~ 0.00015 degrees. Mosaicing was conducted on some runs of images using ENVI 4.1 (RSI).

2.1.3 Capturing data from aerial photographs

The aerial photographs were displayed in ArcMap 9.0. 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. 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, sand and seagrass, the colour intensity and contrast of the image was altered via “stretching” each band. For multi-band 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 or logarithmic scale to reduce or increase the intensity of that band.

The quality of the imagery accessed for this project was consistently high and consequently the aerial photographs were used as a primary source of information to aid in determining the boundaries of the habitat type. Please note, however, that due to the ambiguities inherent in interpretation of through-water imagery in the shallow subtidal environment, careful checking in the field was required to confirm the habitat types.

2.2 Processing of Satellite Imagery

High quality satellite imagery of the Pitt Water area was obtained through participation in the Greater Hobart DigitalGlobe Pilot Project sponsored by Sinclair Knight Merz (SKM). The specifications of the imagery include pan-sharpened RGB pixel sizes of 0.6 m and a positional accuracy of ±3 m for the Pitt Water area. The image quality was excellent due to a combination of the DigitalGlobe processing algorithm and high water clarity.

2.3 Field Data Collection

Great Oyster Bay was mapped based on extensive acoustic field surveys with supplemental information obtained from aerial photography. The nine estuaries were mapped based on a combination of aerial photography and satellite remote sensing, with supplemental field surveys to ground truth aerial photograph interpretations. A combination of small vessels and wading were used to sample the physical and biological attributes of each of the estuaries. Bathymetry, substrate type, temperature, salinity, sediment particle size, and seagrass growth were assessed within the estuaries as outlined in Table 1.

2.3.1 Substrate data

The benthic substrate in Great Oyster Bay was mapped using a Simrad ES60 acoustic echo sounder. A series of parallel transects were conducted throughout the bay. Transects were spaced approximately 200m apart, and ran from shore to a baseline established 1.5km from shore. The echo sounder was set to ping every 0.5 seconds, with a pulse length of 0.256ms and a power setting of 100W. The output from the echo sounder along with positional information from an OmniLite132 differential GPS unit was logged using the Simrad ES60 software (v.1.5.2.76 Kongsberg, Simrad).

The logged sounder output was imported into EchoView 3.30 (SonarData) for classification. Different benthic substrates were determined based on changes in the thickness and intensity of the echo sounder output. Harder substrates, which reflect more acoustic energy, appear with a stronger second echo, while rougher substrates, which scatter more of the acoustic energy, appear with a longer tail on the first echo (Figure 2-1). Seagrass could also be distinguished based on the presence of acoustic reflectance above the sounder detected bottom (Figure 2-1). These acoustically different echo returns were related back to substrate type based on ground truth information collected by underwater video. The echo sounder output was visually classified as reef, sand, seagrass or sparse seagrass.

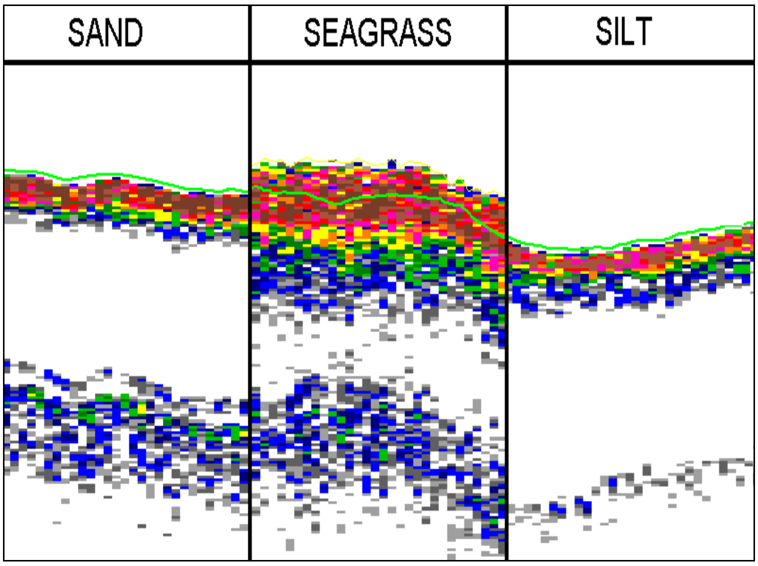

Figure 2-1. An example of the acoustic echo returns from sand, seagrass and silt habitats.

In the nine estuaries the substrate was predominantly mapped from aerial photography. The field surveys conducted in these estuaries were designed to ground truth the aerial photographic interpretations, and collect additional biological and physical information. A series of vessel based transects was conducted over areas identified in the aerial photographs as potentially distinct habitats. A combination of direct visual observation using a bathyscope, sediment cores and underwater video was used to identify the substrate. These field observations of the benthic substrate were logged with positional information from a GPS (either an Omnilite132 differential GPS, a

Garmin GPSMap 135 sounder/GPS unit or a Garmin 12 GPS) into either a laptop computer running SeaBed Mapper 2.4 (Data Vision GIS Pty Ltd, Hobart Tasmania) or a ruggedised iPAQ pocket PC running ArcPad 6.0.3 (ESRI, Redlands California) and HabMap 1.0, a VisualBasic script developed with ArcPad Application Builder 6.0 (ESRI), created for attributing points in the field. In shallow waters (<1 m), habitats were surveyed by wading with a bathyscope and information was logged to the iPAQ pocket PC. In the deeper areas of Pitt Water, visual interpretation of the acoustic sounder was used to gather information on the substrate type using the same methodologies outlined for Great Oyster Bay above. For each of the estuaries, these data and the field observation data logged in ArcPad and SeaBed Mapper were compiled into a spatial database a GIS to support the mapping process.

2.3.2 Bathymetry

Bathymetric information for Great Oyster Bay and some of the estuaries was collected using one of two systems. In Great Oyster Bay and Pitt Water bathymetric information was logged using the Simrad ES60 echo sounder. The logged data files were imported into EchoView 3.30 where the sounder detected bottom was checked for anomalies, corrected for the transducer depth and exported as a comma delimited text file containing depth and position.

For some of the estuaries, bathymetry was collected using a Garmin GPSMap 135 sounder/GPS unit mounted on a 4m shallow draft vessel. A series of broad transects were conducted across the main channels and basins. The output from the Garmin GPSMap 135 sounder was logged to a laptop computer running SeaBed Mapper 2.4. This software logged a depth and position every 2 seconds into an ASCII text file. All the depth information collected was corrected for tidal variation (see Section 2.4) and this corrected information was used to aid in the delineation of habitats.

2.3.3 Temperature/Salinity

Each of the estuaries was sampled to determine if there was stratification of the water column through a series of temperature and salinity profiles. At a series of locations from the mouth of the estuaries to the upper estuarine limit, temperature and salinity profiles were taken using a WTW LF197 meter. The probe was lowered through the water column, with readings taken at the surface and at intervals throughout the water column, with the final reading taken immediately above the bottom. Particular attention was taken to note the position of a thermocline or halocline if present. The data from the WTW meter was recorded along with position from the GPS onto waterproof paper and later transcribed to an Excel worksheet and graphed in JMP 5.1 (SAS).

2.3.4 Sediment Cores

The surficial sediment of each estuary was sampled to provide detailed information on the particle size distribution throughout the estuary. Sediment samples for particle size analysis were collected using 300 mm long, 25 mm diameter clear plastic tubes. The tubes were mounted on either a 4 m pole for the shallow sites or a tri-corer for the deeper sites. The top 5 cm of sediment was stored in zip lock bag, and sieved to assess particle size fractions. The fractions represented the standard Wentworth particle size classes, ranging from <4 phi to –2 phi (i.e., from <63 microns to 2000 microns or 2 mm) (see also Appendix 4). For the purposes of habitat mapping, the fractions are categorised into a simplified classification, where the proportion of clay and silt to sand (of all sizes) is calculated. The proportion between the very fine particles (silt and clay) and the coarser particles (fine to coarse sand and granules) are regarded as biologically important (Edgar and Shaw, 1995). The standard SEAMAP habitat classes are "silt", "silty sand" and "sand", where "silt" consists mostly of silt and clay and less than 20% sand; "sand" consists mostly of sand and less than 20% silt and clay; and "silty sand" consists of all other mixtures of silt and sand. Cores were taken at regular intervals throughout the estuaries to characterise the broad distribution of sediment types and assist in the classification of acoustic, visual and remote sensing data.

2.3.5 Seagrass Condition Sampling

The condition of the seagrass was studied in more detail in Bryans Lagoon, Cloudy Bay Lagoon, Great Swanport, Little Swanport, Pitt Water and Southport Lagoon, as they had significant amounts of this habitat. The seagrass was sampled either by wading or snorkelling, depending on the water depth. Seagrass blade length and percentage cover were estimated using a 50cm by 50cm quadrat. The amount of algal epiphyte/associated algae was also estimated on a ranking scale of 0-5, with 0 representing no algae and 5 representing 100% cover of thick algae. At each sample site, five replicate quadrats were deployed to sample the seagrass, with this repeated at several sites throughout the estuary. The results were recorded onto waterproof sheets in the field and later entered into an Excel spreadsheet for further analysis.

2.3.6 Video Data Collection

A submersible digital video camera, MorphCam (MorphVision, NSW, Australia) was deployed at selected locations throughout Great Oyster Bay and the majority of the estuaries. This was used to verify the aerial photography and echo sounder substrate classification and obtain more detailed information on habitat attributes. Positional information was recorded for each video drop either as a series of GPS co-ordinates or as a direct overlay of the GPS output (position, date and time) onto the video. The video was analysed for dominant flora and fauna, habitat patchiness and physical structuring of habitats.

2.4 Correcting depth measurements for tidal influence

The ebb and flow of the tides implies 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 barometric pressure 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.

Depth measurements from the Garmin GPSMAP 135 and Simrad ES60 were tidally corrected for each of the estuaries identified in Table 1. These depths were corrected for tidal variation based on the predicted tide heights from the National Tidal Facility (http://www.bom.gov.au/oceanography/tides/). The tidal cycle can be described by a harmonic equation:

$$D_i = D[h_1+(h_2-h_1)*(\cos(\pi*((t-t_1)/(t_2-t_1)+1))+1)/2]$$

Where D_i is corrected depth and D is measured depth, $h_{1,2}$ correspond to the heights of the high and low tides, $t_{1,2}$ are the times of the high and low tides with t being the current time. This formula calculates the height of the tidal cycle for a given time and a given location and then applies this as a correction to the measured field data. All depth measures were corrected to Mean Sea Level based on the available standard port measurements.

2.5 Cartography

For Great Oyster Bay, the data files from Seabed Mapper 2.4 and Echo View 3.30 were imported into ArcGIS 9.0 and habitat point data used to generate shapefiles with on-screen digitising of habitat boundaries. At the 1:2,000 scale, the points were carefully connected to form polygons of similar habitat type. The outer (deeper) 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. 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 beds.

The process was similar for the estuaries, but the imagery was able to support greater levels of interpretation due to the improved visibility in the shallower waters. Initial habitat polygons were drafted prior to field data collection. This process also increased familiarisation with the target estuary and enabled logistical decisions to be refined regarding field transect patterns. Following the field visits, all the available evidence was collated in ArcGIS 9.0 including the GPS tracklogs, sounder depth logs, SeaBed Mapper and HabMap habitat records, sediment core particle size results, salinity and temperature profiles, seagrass quadrat results, underwater video transects, field photographs and any relevant historical data, such as archival aerial photography or data collected by other TAFI projects. Reference was also made to extensive field notes.

The field data were assessed for errors before cartography commenced. The resulting habitat polygons are the basis of the habitat maps forming the main body of this report, which were summarised to establish the extent of each habitat class for each estuary.

2.6 Contouring

For Great Oyster Bay, a depth surface was generated from the field-collected data through the interpolation of depth (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 the Triangular Irregular Network (TIN) data model. 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. The contour coverage provides another source of information from which the habitat polygons can be verified against, especially for seagrass, which has a maximum growth limitation.

2.7 Geomorphic facies assessment

The geomorphological processes and forms of estuaries are important to the understanding of the ecological functioning of the systems. The shape and type of geomorphological features (facies) present in an estuary provide useful insights into the processes operating within the estuary including hydrological regimes, salinity and temperature distributions and substrate composition. This information can assist in management actions. The conceptual model developed by Geoscience Australia (Heap *et al*., 2001) for the OzEstuaries project (http://www.ozestuaries.org) was applied to the estuaries. The estuaries are described based on the Geoscience conceptual models to ensure consistency with the OzEstuaries database. Reference is also made to the results of a current NRM coastal geomorphology project (Mowling and Sharples, in prep.).

The key geomorphological components, or facies, of the conceptual models are (adapted from Heap *et al*, 2001):

- **Fluvial (riverine) delta** is the distinct visible area of the river flood plain including the main fluvial channel or channels.

- **Intertidal flats** are the sandy and unvegetated flats that extend from the shoreline to the waterline at low tide. They are usually maintained by the fetch driven wind waves generated within the estuary.

- **Subtidal flats (shallows)** are similar to the intertidal flats, but are subtidal and may support vegetation or filter feeders. They often have a distinct breakline where they drop into the main basin or main channel.

- **Central basin** is the area not allocated to any other facies, which is usually found in wave dominated estuaries with a sedimentary barrier across the mouth. It is the area between the sediments of marine origin (barrier and flood tide delta), the sediments of the fringing flats and shallows, and the sediments of fluvial origin (fluvial delta). It often has a distinct deeper basin and may have associated sub-basins.

- **Main channel** is the distinct, often sinuous, anastomosing and branched channel running from the mouth of the estuary to the main central basin.

- **Flood- and ebb-tide deltas** are the sedimentary deltas formed by the deposition of sediments by the currents (mainly, but not only, tidal) flowing through the main channel.

The classification system developed by Edgar *et al*. (1999) is significantly different to that presented by Heap *et al*. (2001), with the former system related to both physical and biological processes operating within the estuary, whereas the latter system focuses mainly on the physical processes and underlying forms that have shaped the estuary. Some categories can be misinterpreted if taken out of context. For example, the Geoscience Australia category of a "wave dominated estuary" refers to the energy processes that formed, for example, the sand spit ("barrier") that typically forms across the seaward side of the estuary. It does not refer to the wave regime operating within the estuary. Similarly the "barrier" facie does not necessarily close (or bar) outflow from the estuary (although it can), rather it is referring to the barrier between the estuary and the (wave dominated) marine environment.

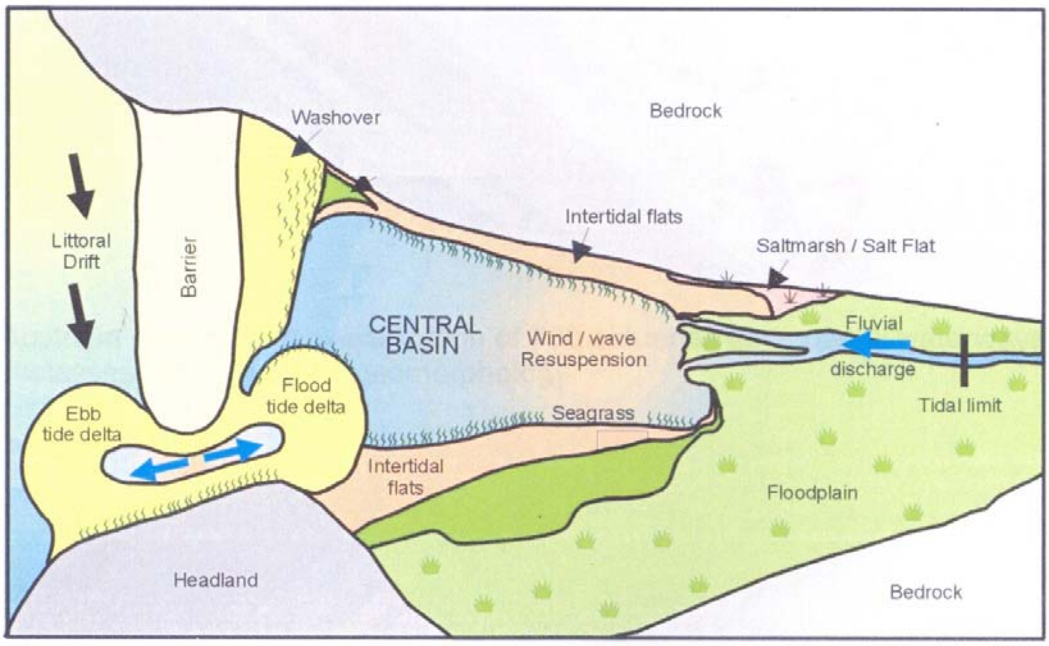

Figure 2-2. Conceptual diagram of a wave dominated estuary (Source: Geoscience Australia).

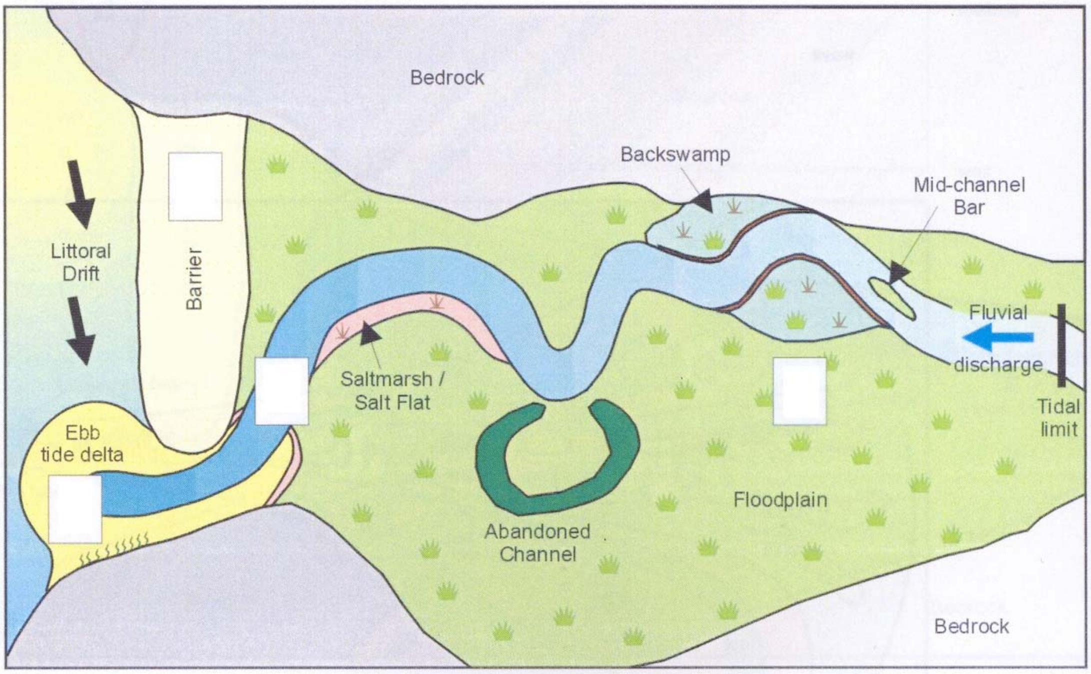

Figure 2-3. Conceptual diagram of a wave dominated delta (Source: Geoscience Australia).

3. Results and Habitat Descriptions

For the purpose of analysis the project is broken down into each estuary and marine zone for description. The extent of each habitat type is presented for each of these areas. The physical baseline data are also described for each area.

The areas covered are the subtidal estuarine habitats of Bryans Lagoon, Catamaran River estuary, Cloudy Bay Lagoon, D'Entrecasteaux River estuary, Little Swanport, Great Swanport, Pipeclay Lagoon, Pitt Water, Southport Lagoon and the marine area of Great Oyster Bay (Please note that they are presented in alphabetic order in the following sections).

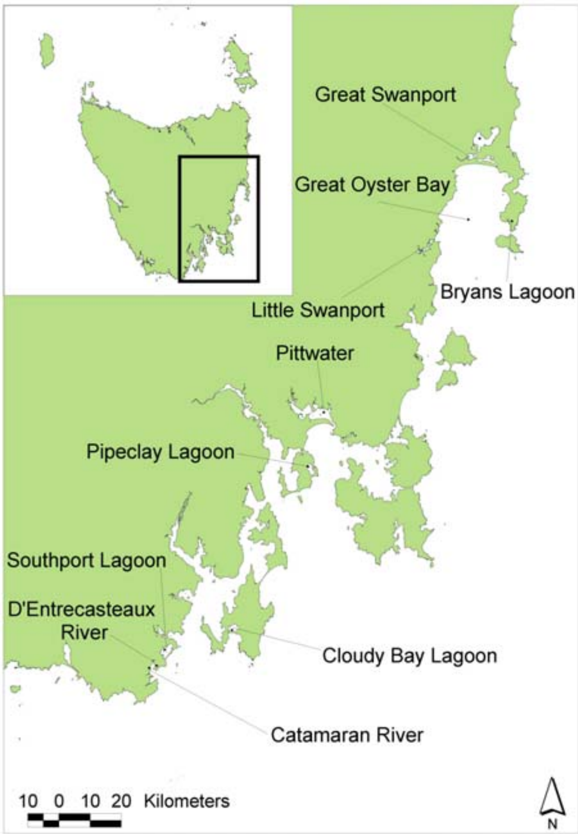

Fig. 2. The location of the selected estuaries and Great Oyster Bay (marine boundary) mapped within the Southern NRM region.

3.1 Biological Communities, including area calculations

The biological communities examined in this survey were restricted to the major cover forming species that could be identified from video drops, namely seagrass and macroalgae. Most of these species are of widespread distribution throughout the bioregion, with their distribution and relative abundance primarily determined by depth and exposure, but with the depth response modified in areas of reduced light availability. In the more sheltered sandy areas, seagrasses are the most visually dominant species found, though in some lagoons (particularly Cloudy Bay Lagoon and Southport Lagoon), significant macroalgal beds were present on unconsolidated substrates. The most common seagrass species were *Heterozostera tasmanica* and *Zostera muelleri*. There were no observations of *Halophila australis*, which is commonly observed outside the estuaries in this region.

By combining these general biological descriptions with the habitat details presented in this report (substrate type and depth) and available from more detailed community descriptions from Tasmanian waters (e.g., Edgar, 1984a, 1997, 2000, 2001; Last, 1989), a good indication of the biological communities in south-eastern Tasmania can be obtained, including fish and invertebrates. Representative images and video of the biological communities associated with habitat types are presented on the SEAMAP Tasmania web site <http://www.utas.edu.au/tafi/seamap/>.

The following tables summarise the habitat extent data (Please note that the results for Great Oyster Bay are presented in Section 3.13 below).

Table 2. Bryans Lagoon habitat areas.

Substrate	(Ha)	(Km^2)
Sand	0.2	0.0
Dense Seagrass	7.2	0.1
Vegetated	25.4	0.3
	32.8	**0.3**

Table 3. Catamaran River habitat areas.

Substrate	(Ha)	(Km^2)
Low Profile Reef	0.3	0.0
Cobble	3.1	0.0
Sand	2.1	0.0
Silty Sand	1.3	0.0
	6.8	**0.1**

Table 4. Cloudy Bay Lagoon habitat areas.

Substrate	(Ha)	(Km^2)
Med Profile Reef	1.0	0.0
Low Profile Reef	4.5	0.0
Hard Sand	7.3	0.1
Sand	340.0	3.4
Silt	13.6	0.1
Silty Sand	37.5	0.4
Dense Seagrass	7.8	0.1
Patchy Seagrass	10.3	0.1
Sparse Seagrass	63.7	0.6
Sparse Patchy Seagrass	63.1	0.6
Macroalgae	64.0	0.6
Land	4.1	0.0
	616.9	**6.2**

Table 5. D'Entrecasteaux River estuary habitat areas.

Substrate	(Ha)	(Km^2)
Cobble	6.0	0.1
Sand	60.4	0.6
Dense Seagrass	0.8	0.0
Patchy Seagrass	2.7	0.0
Sparse Seagrass	0.8	0.0
	70.7	**0.7**

Table 6. Great Swanport habitat areas.

Substrate	(Ha)	(Km^2)
Hard Sand	28.8	0.3
Sand	133.8	1.3
Dense Seagrass	529.7	5.3
Patchy Seagrass	296.4	3.0
Sparse Seagrass	11.2	0.1
Sparse Patchy Seagrass	99.9	1.0
Vegetated	49.7	0.5
Land	16.9	0.2
Unknown	42.4	0.4
	1,208.8	**12.1**

Table 7. Little Swanport habitat areas.

Substrate	(Ha)	(Km^2)
Low Profile Reef	1.5	0.0
Cobble	6.0	0.1
Sand	87.4	0.9
Silty Sand	52.9	0.5
Silt	54.5	0.5
Dense Seagrass	209.9	2.1
Patchy Seagrass	76.2	0.8
Sparse Seagrass	57.1	0.6
Vegetated	48.2	0.5
Land	14.8	0.1
	608.6	**6.1**

Table 8. Pipeclay Lagoon habitat areas.

Substrate	(Ha)	(Km^2)
Low Profile Reef	1.1	0.0
Cobble	6.2	0.1
Hard Sand	20.0	0.2
Sand	470.0	4.7
Dense Seagrass	0.3	0.0
Sparse Patchy Seagrass	0.8	0.0
Silty Sand	42.4	0.4
	540.9	**5.4**

Table 9. Pitt Water habitat areas.

Substrate	(Ha)	(Km^2)
Low Profile Reef	6.3	0.1
Cobble	5.7	0.1
Hard Sand	346.4	3.5
Sand	1,388.8	13.9
Silty Sand	1,509.5	15.1
Silt	504.9	5.0
Dense Seagrass	153.4	1.5
Patchy Seagrass	236.8	2.4
Sparse Patchy Seagrass	125.9	1.3
Vegetated	0.8	0.0
Land	35.1	0.4
Unknown	0.3	0.0
	4,313.7	**43.1**

Table 10. Southport Lagoon habitat areas.

Substrate	(Ha)	(Km^2)
Medium Profile Reef	7.3	0.1
Low Profile Reef	3.6	0.0
Hard Sand	19.9	0.2
Sand	492.7	4.9
Silty Sand	393.8	3.9
Dense Seagrass	9.9	0.1
Patchy Seagrass	49.5	0.5
Sparse Seagrass	89.1	0.9
Land	3.3	0.0
	1,069.0	**10.7**

Note: Macroalgae (~514.1 Ha, 5.1 Km^2) covers most of the silty sand and some of the sand.

The following tables summarise the total area mapped for each estuary (Table 11). Then Table 12 presents, firstly, the summed areas of all seagrass densities, secondly, the proportion of seagrass (all densities) to the area of the estuary, and thirdly, the proportion of dense seagrass to all other seagrass densities (*i.e.*, patchy seagrass, sparse seagrass and sparse patchy seagrass).

Table 11. Total area of each estuary as mapped.

Estuary	Area (Ha)	Area (Km^2)
Pitt Water	4,313.7	43.1
Great Swanport	1,208.8	12.1
Southport Lagoon	1,069.0	10.7
Cloudy Bay Lagoon	616.9	6.2
Little Swanport	608.6	6.1
Pipeclay Lagoon	540.9	5.4
D'Entrecasteaux River	70.7	0.7
Bryans Lagoon	32.8	0.3
Catamaran River	6.8	0.1
	8,468.3	**84.7**

Table 12. Area of seagrass for each estuary and proportions of seagrass by estuary area and proportions of dense seagrass to all densities of seagrass.

Estuary	Seagrass Area (all densities combined)		Percent of seagrass (all densities combined) to area of the estuary	Percent of dense seagrass to all other densities of seagrass
	(Ha)	(Km^2)	(%)	(%)
Great Swanport	937.2	9.4	78	57
Pitt Water	516.1	5.2	12	30
Little Swanport	343.2	3.4	56	61
Southport Lagoon	148.5	1.5	14	7
Cloudy Bay Lagoon	145.0	1.5	24	5
Bryans Lagoon	7.2	0.1	22	100
D'Entrecasteaux River	4.4	0.0	6	18
Pipeclay Lagoon	1.2	0.0	0	29
Catamaran River	0.0	0.0	0	0
Total	**2,102.8**	**21.0**		

3.2 Bathymetry (Depth) and Geomorphology (Shape) of the Estuarine areas and Great Oyster Bay

Depth was recorded during field surveys of the estuaries, lagoons and Great Oyster Bay. For the marine area of Great Oyster Bay, bathymetric contours were generated at 5 m contour intervals, which is a much finer scale than those currently available from marine charts. The fine scale contours are plotted on the detailed 1:25,000 maps in this report. In the estuaries there are extensive shallow areas where sounders operate sub-optimally due to the reduction in the sounding accuracy when the distance between the sounder transducer and the seafloor is less than ~0.6 m. A further complicating factor is provided by the variable nature of tides within estuaries where the speed of the tidal wave within an estuary varies with depth and estuary shape, making depth very difficult to predict. This lack of predictability makes it more difficult to establish an accurate tidal correction factor. In the light of these difficulties, the approach taken was to utilise the sounder tracklogs as tidally-corrected spot-depth maps to assist in characterising their depths when interpreting the other data sources.

The estuaries generally conform to a classic wave dominated estuarine geomorphology (Heap *et al.*, 2001) and have clearly defined deeper central basins surrounded by significant areas of shallows and intertidal flats. Most also have a long sinuous main channel, large flood tide deltas and smaller ebb tide deltas and a major sedimentary barrier. The following table (Table 13) summarises these features for each estuary.

3.3 Freshwater inputs, tides and salinity: Estuaries as mixing zones

For a thorough discussion on the definition of an estuary, you are referred to the major TAFI report on estuaries (Edgar *et al.,* 1999). The general definition of an estuary presented in that report is adopted here, as follows:

"An estuary is a semi-enclosed or periodically closed coastal body of water in which the aquatic environment is affected by the physical and chemical characteristics of both fluvial drainage and marine systems".

Table 13. Estuarine geomorphological components (facies) based on the Geoscience Australia conceptual models (Heap *at al*., 2001).

Estuary	Fluvial Delta	Central Basin	Shallows & Intertidal Flats	Flood Tide Delta	Main Channel (between ebb and flood tide deltas)	Ebb tide Delta	Barrier
Bryans Lagoon	None	Small	Small	None	n.a.	None	Closed (Bryans Beach)
Catamaran River	Indistinct: (Catamaran River)	Very small	Small	None	n.a.	None	None
Cloudy Bay Lagoon	Negligible: (Saintys Creek)	Moderate	Large	Large	Long, branched	Small	Very Large (Cloudy Beach)
D'Entrecasteaux River	Large: (D'Entrecasteaux River)	None	Small	Indistinct	n.a.	Large	None
Great Swanport	Large: (Swan River)	None	Small	Indistinct	Very long, branched	Moderate	Very Large (Dolphin Sands)
Little Swanport	Large: (Little Swanport River)	Moderate	Large (shallows)	Moderate	Short, braided	Small	Moderate
Pipeclay Lagoon	None	Small	Large	Large	Long, branched	Small	Moderate (Cremorne Beach)
Pitt Water	Moderate: (Coal River) Small: (Iron Creek)	Very large	Very large	Very Large	Very long, braided, branched	Indistinct	Very Large (7-Mile Beach)
Southport Lagoon	Small: (Donnellys Creek)	Large	Large	Very Large	Long, branched	Small	Very Large (Big Lagoon Beach)

Many of the common definitions of an estuary refer to the estuary as the location where freshwater and salt water mix (Woodroffe, 2003). Freshwater inputs are a critical variable affecting estuarine systems, both in terms of the energy and processes shaping the estuary and the influence on the biology of freshwater/marine water mixing regimes. Strong fluvial (river) discharge levels can create stratified salinity profiles with denser high salinity waters forming a "salt wedge" underlying lighter freshwater inputs. The position of the salt wedge changes in response to many factors including the river flow rate, the amount of vertical mixing (e.g., through high levels of turbulence levels in water flow) and the tidal exchange rate. Lower fluvial discharges can result in estuaries that are dominated by the marine salinity levels or, when coupled with high evaporation rates and low tidal exchange, hypersaline conditions. Estuaries are commonly categorised as "well mixed", "partially mixed" or "stratified". Well mixed estuaries generally have salinities approaching the level found in seawater throughout the waterbody. Partially mixed estuaries may be stratified in part of the estuary (typically near the fluvial inputs) and well mixed throughout the rest of the waterbody, or stratified for some of the time under strong fluvial discharges (e.g., during winter or during flood events) and then become well mixed at other times.

The data presented in Table 14 are defined in detail in Edgar *et al*. (1999), though, in brief: the mean annual rainfall (Rav) is obtained from interpolated long-term BOM rainfall records; the mean annual runoff (MAR) is obtained from measured runoff per unit catchment area at gauging stations where they are available and predicted via a linear regression (r^2=0.92) to the estuaries without a gauging station; and the runoff coefficient is MAR/Rav. The total annual rainfall (TAR) is the annual rainfall summed across the entire catchment.

Table 14. Freshwater inputs: rainfall, runoff and area of catchments (from Edgar *et al.*, 1999).

Estuary	Rainfall mean annual (mm)	Runoff mean annual (mm)	Runoff Coefficient	Rainfall total annual (gl)	Entire Catchment Area (km2)	Direct Drainage Area (km2)
Bryans	695	109	0.16	4.1	5.8	5.8
Catamaran River	1,489	812	0.55	102.2	68.6	2
Cloudy Bay Lagoon	934	321	0.34	39.9	42.7	18.1
D'Entrecasteaux River	1,399	733	0.52	110.0	78.6	5.2
Great Swanport	759	166	0.22	782.8	1,031.2	140.8
Little Swanport	709	121	0.17	519.9	733.7	55.9
Pipeclay Lagoon	650	69	0.11	10.7	16.5	16.5
Pitt Water	631	52	0.08	582.3	922.9	109.4
Southport Lagoon	1,215	570	0.47	33.1	27.2	13.8

3.4 Bryans Lagoon

3.4.1 Overview and Special Features

Bryans Lagoon was selected for inclusion in this project on the basis of its high conservation status as established in a statewide survey of estuaries (Edgar *et al*., 1999). It was given Class A status as near pristine estuary with the highest possible ranking on the Naturalness Index, which indicates there is no cleared land or urban areas within the catchment. It is located within the Freycinet National Park.

The Lagoon is a superb example of a small closed shallow brackish estuary with episodic freshwater inputs from ephemeral creeks in a granitic catchment. There are thick dense beds of aquatic macrophytes throughout the lagoon with evidence of swan breeding taking place in the reed beds within the broader basin in the north. The lagoon is fringed with saltmarsh.

Special Features

- A system with a clear boundary between the vegetation in the brackish open basin and the more saline channel.
- A dense coverage of aquatic macrophytes throughout the lagoon.
- A closed barway, with a large steep beach across the entrance.

Figure 3-1. The mouth of the estuary (and Schouten Island) to the south east along the narrow shallow channel (20th September 2005).

Figure 3-2. Shallow reedy habitats in the brackish northern end of Bryans Lagoon (20th September 2005).

3.4.2 Geomorphology and Sediments

Bryans Lagoon is a very small wave dominated estuary (~33 Ha) with a closed sediment barrier that is maintained by strong southerly swell conditions accumulating large volumes of sand along Bryans Beach, including across the entrance to the lagoon. Geoscience Australia (Heap *et al*., 2001) also assigns the estuary to a sub class of "strand plain", indicating that the barway is rarely, if ever breached. There may be occasional inputs of marine water across the barrier under high tide and heavy swell conditions. The estuary has no regular freshwater inputs receiving only periodic influxes from the small ephemeral creeks, which form in the surrounding steep granitic basin following periods of heavy rainfall. The constitution of the sediments is very similar throughout the lagoon and is predominantly comprised of well-sorted moderate to fine sands. There are occasional patches of poorly sorted sediments and even some gravel in places, most likely due to deposition from the ephemeral watercourses. The within estuary wave climate is limited to small wind driven waves.

Table 15. Bryans Lagoon geomorphological features (from the OzEstuaries Database).

Estuary Number	1025	**Condition**	Near pristine
Classification	Wave dominated	**Sub Classification**	Strand plain
Longitude	148.29	**Latitude**	-42.261
Datum	GDA 94	**Mean Wave Height (m)**	0.00
Perimeter (km)	4.09	**Max Wave Height (m)**	0.00
Entrance Width (km)	0.05	**Tidal range (m)**	0.00

The open body of water at the head of the estuary occupies 22 Ha and the balance of the lagoon narrows from over 80 m wide at the lagoon head, to only 20 m wide near the terminating barrier. The channel extends parallel to the barrier for 1.2 km were it terminates at the sediment barrier behind a steeply shelving beach. The distance of the end of the lagoon from the sea is about 60 m. It is unknown whether the lagoon breaches the barrier.

3.4.3 Circulation and Salinity Profiles

The salinity of Bryans Lagoon was found to be the lowest of all the estuaries surveyed and could be described as brackish water. This lagoon was surveyed directly after a period of heavy rain on the east coast and this may explain the low salinity values. This estuary exhibited salinities in the range of 10-15 ppt at the seaward end of the estuary. At the top of the estuary these salinity readings fell below 10ppt (Figure 3-3). This was the only estuary surveyed that did not have a permanent open channel to the sea and thus would not experience the same flushing and mixing as some of the other estuaries. There is the potential for this lagoon to exhibit high salinity values in summer, when the rainfall on the east coast is low and evaporation is high. Periodic influxes of marine water may occur through swells washing over the barrier.

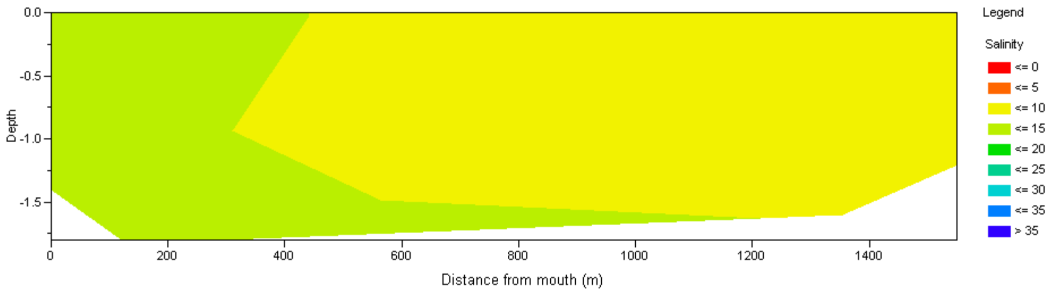

Figure 3-3. Salinity profile of Bryans Lagoon

3.4.4 Seagrass Condition Sampling

Three sites were surveyed in Bryans Lagoon for seagrass condition. These sites were located along the main channel in the *Ruppia* sp. and *Heterozostera tasmanica* seagrass beds (see Figure 6-1). Site 1 was the most variable with blade length ranging from 5-30cm and the cover from less than 10% to 100% (Figure 3-4). The epiphyte loading at this site was medium to high. The other two sites were characterised by denser and less variable growth. The seagrass at site two ranges from 20-55cm blade length and 75-100% cover, while that at site 3 ranged from 25-35cm and 70-100% cover (Figure 3-4). Both these sites had a medium amount of epiphyte growth.

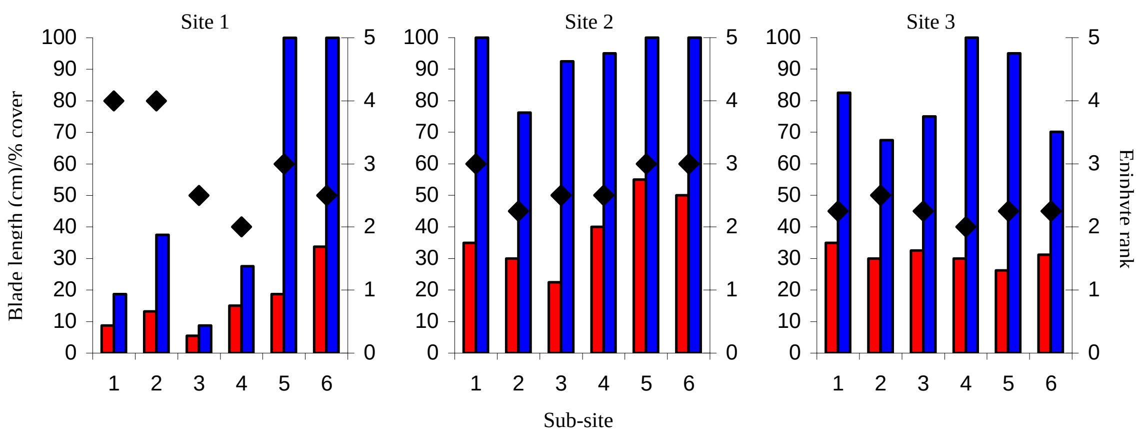

Figure 3-4. Graphs of average seagrass blade length (red bars), average % cover (blue bars) and average epiphyte ranking (black diamonds) for the three sites surveyed in Bryans Lagoon.

3.4.5 Community Types

Bryans Lagoon is a small lagoon with two distinct biological communities, one in the freshwater-influenced reedy open basin of the lagoon at its north western end and the long narrow channel that has a stronger saline influence. The channel is dominated by macrophytes including *Ruppia* sp. and, near the south eastern end, seagrass *Heterozostera tasmanica*. All the macrophyte exhibited high percent cover and long blade lengths and the epiphytic abundance was consistently moderate (~3 rank). The lagoon has a minor area of unvegetated unconsolidated substrates near the mouth of the estuary consisting of medium fine to fine sands.

3.5 Catamaran

3.5.1 Overview and Summary

The Catamaran River estuary was included in this project due to its high conservation significance, with a Class B rating by Edgar *et al*. (1999) indicating low levels of human impact within the catchment. The river has a high discharge rate and the estuary is formed more by this and tidal energy than wave energy. The lack of a sedimentary barrier formation near the mouth is possibly also due to the presence of bedrock points. The estuary has little seagrass, possibly due to the high tannin levels in the river water and, reflecting a strong fluvial influence, it has a narrow cobbled channel and, at least at the time of sampling, a definite salt wedge.

Special Features

- A lack of a sedimentary barrier at the mouth of the estuary, probably due to high fluvial flows and bedrock points at the mouth.
- A long cobbled channel bed in the upper reaches of the estuary.

Figure 3-5. An aerial view of the Catamaran River delta where it enters Recherche bay (Image courtesy of Andy Short, University of Sydney, 19th February 2003). Note the high tannin levels.

3.5.2 Geomorphology and Sediments

The Catamaran estuary is a small (~6.8 Ha), wave dominated estuary that enters Recherche Bay from the west. The central basin formation is so small that it is bordering on a wave dominated delta. The river has high average annual rainfall, which combined with a high runoff coefficient (see Table 14), indicates a strong fluvial discharge, which would partially explain the small size of the barely discernible small central basin. Measuring ~1.6 km in length, the estuary gradually widens from a few metres at its upper reaches, to over 120 m wide near the mouth. Dominated by a hard cobbled substrate in the upper reaches, as the estuary widens in the lower reaches, the dominant substrate consists of well sorted medium to fine sand with areas of less well sorted sand that includes coarser sand and shell fragments. The increase in width of the estuary is likely to result in a slight decrease in fluvial flow energy, which is consistent with the presence of a large intertidal sandbank 600 m from the mouth. The central basin of the estuary is located just inside the mouth and covers ~0.13 Ha with an average depth of 2.5 m. Fringing reef outcrops on two sides, causing a constriction in water flow through the mouth of the estuary and probably limiting the formation of a sediment barrier, enclose the mouth of the estuary. The outcropping reef may have also limited the formation of ebb and flood tide deltas by increasing the water speed through this section, and thus limiting the deposition of sediment.

Table 16. Catamaran River Estuary geomorphological features (from the OzEstuaries Database).

Estuary Number	1013	**Condition**	Near pristine
Classification	Wave Dominated	**Sub Classification**	Other
Longitude	146.89	**Latitude**	-43.553
Datum	GDA 94	**Mean Wave Height (m)**	
Perimeter (km)	2.46	**Max Wave Height (m)**	
Entrance Width (km)	0.16	**Tidal range (m)**	0.7
Water Area (km^2)		**Tidal period**	
IBRA Class		**IMCRA Class**	
Catchment Area (km^2)		**MDL Code**	
Intertidal Flats Area(km^2)		**Open Water Area**	

3.5.3 Circulation and Salinity Profiles

The Catamaran River displayed a classic salt wedge in the salinity profile. The salt-water layer extended approximately 1km up the river with a surficial freshwater layer running to the mouth of the estuary (Figure 3-6). Approximately 1.1km from the mouth of the estuary the salinity throughout the water column was less than 5ppt.

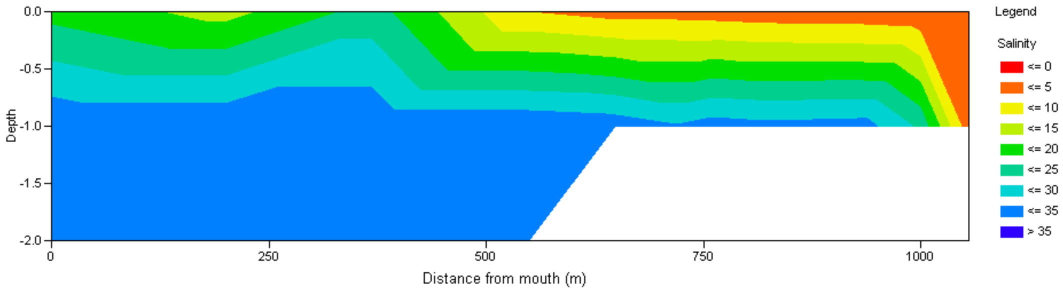

Figure 3-6. Salinity profile of the Catamaran River

3.5.4 Community Types

The main habitat types were the cobble channel and the unvegetated medium to fine sand banks and flats. There were reefs with macroalgae at the mouth of the estuary. There were only small amounts of seagrass within the Catamaran estuary. These were generally in small beds less than 5 m across and were not deemed a significant habitat.

3.6 Cloudy Bay Lagoon

3.6.1 Overview and Special Features

Cloudy Bay Lagoon is a Class B estuary in terms of its conservation significance (Edgar *et al*., 1999), indicating low levels of human impact. It has a Naturalness Index of 1.28, 35% of the catchment is privately owned land, and there is an oyster farm on the flood tide delta.

Special Features

- Large beds of macroalgae growing on unconsolidated substrates.
- Low freshwater influence.
- Native flat oysters present in small patches.
- Large areas of intertidal seagrass.

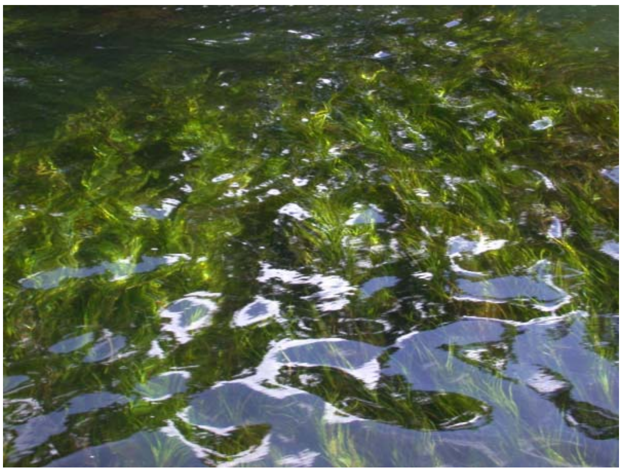

Figure 3-7. Very high density and long bladed seagrass (*Heterozostera tasmanica*) with very low epiphytic loading near the estuary mouth (The Inlet) to Cloudy Bay Lagoon (18th March 2005).

3.6.2 Geomorphology and Sediments

In terms of overall geomorphological structure, Cloudy Bay Lagoon is a wave dominated estuary of approximately 617 Ha with most of the energy that has shaped the estuary being delivered by large oceanic swells and the tidal flow. Within the estuary, the wave climate is limited to waves generated by the wind across the fetch of the lagoon itself. There are several small freshwater inputs, the most significant of which is Saintys Creek, in the northeastern corner. The estuary does not have any fluvial bay head deltas as the edges of the lagoon are dominated by large areas of well sorted fine sand intertidal flats, surrounding a large central basin. The flats appear to be maintained by small wind-driven waves that are generated within the estuary. The central basin consists of extensive shallows about 1 to 2 m deep and a smaller deeper basin occupying ~200 Ha with depths of 5 to 7 m. The deeper basin has a substrate consisting of less well sorted sediments including higher proportions of silt and clay. The flood tide delta (~110 Ha) encroaches on the western side of the central basin and is linked to the sea at the far western end of Cloudy Bay beach through a branched sinuous main channel 2 km long, known as The Inlet. The Inlet is dominated by hard sandy substrates, with shelly substrates lining the fast flowing channels and the sand flats along its sides consisting of very well sorted fine sand. The small 15 Ha ebb tide delta is mainly controlled by wave energy from the constant large swells. The very large estuarine barrier forms the entire southern side of the lagoon and includes Conleys Point.

Table 17. Cloudy Bay Lagoon geomorphological features (from the OzEstuaries Database).

Estuary Number	583	**Condition**	Near pristine
Classification	Wave Dominated	**Sub Classification**	Wave Dominated Estuary
Longitude	147.202	**Latitude**	-43.44
Datum	GDA 94	**Mean Wave Height (m)**	1.62
Perimeter (km)	13.51	**Max Wave Height (m)**	6.50
Entrance Width (km)	0.22	**Tidal range (m)**	1.20
Water Area (km^2)	10.03	**Tidal period**	Diurnal
IBRA Class	D'Entrecasteaux	**IMCRA Class**	Bruny
Catchment Area (km^2)	48	**MDL Code**	SCUBN
Intertidal Flats Area (km^2)	3.83	**Open Water Area (km^2)**	2.7

3.6.3 Circulation and Salinity Profiles

The salinity measurements in Cloudy Bay Lagoon showed little variation across the lagoon. The whole lagoon was around 35ppt, the same as the incoming seawater (Figure 3-8). At the top end of the lagoon the salinity was slightly hypersaline. This reflects that this lagoon has little freshwater influence and potentially evaporation at the top of the estuary is responsible for the slightly hyper saline readings. The fluvial inputs to the lagoon are relatively minor and have a magnitude similar to Southport Lagoon (see Table 14). The depth and shape of the main channel suggests that this estuary has a strong tidal flow through the main channel allowing a good exchange between the sea and the lagoon water.

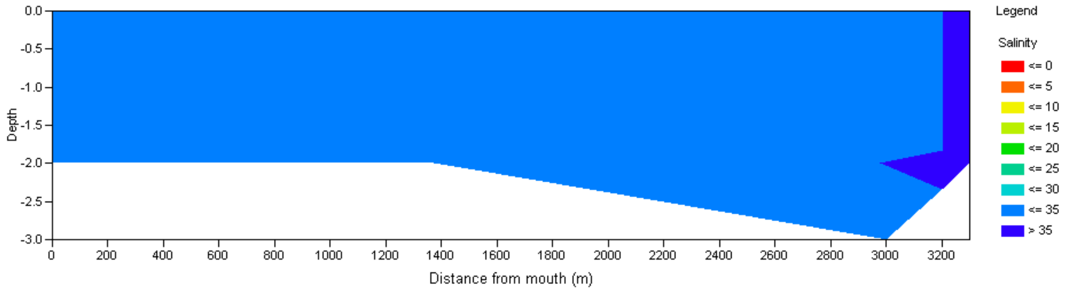

Figure 3-8. Salinity profile of Cloudy Bay Lagoon

At four sites the seagrass was surveyed (see Figure 6-3) using quadrat estimates of blade length, percentage cover and algal epiphyte growth.

3.6.4 Seagrass Condition Sampling

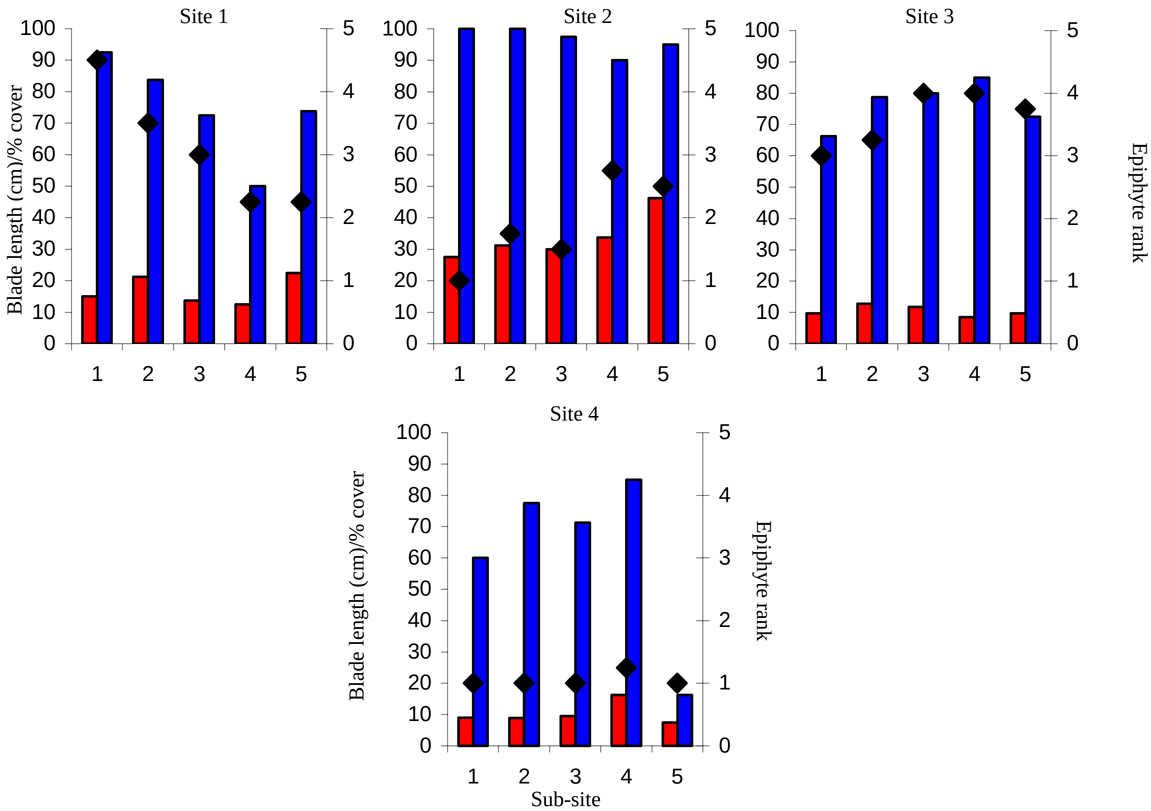

Figure 3-9. Graphs of average seagrass blade length (red bars), average % cover (blue bars) and average epiphyte ranking (black diamonds) for the four sites surveyed in Cloudy Bay Lagoon.

The seagrass at site 1, *Heterozostera tasmanica*, was characterised by blade lengths 15-25 cm of relatively high densities, greater than 50% cover and up to 90% cover (Figure 3-9). The epiphyte loading at this site was medium to high. The seagrass at site 2, *Heterozostera tasmanica*, was closest to the entrance channel and had the longest blades of all the seagrass surveyed. The average blade length at this site ranged from 25-45cm with close to 100% cover at all sub-sites surveyed. The epiphyte loading at this site was generally low to medium (Figure 3-9). Site 3, located in the intertidal zone at the north of the lagoon, was characterised by *Zostera muelleri* with short blades (<10 cm) and medium high densities (60-80%). This site had the most epiphyte growth, generally ranking 3-4 (Figure 3-9). The seagrass at site 4 was also *Zostera muelleri* and had similar abundances but had low epiphyte abundance, and in one sub-site had low percentage cover (Figure 3-9).

3.6.5 Community Types

Cloudy Bay Lagoon has extensive seagrass beds. The beds range from dense beds with long blades in the entrance channel to sparse beds with short blades on some of the sand banks. The habitat map, Figure 4-4, shows the densest seagrass to be associated with the channels around the entrance of the lagoon and into the margins of the lagoon proper. The seagrass in the main channel (*Heterozostera tasmanica*) exhibited dense growth with little or no epiphytes. Where the main channel turns east around Conleys point to where it enters the main basin has dense and dense patchy beds of *Heterozostera tasmanica.* There was sparse seagrass present on many of the shallow banks throughout the lagoon. The intertidal flats fringing the northern and eastern sides of the main basin have large beds of short, sparse and sparse patchy *Zostera muelleri*. A small bed of flat oyster (*Ostrea angasi*) was identified in the main basin near the oyster farm. Extensive (~60 Ha) macroalgal beds, including *Gracilaria* sp., grow on the unconsolidated sediments in the main basin. Large areas of mounding (bioturbation) in the unconsolidated sediments provide evidence of benthic infauna communities. There are mixed macroalgal and seagrass beds along the western shore of The Inlet with the macroalgae occurring either on hard rocky substrates or hard packed sand of the channel bottom.

3.7 D'Entrecasteaux

3.7.1 Overview and Special Features

The D'Entrecasteaux River estuary is characterised by high fluvial discharges, a long cobbled channel, and a lack of a sedimentary barrier near the mouth. There is a small amount of seagrass fringing the main channel and a small patchy bed on the ebb tide delta. The estuary was selected for inclusion in this project because of its Class B rating by Edgar *et al.* (1999). The majority of the land in the catchment is Crown land, implying little or no human impact on the estuary, although there is an active oyster farm on the flood tide delta.

Special Features

- There is evidence of a strong fluvial influence in the absence of a central basin, the salt wedge and the strongly defined long cobbled channel bed that extends into the middle reaches of the estuary.
- Longitudinal fringing beds of seagrass in the middle and upper reaches.
- Extensive sandy delta, protected from swells by two points immediately to the

south.

Figure 3-10. An aerial photograph (5/3/2002) of the D'Entrecasteaux River delta and immediate surrounds.

3.7.2 Geomorphology and Sediments

The D'Entrecasteaux River estuary is a small (~70.7 Ha) wave dominated delta, with no significant entrance barrier or central basin. The high rainfall combined with a high runoff coefficient (see Table 14) indicates very high river discharge rates. The absence of a sediment barrier can also be explained by the reduced wave energy from swells caused by a narrowing of the bay about 2km to the south of the estuary mouth by Bennetts and Ryans Points. Measuring 2.3 km long, the estuary has an average width of 45 m for the first 1 km from the upper tidal limit, then widens significantly, with the presence of braided channels and large sand flats. The upper reaches are dominated by a hard cobble substrate, which rapidly changes to sandy substrates with a widening in the estuary channel. The unconsolidated substrates generally consist of well-sorted medium to very fine sands. The main channel maintains a constant width of 90 m to the ebb tide delta where it widens into the bay. The ebb tide delta extends over 200 m from the termination of the channel, occupying an area of roughly 25 Ha.

3.7.3 Circulation and Salinity Profiles

The D'Entrecasteaux River estuary displayed a salt wedge in the salinity profiles (Figure 3-11), though this was less stratified than the Catamaran River estuary (Figure 3-6). This may reflect either differences on the magnitude of the river flows or different tidal states at the time of sampling. At the mouth of the estuary the water was still brackish, between 20 and 30ppt. This indicates that the freshwater layer extends out into Pigsties Bay. Approximately 1.8km up the estuary, the water was dominated by freshwater (less than 5ppt).

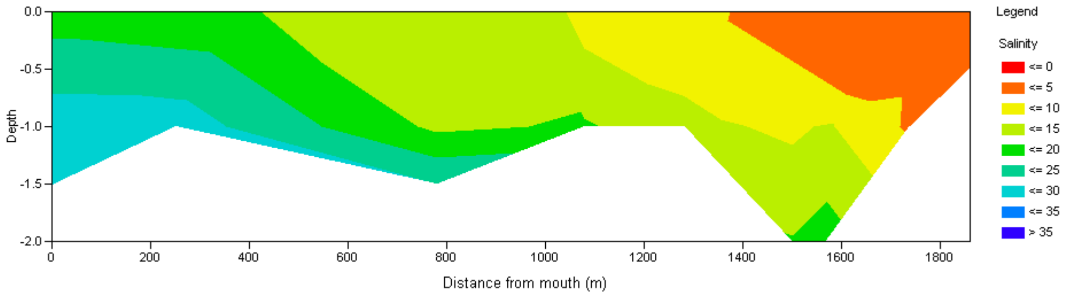

Figure 3-11. Salinity profile of the D'Entrecasteaux River

3.7.4 Community Types

There were no significant seagrass beds within the D'Entrecasteaux River estuary. Similar to the Catamaran River estuary, the D'Entrecasteaux River estuary has a long narrow cobbled channel habitat in the upper and middle reaches. The D'Entrecasteaux, though, has some longitudinal seagrass beds fringing the sides of the channel and the braided channels of the middle reach (Saltwater Inlet). The extensive moderately well sorted sandy delta has a scattering of patchy and patchy sparse seagrass beds.

3.8 Great Swanport

3.8.1 Overview and Special Features

Great Swanport is a very large system that is well covered with aquatic macrophytes including dense seagrass. Consistent with east coast rainfall patterns, it has large volumes of freshwater episodically passing through the system. Moulting Lagoon (not mapped for this study) contributes to the tidal flow through the large sinuous main channel of Great Swanport.

Special Features

- Great Swanport has the largest area of seagrass (over 900 Ha) of the estuaries in this report (see Table 12 for a comparison).
- It is a large complex system accepting water from two catchments and with Pelican Bay as a significant sub-basin.
- It has the largest freshwater inputs of all the estuaries studied (see Table 14 for a comparison).
- The Swan River delta area is an extensive shallow marine macrophyte habitat.

Figure 3-12. The broad shallows near the junction of the Swan River and the main channel from Moulting Lagoon with the very large sedimentary barrier (Dolphin Sands) and the Hazards to the south east (14th September 2005).

3.8.2 Geomorphology and Sediments

The Great Swanport estuary is a subsystem within the larger estuarine system formed by the Apsley and Swan Rivers and includes Moulting Lagoon (not mapped), Pelican Bay and Great Swanport. A main central basin feature is absent within the mapped area, and is similar in this way to Lower Pitt Water. In the case of the Apsley River, Moulting Lagoon forms the central basin, while in the case of the Swan River, there is no apparent central basin, though a large area near the mouth of the Swan could be a completely filled basin. Moulting Lagoon is a large body of water, which contributes to the tidal flows through much of Great Swanport, and these tidal flows contribute the location, sinuosity and size of the main channel. The area of Great Swanport mapped for this project is 12 km^2 (1,200 Ha), which is similar in size to Southport Lagoon and about a quarter the size of Pitt Water.

This wave-dominated estuary receives significant freshwater inputs from the Swan and Apsley Rivers (see Table 14). The estuary has a very large catchment (1,031 km^2) and, despite the relatively low rainfall it receives and its moderate runoff coefficient, it has the largest runoff of the all the estuaries covered in this project (see Table 14). The Swan has a delta covering approximately 430 Ha and, within this area, there are a number of large sedimentary islands covered with saltmarsh and the main channel is thin, sinuous and branching. Once the Swan joins the water from Moulting Lagoon, the main channel sustains an average width of 60 m and average depth of 4 m. The substrate is moderately well sorted medium to fine sand with up to 20% silt at some locations.

Great Swanport is a long narrow estuary; about 10 km from the mouth to Moulting Bay and about 11.5 km to where the Swan Rivers narrows. It has proportionally smaller areas of shallows and intertidal flats compared to the other wave dominated estuaries (*e.g.*, Pitt Water), however, they are still substantial in absolute terms. They are located at the mouth of the Swan River and some around Pelican Bay, mostly consisting of well-sorted medium and fine sands. About half way along the northern side of Great Swanport, the much smaller channel from the small secondary basin of Pelican Bay joins the main channel. Pelican Bay has very low fluvial inputs and generally has a well-sorted medium to fine sand substrate. The mouth of the estuary has braided channels consisting of very well sorted fine sands as it bends past Swanwick at the eastern end of Nine Mile Beach. The ebb tide delta occupies approximately 37 Ha and has a classic fanned deltaic shape (Woodroffe, 2003).

Table 18. Great Swanport geomorphological features (Source: OzEstuaries Database).

Estuary Number	568	**Condition**	Near pristine
Classification	Wave dominated	**Sub Classification**	Wave dominated estuary
Longitude	148.235	**Latitude**	-42.1
Datum	GDA 94	**Mean Wave Height (m)**	0.71
Perimeter (km)		**Max Wave Height (m)**	3.20
Entrance Width (km)	0.23	**Tidal range (m)**	1.40
Water Area (km^2)		**Tidal period**	Diurnal
IBRA Class	Freycinet	**IMCRA Class**	Freycinet
Catchment Area (km^2)	1070.00	**MDL Code**	SCBCE
Intertidal Flats Area (km^2)	11.06	**Open Water Area (km^2)**	42.43

3.8.3 Circulation and Salinity Profiles

The Great Swanport estuary displayed a weak but clear salt wedge, consistent with the high rainfall events prior to the field visit. Salinity measures were not measured at the mouth of the estuary, but at the first sample station the salinity was between 25 and 35ppt. These decreased 11 km up the estuary to <20ppt. The highest salinity readings of 30-35ppt were recorded in the deeper parts of the middle estuary (Figure 3-13).

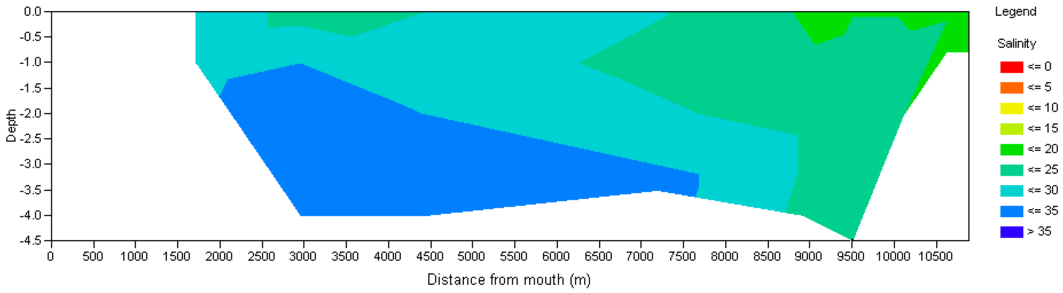

Figure 3-13. Salinity profile of Great Swanport

3.8.4 Seagrass Condition Sampling

Six sites were surveyed in Great Swanport (see Figure 6-5). *Heterozostera tasmanica* was common except for the intertidal Site 3, which was *Zostera muelleri* and Site 1, which was *Ruppia megacarpa*. Site 1 was located at the entrance to Moulting Lagoon. This site showed a high degree of patchiness with blade lengths ranging from 35-60cm and from 30-90% cover (Figure 3-14). The seagrass at Site 2 was more uniform, with blade lengths around 20-30cm and cover greater than 80%. Site 3 had the shortest blade lengths sampled in the estuary at 7-10cm and was located on an intertidal sand bank. The percentage cover at these sites was 30-85% (Figure 3-14). The remainder of the sites, which were located towards the mouth of the estuary, were uniform with blade lengths from 30-50cm and 100% cover (Figure 3-14). At all sites in the estuary the epiphyte ranking was between 2-4 (Figure 3-14).

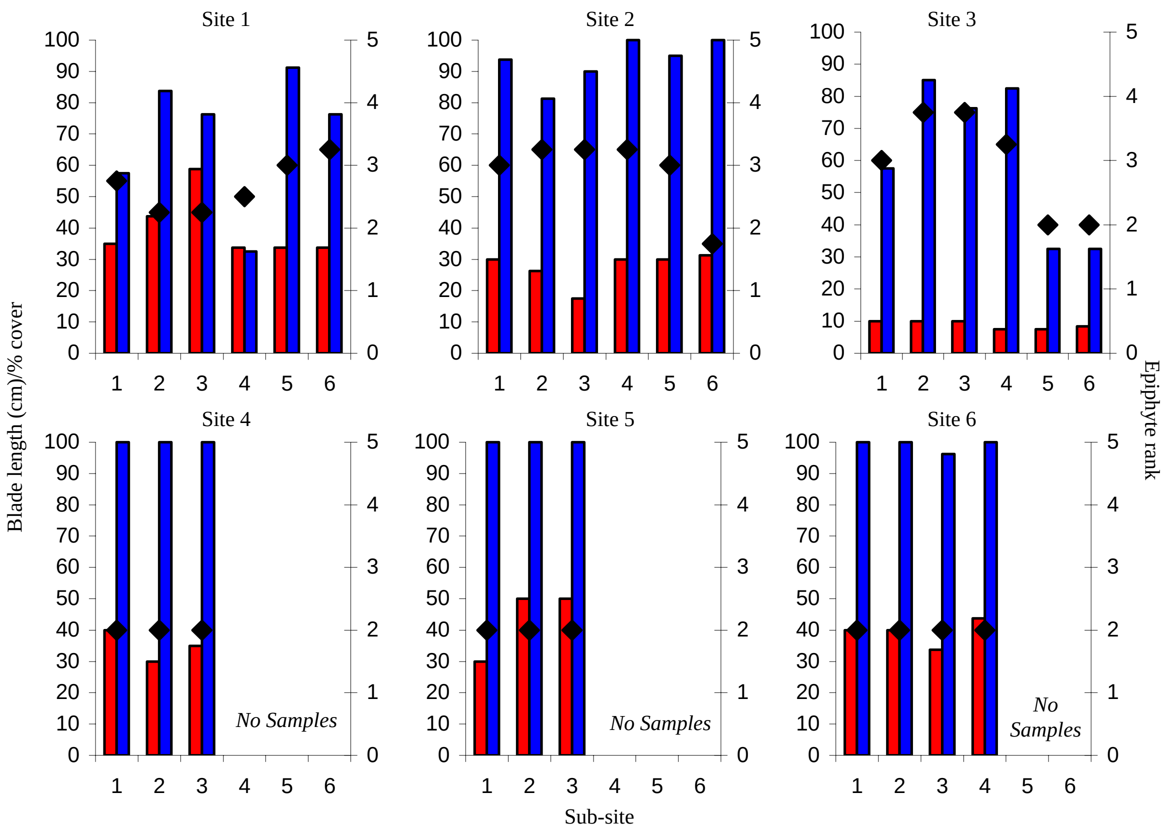

Figure 3-14. Graphs of average seagrass blade length (red bars), average % cover (blue bars) and average epiphyte ranking (black diamonds) for the six sites surveyed in Great Swanport.

3.8.5 Community Types

Great Swanport has an extensive area of brackish aquatic macrophytes, including *Ruppia* sp., in the wide shallow basin where the Swan River enters the estuary. The *Ruppia* sp. also occurs further down the estuary past Woolshed Point to the Yellow Sandbanks, as well as in the main basin of Pelican Bay. Very large areas of both *Heterozostera tasmanica* and *Zostera muelleri* occur in the subtidal and intertidal areas respectively. At ~937 Ha of seagrass, the estuary has the largest area of this habitat of all the estuaries in the study by a significant margin. The next largest is Pitt Water, which has ~516 Ha of (see Table 12). The large intertidal flats have patchy and sparse patchy beds of *Z. muelleri* and the subtidal areas including the much of the main channel is covered in *H. tasmanica* beds, mostly with continuous canopies. The *H. tasmanica* in the lower part of the estuary is extraordinarily uniform, with blade lengths to 40 cm and low epiphytic loadings. There is very little hard substrate in the estuary apart from a couple of small reefs at Pelican Rocks. The braided channels of the estuary entrance exhibit mixed seagrass and macroalgae in places, though the channel bottom is largely shelly hard packed sand with well-sorted fine sand on the surrounding banks.

3.9 Little Swanport

3.9.1 Overview and Special Features

Little Swanport was mapped for another TAFI project in 2005 and the habitat mapping results are included in this report. Little Swanport is an important estuary on the mid-east coast, supporting oyster production as well as providing suitable habitat for many plants and animals including large numbers of black swans. Edgar *et al*. (1999) give the estuary a C Class rating in terms of its conservation significance with a mid-range Naturalness Index of 2.38. This rating is partly due to the marine farming activities and the higher human population densities compared to other higher classed estuaries. The rating is also influenced by the relatively low proportion of the land within the catchment that is protected by reserves or national park (~35%) when compared to other higher classed estuaries. Recent research by TAFI taking place in Little Swanport has produced a detailed study of the physical, chemical and biological aspects of the estuary (Crawford *et al*., 2005).

Special Features

- The estuary has very thick dense beds of aquatic macrophytes throughout, though especially in the upper and middle reaches.
- *Ruppia* sp., *Zostera muelleri* and *Heterozostera tasmanica* are the dominant species.
- There is a complex flood tide delta with many braided channels and a large island dividing the main channel.
- In the upper reaches of the estuary, the fluvial discharge of the Little Swanport River has created multiple short deep discontinuous channels and deposited a very large fluvial delta, including the Duck Island formations, which are all

indications of a strong discharge rate.

Figure 3-15. The upper reaches of Little Swanport depicting the well-developed delta of the Little Swanport River, including the Duck Islands (Image courtesy of Francisco Neira, TAFI, 17/4/2004).

Figure 3-16. The mouth of the Little Swanport estuary showing the strongly braided channels and part of the flood tide delta (Image courtesy of Francisco Neira, TAFI, 17/4/2004).

3.9.2 Geomorphology and Sediments

Little Swanport is a medium sized (~608 Ha) wave dominated estuary with significant freshwater inputs from the Little Swanport River (Table 14). The river channel is cobbled and the large fluvial bay head delta is multi-branched and covers ~260 Ha including the depositional Duck Islands. There are a number of smaller creeks delivering freshwater inputs along the west and south of the upper estuary and there is a large shallow basin in the western end of the estuary (Watch House Bay) and another shallow bay along the southern shore (Luttrells Bay). The main central basin appears to conform tightly to the surrounding geological structure and extends nearly 3 km downstream. The sediments are poorly sorted and include up to 40 to 50 % silts and clay. The basin has an average width of 300 m and is about 55 Ha in extent.

Ram Island dominates much of the estuary where the main central basin meets the flood tide delta. This narrowing is likely to increase the speed of the water flow, particularly in the narrow channel along its northern side. This observation is also supported by the shape of the channel at this location, which is deep with steep sides, especially at the western end. The flood tide delta (~22 Ha) is well channelled, which has produced distinctive broad banks between Ram Island and the estuary entrance at Limekiln Point. The sediments here consist mostly of well-sorted fine sand. The shape of the sediment barrier is likely to be partly influenced by long shore sediment drift as well as the swells and wind waves arriving from Great Oyster Bay. The ebb tide delta creates a barway at the mouth of the estuary that occupies an approximate area of 15 Ha.

Table 19. Little Swanport geomorphological features (Source: OzEstuaries Database).

Estuary Number	569	**Condition**	Modified
Classification	Wave dominated	**Sub Classification**	Wave dominated estuary
Longitude	148	**Latitude**	-42.312
Datum	GDA 94	**Mean Wave Height (m)**	0.50
Perimeter (km)	31.30	**Max Wave Height (m)**	1.90
Entrance Width (km)	0.39	**Tidal range (m)**	1.20
Water Area (km^2)	4.28	**Tidal period**	Diurnal
IBRA Class	Freycinet	**IMCRA Class**	Freycinet
Catchment Area (km^2)	723	**MDL Code**	SCBBN
Intertidal Flats Area (km^2)	1.67	**Open Water Area (km^2)**	4.89

3.9.3 Circulation and Salinity Profiles

The Little Swanport estuary displayed a slight salt wedge in the salinity profiles. The first half of the estuary was dominated by seawater to approximately 3.5-4km from the mouth. Above this the salinity values slowly dropped, to 10-15ppt at 7.5km from the mouth (Figure 3-17). This suggests relatively little freshwater input into the estuary during the sampling period. Other work in this estuary has demonstrated that the positions of these changes in salinity are strongly affected by the tidal cycle and by the flow of the Little Swanport River. Consistent with the east coast rainfall pattern, this estuary is also subject to large changes in salinity due to elevated freshwater flows during the episodic rainfall events. The tidal flushing rate of the estuary is very high; with the equivalent of the high water volume (~7.9 gigalitres) exchanged every 2.32 tidal cycles (i.e., about once a day) (Crawford and Mitchell, 1999).

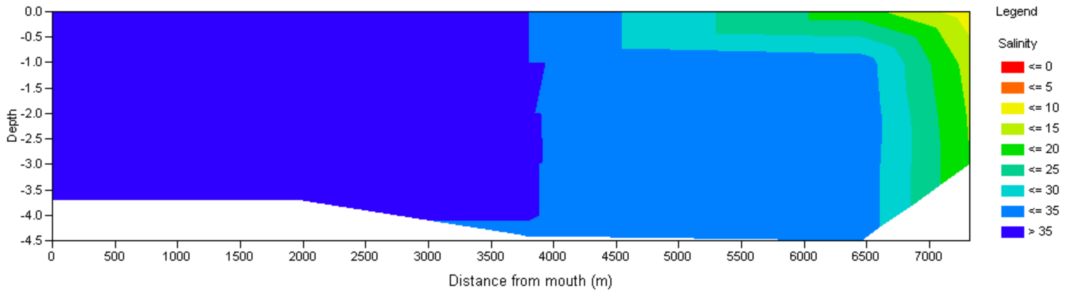

Figure 3-17. Salinity profile of Little Swanport

3.9.4 Seagrass Condition Sampling

Three sites were sampled for seagrass condition, all being in the middle part of the estuary (Sites 1-3 in Figure 6-4). The seagrass *H. tasmanica* was present at all these sites. The seagrass at these sites was found to be uniformly dense, with 100% cover. The blade length was variable both between these sites and also within a single site. At site 1 the blade length varied from 20-60cm, at site 2 10-60cm, while site 3 had the least variation at 25-40cm. The epiphyte loading at the time of survey was relatively low at all sites.

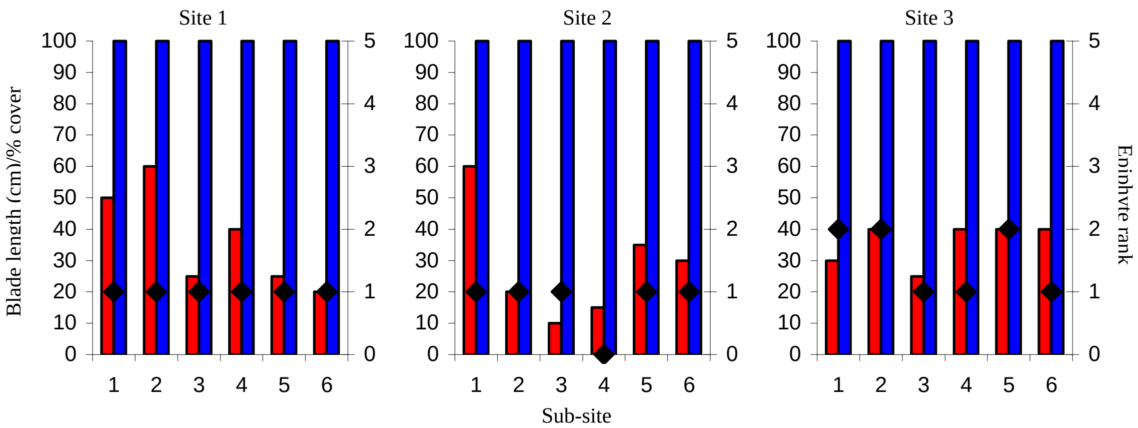

Figure 3-18. Graphs of average seagrass blade length (red bars), average % cover (blue bars) and average epiphyte ranking (black diamonds) for the three sites surveyed in Little Swanport.

3.9.5 Community Types

Very large thick, dense beds of aquatic macrophytes, particularly in the upper and middle reaches, dominate the marine habitats of Little Swanport, including the shallow embayments of Watch House Bay and Luttrells Bay (Figure 4-7). The species present include mainly *Ruppia* sp., *Heterozostera tasmanica* and *Zostera muelleri*, though

Lepilaena sp. has also been identified (Hughes and Davis, 1989) as occurring in the upper and middle reaches. Unvegetated unconsolidated sediments form the primary habitat type on the bottom of the main central basin. In the lower reaches, native flat oysters (*Angasi ostrea*), and the associated filamentous macroalgae and other filter feeders cover large areas, especially in and along the sides of the braided tidal channels. In between and along the channels are extensive sparse and patchy seagrass beds, while the main channel along the northern side of the flood and ebb tide deltas is lined with low profile reef with associated macroalgae, and hard packed sand and shelly substrates.

3.10 Pipeclay Lagoon

3.10.1 Overview and Special Features

Pipeclay Lagoon is a Class D (degraded) estuary of low conservation significance but was included in this project as it is under increasing pressure from catchment, coastal and aquaculture development. It received a relatively poor Naturalness Index rating of 4.28 (Edgar *et al*., 1999) due to high population densities, no reserved land in its (very small) catchment and the substantial areas of oyster farming within the estuary. The very low freshwater inputs and permanently open entrance channel allows regular flushing of the high water volume (~ 6.9 gigalitres), this infers that the lagoon is strongly dominated by marine waters.

Special Features

- Almost a complete lack of seagrass
- Strongly marine influenced waters, caused by the extraordinarily high tidal flushing rate, where almost the whole volume of the lagoon is exchanged each tidal cycle, coupled with very low freshwater inputs.
- Extensive areas of intertidal flats and subtidal shallows
- The most diverse habitats are along the main channel near the mouth of the lagoon.
- Extensive aquaculture activities, land clearing and urban development, in and around the lagoon (see Figure 3-19).

3.10.2 Geomorphology and Sediments

Pipeclay Lagoon is a large wave dominated estuary covering ~ 540 Ha. The estuary has a strong tidal influence (Crawford and Mitchell, 1999) with no significant fresh water inputs (Table 14). The lagoon is characterised by a lack of a fluvial bay head delta, with significant permanently submerged and intertidal flats, fringing the central basin. There are lobes of shallow well-sorted fine sand flats to the west and north. The central basin occupies ~ 42 Ha, and has an average depth of 4 m. The sediments are moderately well sorted with a higher proportion of silts and clays. The large flood tide delta covers ~125 Ha and is linked to the sea by the narrow braided and branching main channel, including Bens Gutter. The channel is over 4 km long with an average width of 75 m increasing to over 100 m behind the sediment barrier, and is comprised primarily of hard sands and, towards the mouth, cobbles. Its location is strongly influenced by the presence of a headland (Pipe Clay Head) on the southern side near the entrance. The channel's fringing intertidal flats consist of very well sorted fine sands. At ~10 Ha, the small ebb tide delta is likely to be maintained by the high wave energy of Cremorne Beach. The main barrier forms the southern end of Cremorne Beach.

Figure 3-19. An aerial photograph (28/3/2004) of Pipeclay Lagoon, illustrating the broad expanses of sand, the well developed branching main channel, the narrow Cremorne Spit and a lack of seagrass beds (The photo is oriented north and shows an area approximately 2.8 km wide).

Table 20. Pipeclay Lagoon geomorphological features (Source: OzEstuaries Database).

Estuary Number	1019	**Condition**	Modified
Classification	Wave dominated	**Sub Classification**	Wave dominated estuary
Longitude	147.539	**Latitude**	-42.96
Datum	GDA94	**Mean Wave Height (m)**	0.00

Perimeter (km)	13.80	**Max Wave Height (m)**	0.00
Entrance Width (km)	0.23	**Tidal range (m)**	0.00

3.10.3 Circulation and Salinity Profiles

At the time of sampling, Pipeclay Lagoon displayed a similar salinity level throughout its extent. The salinity values at the mouth reflected the seawater influence, with the salinity values in the basin at the top of the lagoon being slightly higher (Figure 3-20). In spite of very high flushing rates (1.36 tidal cycles)(Crawford and Mitchell, 1999), this suggests that evaporation in the upper reaches is not completely cancelled out by the very strong tidal mixing of the lagoon, causing increased salinity values. The lack of freshwater input is due to the very small catchment and a very low runoff coefficient (see Table 14). The amount of freshwater input is similar in magnitude to Bryans Lagoon.

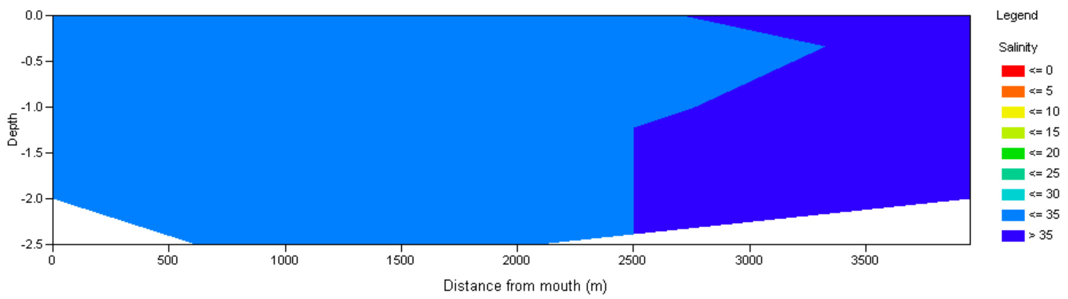

Figure 3-20. Salinity profile of Pipeclay Lagoon

3.10.4 Community Types

There is no significant seagrass in Pipeclay Lagoon, though there are a few small beds lining the main entrance channel, dense near the mouth and sparser where the channel turns easterly around the spit. Similarly, there is low profile reef and cobble habitat in the main entrance area. On the intertidal flats of the lagoon, there are some areas of sparsely distributed ascidians (possibly cunjevoi, *Pyura stolonifera*) and associated dark green macroalgae (possibly *Codium fragilis*) found growing on old flat oyster shells, particularly around the shallow lobe of flats to the north, and some minor algae beds at the eastern end of the main central basin. The dominant community type is open sand flat consisting primarily of well-sorted fine sands.

3.11 Pitt Water

3.11.1 Overview and Special Features

Pitt Water has the largest area of the group of estuaries studied in this project and, at ~43 km^2, is 3.5 times larger than the next largest, Great Swanport (see Table 11). It is a very complex estuarine system with three rivers delivering freshwater inputs, though the Coal River, in particular, is in the driest river catchment on mainland Tasmania (NLWRA, 2000) and is rated as “substantially modified” on an Environmental Index and “significantly impaired” on a Biota Index (Norris *et al*., 2001). The Coal River and its tributaries streams are regularly completely dry due to the harvesting of water for irrigation of horticultural crops (NLWRA, 2000). It is rated as one of the four most impaired catchments in Tasmania (RPDC, 2003). The estuary's large main central basin is associated with the Coal River and is north of the eastern-most causeway, with the next smallest basin, Orielton Lagoon (not mapped), associated with the Orielton Rivulet and, finally, the small sub-basin of Iron Creek Bay is associated with Iron Creek. Pitt Water is included in this project as it is an estuary of some significance in the south-eastern region, largely due to its sheer size and proximity to human habitation. The estuary is clearly impacted by human activity with two causeways cutting across its centre, high densities of human populations around its shores (Midway Point and Sorell) with some light industrial and intensive agricultural and horticultural activities taking place in its catchments. Furthermore, less than 15% of the catchment is reserved or owned by the Crown. All of these factors contribute to the estuary receiving a high 3.07 Naturalness Index (4.09 around the estuary itself) and a conservation significance of Class D (degraded) (Edgar *et al*., 1999).

Although the freshwater inputs are low, the estuary has a massive tidal flow with a tidal prism of ~23.4 gigalitres (i.e., ~23.4 million cubic metres) and a very high exchange rate of 22.94% (Crawford and Mitchell, 1999). This means that the flushing time for the whole estuary is approximately 4.36 tidal cycles and that approximately a fifth of the total high water volume of the estuary (~101.8 gigalitres) moves in and then out on each tidal cycle. The very large main channel system, formed by these large tidal flows, produces good mixing of the fresh and marine waters (Woodroffe, 2003). The regular influx of marine waters stabilises the temperature, salinity and nutrient levels within the estuary, while the high flow rates influence the structure and composition of the estuary substrates and control the location of suitable sites for seagrass (Butler and Jernakoff, 1999; Gillanders and Kingsford, 2002). Even though the estuarine area is 3.5 time that of Great Swanport, the estuary currently has half the seagrass of Great Swanport in absolute terms.

Special Features

- Pitt Water has very large tidal flows and very small freshwater inputs.
- The seagrass beds are clustered around the well-formed parabolic flood tide delta (see Figure 3-21).
- There are very extensive intertidal flats and subtidal shallows, including (~350 Ha) of sparse ascidian (possibly cunjevoi or *Pyura* sp.) habitat.
- The causeway appears to affect the distribution of sediments within the estuary.
- The main entrance channel has deep "holes" up to 20 m deep formed by strong scouring flows.

3.11.2 Geomorphology and Sediments

Pitt Water is a very large wave dominated estuary of about 43.1 km^2 (4,314 Ha). The Coal River fluvial bay head delta delivers sediments from the Richmond area into the 500 Ha main central basin, which extends to the causeway with the substrate consisting of fine silt. There is a complex system of small secondary basins, and associated intertidal flats and banks, between the bay head delta, formed by the Coal River near Horatio Point, and Railway Point, where the main central basin starts. The very extensive intertidal sand flats surrounding the depositional basins in upper Pitt Water are mostly well-sorted very fine sand, often with 10-20% silt content.

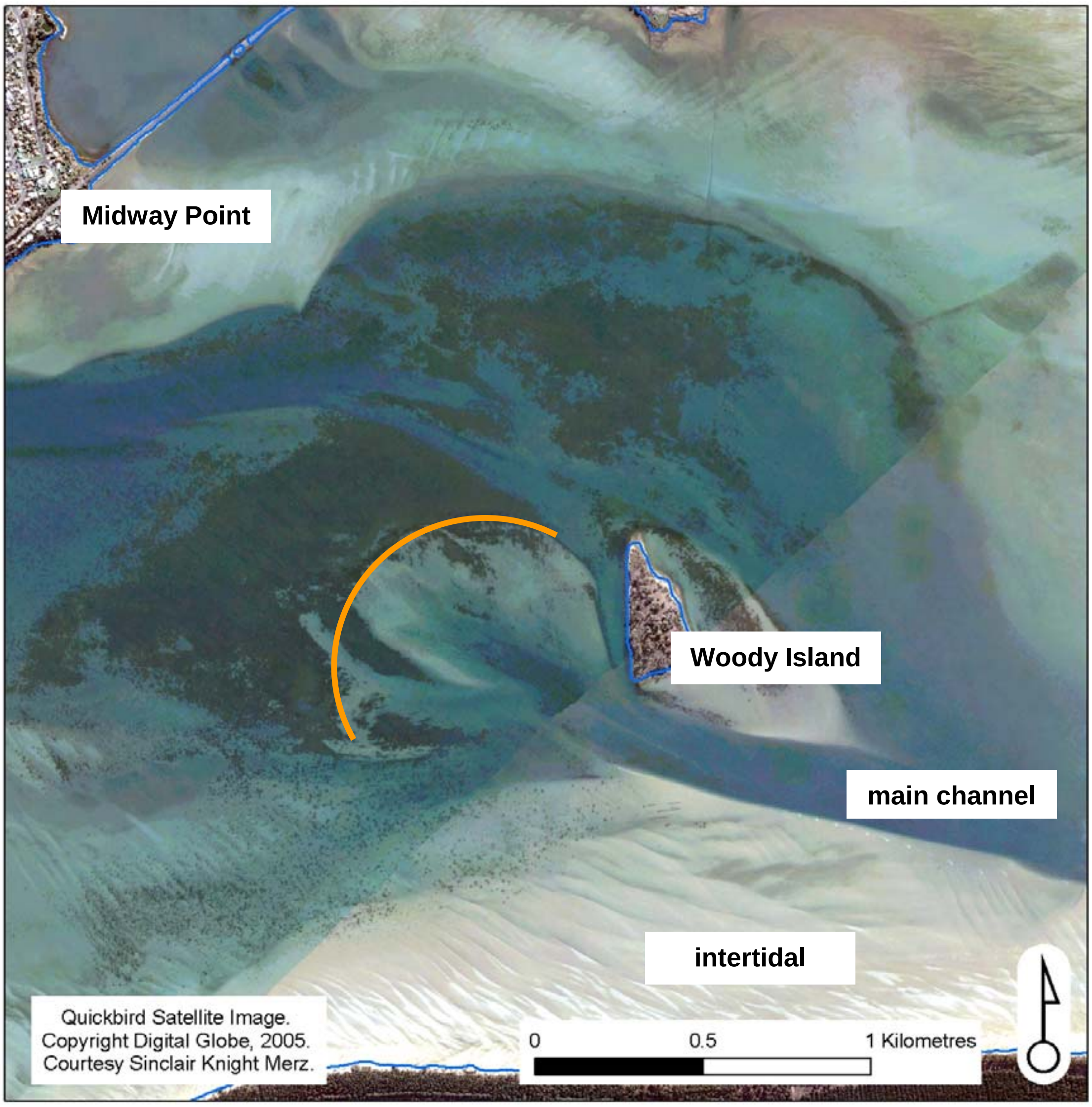

Figure 3-21. The parabolic flood tide delta (marked with a curved line) at the end of the main channel is clearly visible to the west of Woody Island, with dense seagrass beds on its eastern and northern sides. The broad channel to the north of Woody Island also has dense seagrass beds.

The artificial restriction of water flow created by the causeway at the Sorell Bridge ensures a deep channel is maintained with a hard packed sandy bottom. The causeway also influences the distribution of sediments, with fine sands collecting in the areas of low water flow on either side of the causeway away from the bridge. A 12 km long main channel links the large central basin north of the causeway to the ebb tide delta at the mouth of the estuary in Fredrick Henry Bay.

In Lower Pitt Water, the main channel splits around the rocky outcrop of Woody Island. While there is a complex flow of water in Pitt Water, in general terms, the main channel carrying incoming water lies to the south of the island and the main outgoing flow moves to the north and east of Woody Island. There is also a narrow deep ebb tide channel hugging the western side of the island. To the west of Woody

Island, a flood tide delta has formed, where the energy of the incoming tidal flow drops and well sorted fine sand is deposited in a characteristic parabolic shape. The channel has an average width of 450 m and an average depth of 8 m. This pattern is constant with the exception of a 15 to 20 m deep hole off Jones Bay near Lewisham. The very extensive intertidal flats, consisting of well sorted fine sand, extend along the back side of the main barrier forming Five Mile Beach, as well as stretching along the northern and eastern shores of the lower estuary from Midway Point, past Oaks Point and Grassy Point across to Ironstone Creek Bay. These flats and shallows are maintained by the substantial wind waves that form within the large fetches in Pitt Water. Iron Creek Bay is a minor estuarine basin for Iron Creek, and the fluvial inputs from Iron Creek and the tidal flows create a small channel across the large sandy flats along the eastern shore of Pitt Water. The full extent of the ebb tide delta is not clear; however the position of the delta closest to the estuary mouth is clearly influenced by the rocky outcrop of Tiger Head. There are large sandy sediment deposits on the western side of the main channel in this area.

Table 21. Pitt Water geomorphological features (Source: OzEstuaries Database).

Estuary Number	576	**Condition**	Extensively modified
Classification	Wave dominated	**Sub Classification**	Wave dominated estuary
Longitude	147.61221	**Latitude**	-42.8512
Datum	GDA94	**Mean Wave Height (m)**	1.06
Perimeter (km)	80.39	**Max Wave Height (m)**	4.90
Entrance Width (km)	0.56	**Tidal range (m)**	1.20
Water Area (km^2)	42.71	**Tidal period**	Diurnal
IBRA Class	Freycinet	**IMCRA Class**	Bruny
Catchment Area (km^2)	1029	**MDL Code**	SCUBN
Intertidal Flats Area (km^2)	7.76	**Open Water Area (km^2)**	52.41

3.11.3 Circulation and Salinity Profiles

Pitt Water displayed little change in the salinity throughout its extent during the sampling period. The salinity at the mouth was just less than 35 ppt and the salinity remained at similar levels along the 17 km of the system surveyed (see Figure 3-22). Though these data are from a single "snapshot", they are consistent with low freshwater flow rates within the Coal River (NLWRA, 2000). Rainfall over the Pitt Water catchment is the lowest of all the estuaries in the project as is the runoff coefficient (see Table 14), and though the estuary has a large catchment compared to the other estuaries studied; very little water reaches the estuary (NLWRA, 2000).

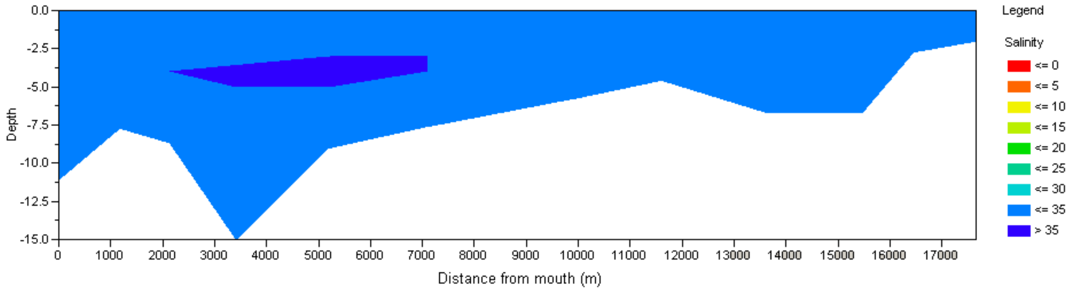

Figure 3-22. Salinity profile of Pitt Water

3.11.4 Seagrass Condition Sampling

Six sites were surveyed in Pitt Water to the east of the causeway (see Figure 6-2), while none were surveyed above the causeway due to the high turbidity of the water making visual assessment difficult. The blade length was relatively consistent at each site, ranging from 10-25cm at Site 4, to 25-35cm at Site 6 (Figure 3-23). The remainder were somewhere in between these two sites. The cover was also relatively consistent, at over 80% at most sites, only Sites 2 and 4 had lower cover, with two sub-sites at Site 2 having less than 60% cover and site four varying from 40-60% cover. The epiphyte loading was low at Sites 1, 4 and 5 and medium to high at the remainder of the sites (Figure 3-23).

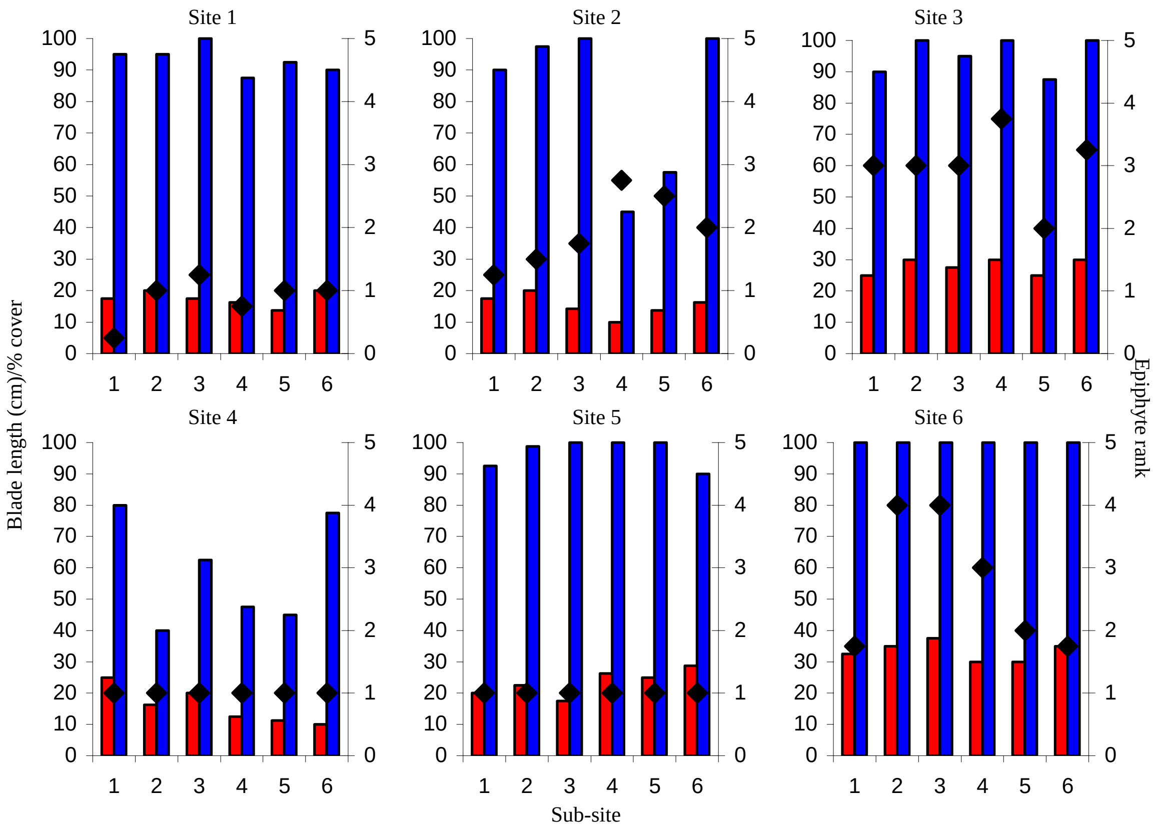

Figure 3-23. Graphs of average seagrass blade length (red bars), average % cover (blue bars) and average epiphyte ranking (black diamonds) for the six sites surveyed in Pitt Water.

3.11.5 Community Types

The seagrass beds of Pitt Water are almost exclusively *Heterozostera tasmanica* and are clustered around the middle part of the lower estuary, where the turbulence and flow rate of water in the main channel eases and the water clarity and nutrient levels are suitable for seagrass growth (Butler and Jernakoff, 1999; Gillanders and Kingsford, 2002). This is particularly evident on and around the flood tide delta, near Woody Island, where a gradient of seagrass density occurs from dense on the crescent shaped delta itself to patchy as distance from the delta increases (see Figure 3-21). There is a major area of dense seagrass habitat in the deeper parts of the broad ebb tide channel to the north and east of the flood tide delta. In contrast, the seagrass beds on the silty sand banks around the upper parts of the central basin in the upper estuary are sparse and patchy.

Across the subtidal shallows around the main channel, there are extensive areas (~350 Ha) of sparse ascidians (possibly cunjevoi or *Pyura* sp.), a filter feeder, and a dark green macroalgae (possibly *Codium fragile*) that, on these substrates, attach to dead bivalve shells. The habitat type appears to occur on more stable well-sorted fine sand flats and shallows, and is interspersed with areas of more mobile fine sand. The seagrass that is present in these areas occurs in small characteristic (almost circular) patches, particularly on the southern side of the flood tide delta (see Figure 3-21) and on the deeper parts of the southern end of the vast eastern shallows, within 300-500 m of the main channel. Similar circular patch formations of seagrass are found immediately adjacent to the eastern side of Woody Island. All these areas are subject to strong tidal currents, though at slightly lesser rates than in the main channel.

As the main channel approaches the estuary mouth, the shoreline becomes rocky on the eastern side with wide sand flats on the west. There are mixed seagrass and macroalgae beds growing on the banks of the main channel throughout the lower estuary and the bottom of the channel is hard packed with scoured sand. Macroalgae is also present on the rocky low profile reefs around Woody and Barren islands and Midway Point.

3.12 Southport Lagoon

3.12.1 Overview and Special Features

Southport Lagoon is protected under the Southport Lagoon Conservation Area proclaimed under the *Nature Conservation Act 1998* on the 30/4/1999. This is unusual for a Tasmanian estuary and greatly increases its conservation significance. A management plan is currently undergoing the public comment period (November 2005). While the Naturalness Index of the estuary and the Conservation Significance are both the highest possible at 1.0 and Class A respectively, there are ongoing concerns with high levels of erosion from the rutted and braided four wheel drive tracks at the southern end of the estuary (see Figure 3-26) and within the Donnellys Creek catchment, near the south-eastern end of the estuary. The lagoon is uniformly shallow with most of the basin averaging 2-3 m and a small area of 4-5 m. The very large areas of shallows and intertidal flats are about 1.5 m and less. The lagoon has low freshwater inputs due to its small catchment (see Table 14) and the waters are marine dominated with a strong tidal flow evidenced by the depth of the main entrance channel. The absence of seagrass in the shallow main central basin is unexpected when compared to other estuaries of this physical type. Instead, the basin has extensive areas of anoxic (anaerobic) sediments with widespread patches of a low-growing macroalgae and some evidence of bacterial mats (possibly *Beggiatoa* sp.). The latter is usually associated with high levels of organic material that is in the process of decomposing.

The majority of the seagrass grows on the very large flood tide delta, particularly fringing the main entrance channel. The seagrass density ranges from dense to sparse patchy. There are also high numbers of filter feeders (ascidians, possibly cunjevoi or *Pyura* sp.) and green macroalgae (*Ulva* sp.) indicating high tidal current flows with sufficient food particles and nutrients to maintain these communities. The unvegetated sediments exhibit exceptionally high levels of bioturbation indicating the infauna is actively reworking these sediments. This is particularly evident in the small northern lobe of the central basin, to the north of the main channel. The lagoon features multiple medium profile reefs spread throughout the main central basin, providing a rich and diverse variety of microhabitats for the communities occurring here.

Special Features

- Very high levels of biological activity in the unconsolidated sediments in the main basin.
- A very large flood tide delta with a variety of seagrass densities and high levels of filter feeders and green macroalgae.
- Isolated reefs spread throughout the estuary.
- A lack of seagrass in the large shallow main basin and a presence of bacterial mats and anoxic sediments.

Figure 3-24. The barrier and main entrance to the northeast across the shallows of Southport Lagoon (23rd September 2005).

3.12.2 Geomorphology and Sediments

Southport Lagoon is a large wave dominated estuary covering about 1070 Ha. Within the estuary there is a strong tidal influence with only minor fresh water inputs from Donnelly's Creek, which is located on the western side of the lagoon. The estuary does not have any fluvial bay head deltas, but is characterised by a very large central basin consisting of shallow (1 to 2 m) permanently submerged poorly mixed anoxic sandy substrates fringing a small (~85 Ha) deeper basin (3 to 4 m). At the time of the field survey, there was an ~5 mm layer of silt and clay of unknown origin overlaying the substrates in many of the large shallow depressions in the floor of the basin. This, in combination with the turbid state of the water in the southwest corner of the estuary, possibly indicates an active source of erosion within the catchment, though the quantity and source of material cannot be estimated from the available data. There is a smaller secondary depositional basin in the north of the lagoon that is surmised to be a part of a larger original basin that has slowly been separated by the encroaching flood tide delta (Woodroffe, 2003). The central basin has several exposed dolerite rock outcrops, including three forested islets and two long thin peninsulas, all with medium profile fringing reefs. There are also several isolated subtidal reefs scattered throughout the central basin. These isolated reefs, particularly on the eastern side of the lagoon, appear to play a role in controlling the deposition of sediments as evidenced by the marked extension of the adjacent sand flat (see Figure 3-27).

Figure 3-25. The small rocky island (unnamed) with fringing medium profile reef off the northern tip of the sharply pointed peninsula (unnamed) on the southern side of Southport Lagoon.

Figure 3-26. Braided and rutted vehicular tracks at the southern end of Southport Lagoon (26th November 2004).

Apart from on the south-western side, broad intertidal flats and an extensive (~170 Ha) flood tide delta surround the main central basins, both consisting of very well sorted fine sand. The flats and shallows are maintained by waves generated by the wind across the long fetches of the estuary. The flood tide delta is extensive, indicating a plentiful supply of sand is driven through the entrance channel by a combination of the incoming tide and southern ocean swells. The main channel links the central basin to the sea through a sinuous 3 km channel that is primarily comprised of hard shelly substrate. The channel bends sharply around a stable vegetated sediment island before flowing out to the sea through the narrow heads created by the lagoon's sediment barrier. The small 10 Ha ebb tide delta extends 500 m past the end of the main channel, with its size maintained by the swells. The flood tide delta forms the Southport Lagoon barway. The very large estuarine barrier forms most of the southeastern side of the lagoon and the seaward side is known as Big Lagoon Beach.

Figure 3-27. The sand flat extension to the isolated reef in the southeastern side of Southport Lagoon (Source: ILS, DPIWE, aerial photo 1123-2).

Table 22. Southport Lagoon geomorphological features (Source: OzEstuaries Database).

Estuary Number	585	**Condition**	Near pristine
Classification	Wave Dominated	**Sub Classification**	Wave Dominated Estuary
Longitude	146.98	**Latitude**	-43.489
Datum	GDA 94	**Mean Wave Height (m)**	1.06
Perimeter (km)	20.93	**Max Wave Height (m)**	4.05
Entrance Width (km)	0.24	**Tidal range (m)**	1.20
Water Area (km^2)	10.03	**Tidal period**	Diurnal
IBRA Class	D'Entrecasteaux	**IMCRA Class**	Davey
Catchment Area (km^2)	43	**MDL Code**	SCUBN
Intertidal Flats Area(km^2)	.72	**Open Water Area (km^2)**	10.18

3.12.3 Circulation and Salinity Profiles

At the time of sampling, the water in Southport Lagoon was generally marine influenced throughout its extent with the salinity generally not dropping below 35ppt. The inflowing seawater dominated the majority of the lagoon, with only a small influence apparent from the streams flowing in at the top of the lagoon (Figure 3-28). These findings are consistent with rainfall and runoff data presented in Table 14. The lagoon is in a moderately high rainfall area (average annual rainfall is 1,215 mm) and it also has a moderate runoff coefficient, however the small size of its catchment means there is relatively little freshwater input.

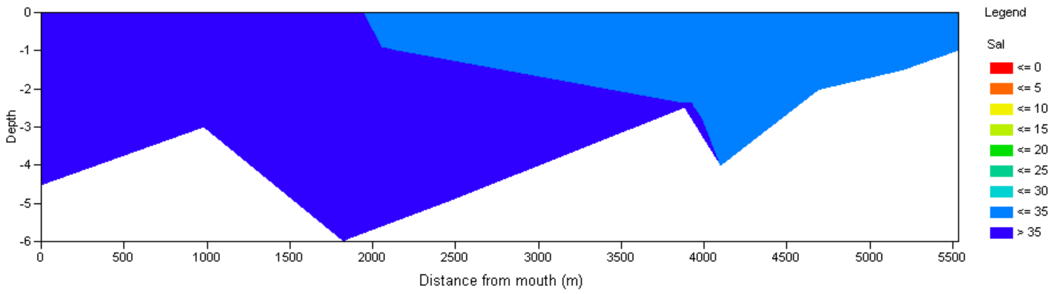

Figure 3-28. Salinity profile of Southport Lagoon

3.12.4 Community Types

The main basin of the lagoon is mainly characterised by unconsolidated sediments. This area exhibits active benthic bioturbation, indicating high levels of benthic infaunal biological activity and also has regions of scattered ascidians (possibly cunjevoi or *Pyura* sp., a filter feeder) and macroalgae. The small northern lobe of the main basin (off the main channel) is very shallow and had some of the largest bioturbation mounds. Extensive beds of macroalgae covered much of the unconsolidated sediments on the bottom of the main basin. Interpretation of historic archival aerial photography indicates that the extent of these algal beds rapidly fluctuate through time. The sediments largely consisted of ~30% fine silt and sulphurous smelling (anoxic) sediment and the rest as broken shells of molluscs. In some locations there appeared to be large areas of bacterial mats (possibly *Beggiatoa* spp.) covering the surface. These bacteria live at the interface between hypoxic water and hydrogen sulphide-rich, anoxic sediments (MacLeod *et al*., 2004). Their presence indicates a rich source of organic material, which, in this case, is possibly decomposing macroalgae The small isolated reefs scattered throughout the main basin and the fringing medium profile reefs have dense patches of macroalgae.

There are extensive areas of seagrass (either *Zostera muelleri* or *Heterozostera tasmanica*) on the very large flood tide delta and shallow sand banks that dominate the eastern and northern sides of the lagoon, particularly around the main channel and along the edges of the flood tide delta adjacent to the main central basin. In terms of their density, these seagrass beds range from dense through to patchy and very sparse. There are a large number of macroinvertebrates filter feeders, such as ascidians (possibly cunjevoi or *Pyura* sp.), associated with the seagrass and moderate to high levels of green macroalgae, such as *Ulva* sp.. Both of these latter species indicate the presence of a good supply of nutrient and particulate food, usually associated with regular and strong tidal currents. The sinuous and branched main channel is lined with a hard shelly bottom and banks, indicating both high levels of biological activity and a strong tidal current. The banks fringing the channel are typically covered in seagrass and, where flora is present on the channel floor, by a mixture of seagrass and macroalgae. Both *Zostera* and *Heterozostera* are known to be active colonisers and it is not unusual for the extent and density of these species to vary considerably from year to year, and decade to decade, for reasons that are not yet clear. The limiting factors on the development of seagrass beds in the main basin may be a combination of light and temperature, as nutrients don't appear to be limiting, as evidenced by the dense macroalgae beds (Dennison, 1987; Dennison *et al.*, 1993). Limits to light availability could perhaps be due to low levels of water clarity, possibly caused by high levels of CDOM (tannins) and/or suspended sediments (turbidity)(Dennison and Abal, 1999). The temperatures could also be elevated by these same factors in combination with solar absorption in the broad areas of the Southport Lagoon shallows during summer, though the effect of this on the distribution of seagrass can only be surmised. It is also not possible to draw conclusions about the reason for the anoxic sediments found throughout the main central basin.

Please note that while there are large amounts of seagrass in Southport Lagoon, access difficulties curtailed a thorough sampling effort. The observations made during the field visit with the bathyscope and one set of quadrat samples obtained on the flood tide delta support the assertion that the seagrass is occurring in very high densities in places and with high abundances of ascidians (possibly cunjevoi or *Pyura* sp.) and sea lettuce (*Ulva* sp.) present.

3.13 Great Oyster Bay

3.13.1 Background and summary

Great Oyster Bay falls within the Freycinet Bioregion on the east coast of Tasmania. It forms a boundary with the Bruny Bioregion to the south at Hellfire Bluff and the southern tip of Maria Island. This southern boundary of the Freycinet Bioregion is essentially determined by the average position of the interface between warm East Australian Current waters and colder sub Antarctic waters. As this southern interface is somewhat variable in position through time, there is a degree of overlap in biota between the northern end of the Bruny Bioregion and the southern end of the Freycinet Bioregion. The area within the mapped zone of Great Oyster Bay for this study comprised of 1055 km^2 of seabed. The total area mapped was 662 km^2 of seabed, which comprised 62% of the total area, most of which, is inside the 20 m depth contour. The unmapped area was 38% (or 393 km^2 of the Bay, mainly outside the 20 m depth contour). This area was not mapped because of the inaccessibility of the open water by small craft.

In terms of exposure, the majority of the coastline from Lords Bluff to Seaford Point is subject to easterly weather systems and swells, at which times the rest of Great Oyster Bay is being sheltered by Freycinet Peninsula. The remainder of Great Oyster Bay is subject to southerly and south easterly swells. However, the very large fetches within the bay allow the rapid build up of wind driven waves.

Prior to this study little was known about the distribution of marine habitats within Great Oyster Bay. Some studies of the seagrass beds within small embayments off Coles Bay have been completed by Moltschaniwskyj *et al*. (2003) and Rees (1993), and of habitat associations with key inshore fish species (Jordan *et al*., 1998). Other mapping has been completed at a very course scale (Edyvane *et al*., 2000), which was initiated by Hugh Kirkman from CSIRO as part of a larger survey of Tasmanian coastal water. 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, which is the lower limit of surface visibility in most Tasmanian waters. 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.

Many small bays make up the coastline including the two major estuaries of Little Swanport and Great Swanport and the lagoons; Bryans Lagoon and Lisdillon Lagoon. All have now been mapped as part of this study except for Lisdillon Lagoon.

3.13.2 Habitat descriptions

3.13.2.1 Habitat area calculations

The following table (Table 23) summarises the major classes mapped within Great Oyster Bay by depth using GIS and the habitat mapping data.

Table 23. Summary of habitat type area (km^2) by depth class (m) for Great Oyster Bay from mean sea level to the seaward depth of 50 m.

Depth Class	Reef	Sand	Hard Sand	Seagrass	Patchy Seagrass	Sparse Patchy Seagrass	Total
0-5 m	5.7	16.6	0.0	0.2	0.1	0	**22.6**
5-10 m	5.7	38.3	0.0	0.2	4.3	0.6	**49.1**
10-15 m	5.0	38.2	0.0	0.4	4.1	0.7	**71.6**
15-20 m	4.8	35.1	0.0	0	0.3	0	**40.2**
20-25 m	3.2	37.6	0.2	0	0.1	0	**41.1**
25-30 m	3.3	9.8	1.5	0	0	0	**81.3**
30-35 m	3.8	12.5	8.4	0	0	0	**24.7**
> 35 m	31	385.3	105.9	0	0	0	**422.1**
Total	**62.3**	**563.4**	**116.1**	**0.8**	**8.9**	**1.3**	**752.7**

It is noted that the relative proportion of reef to sedimentary substrates within Great Oyster Bay is small, given that most reefs within the region are coastal fringe reefs except for one large reef system to the south east of Schouten Island.

Reef is distributed quite evenly between the depth strata from 0-35 m at the given intervals. Sand comprises 78% of the area within the 5-10 m habitat zone and unconsolidated habitats in general dominate the habitat types for most of Great Oyster Bay. Seagrass (although patchy) is still found in depths up to 20-25 m in Promise Bay. These habitats are described in further detail in the following section.

3.13.2.2 Reef

Approximately 62 km^2 of reef was mapped in Great Oyster Bay and south to Cape Bougainville, including around Ile de Phoques. Great Oyster Bay itself contains a large amount of fringing reef, with more extensive reef systems to the south of Little Swanport and Schouten Island. The reef south of little Swanport generally runs off all the major headlands, including Cape Bougainville, Grindstone Point, Barwell Point, Point Bailey and Seaford Point, as well as patches of offshore reef off Bolton's Beach and Cape Bougainville. Much of this reef extends to depths between 20 and 30 m depth and some over 1.5 km from the coast.

North of Little Swanport the reef is less comprehensive, with mainly fringing reef extending 10-15 m depth and generally less than 250 m from the shore. Near Swansea there is an extensive area of low profile cobble bottom. This entire western shoreline is dominated by dolerite geology, which contrasts with the opposite side of the bay where the granite of the Freycinet Peninsula dominates. No reef was observed along the length of Nine Miles Beach.

From Coles Bay to Promise Bay the reef was characteristically fringing granite reef. The majority quickly dropped off to sand by a maximum depth of around 15 m and rarely reached further than 200 m from the shore. South of Promise Bay the reef became a mix of granite, sandstone and dolerite. Extensive areas of reef were mapped to the west and south of Schouten Island and much of this reef extended to 40 m plus depth and up to 2.2 km from the shore. Large patches of low flat reef were mapped in a broad band extending from the south west of Schouten Island, past Ile de Phoques and towards the northern tip of Maria Island.

The distribution of algal communities supported on this reef were structured by a combination of depth and exposure. The reefs south of Little Swanport and Schouten Island, which had the highest exposures in the region, were characterised by a gradation of algal species along the depth gradient. In the most exposed areas bull kelp (*Durvillaea potatorum*) was present in the first 1-2 m of the reef. Below this cray weed (*Phyllospora comosa*) became the dominant algae. This species generally extended to 10-15 m depth, where the kelp *Ecklonia radiata* gradually replaced it. This species was then found down to a depth where light became limiting and it was replaced by a combination of mixed red algae and occasional sponges. This was generally in depths greater than 30 m.

Further into Great Oyster Bay the exposure levels were lower and the water clarity was also noticeably reduced. This resulted in a change in the depth distribution of the algae, with the *Durvillaea* dropping out and *Phyllospora* becoming the dominant algae in the shallow waters. Often the reef was not deep enough for the full transition to *Ecklonia*, so the outer margins were a mix of *Phyllospora* and *Ecklonia*. Further into the bay, around Swansea and Coles Bay algae such as *Caulocyctis uvifera*, and *Cystophera sp.*, the occasional *Sargussum sp.*, mixed reds and occasional *Caulerpa* sp. formed the dominant algae community. These algae are generally indicative of waters with low wave exposure. This mix of algae was also present around the Coles Bay to Promise Bay region.

South of Promise Bay the algae community shifted back to *Phyllospora* and *Ecklonia* mix similar to the opposite shoreline around Little Swanport. The *Phyllospora* dominated the first few meters with a mix of this and *Ecklonia* to the reef edge. Further south on Schouten Island the depth of the Phyllospora gradually increased with the increasing exposure. *Ecklonia* and a mix of reds and occasional *Caulerpa* were present on the deeper parts of the reef. Around the southern side of Schouten Island small amounts of *Durvillaea* were observed in the shallow depths, below this were *Phyllospora* and *Ecklonia*. In the deeper parts of the reef in greater than 25 m mixed red algae and *Ecklonia* became the dominant algae species. The large areas of reef between the northern tip of Maria Island, Ile de Phoques and Schouten Island were dominated by *Ecklonia radiata* and mixed red algae in the shallower portions, with sponges becoming dominant in depths greater than 40 m.

The introduced algae *Undaria pinnitifida* was noted around the boat ramp at Swansea and an isolated specimen was found on Bryans Beach. It is also known to be present just to the south of the area mapped at Lords Bluff. This species has the potential to establish in areas of reef, especially where the native algae have been removed either due to grazing pressure or storm events.

3.13.2.3 Unconsolidated Vegetated Habitats

Unconsolidated vegetated habitats were present in Great Oyster Bay from Little Swanport around to Schouten Island; though none of this habitat type was present south of Little Swanport or Schouten Island. These unconsolidated vegetated habitats consisted mainly of seagrass beds, with two species present, *Heterozostera tasmanica* and *Amphibolis australis*. Combined, these comprised approximately 11 km^2 of seafloor. The majority of this area consisted of sparse *Heterozostera*, which occurred along the eastern shore of Great Oyster Bay between Schouten Island and Coles Bay. Sparse seagrass occurred in a band between the 5 and 15 m contours to the north of Sand Spit point on Schouten Island, off Bryans Beach and throughout Promise Bay. Further into Great Oyster Bay, the maximum depth at which this seagrass occurred was reduced, such that in Coles Bay, the seagrass only extended to approximately 11 m depth. Much of this sparse seagrass had extensive epiphyte and associated algal cover and in some circumstances this was more dominant than the seagrass.

Small dense beds of *Heterozostera* were observed off Gravelly Beach, Cooks Beach, fringing some of the shore in Promise Bay, in Coles Bay, and a few small patches south of Swansea. These dense beds were generally small and were shallower than much of the sparse seagrass. There were also several beds of *Amphibolis* present in this region. The major beds occurred in Promise Bay and off Piermont to the south of

Swansea. These beds are known to be an important spawning habitat for the southern calamari (*Sepioteuthis australis*).

3.13.2.4 Unconsolidated Unvegetated Habitats

The unconsolidated unvegetated habitats of Great Oyster Bay and south to Maria Island consisted mainly of sands and hard sands. Approximately 589 km^2 of unconsolidated unvegetated habitat was mapped. The shallow waters were dominated by sand, with the deeper waters south of Schouten Island and around Ile de Phoques with a mixture of sand and hard sand. The hard sand in this area consisted of a mixture of rippled sand and shell material.

Other surveys in the Great Oyster Bay area have identified scallop bed in several locations throughout the bay (Lyle and Morton, 2005). These beds include both the commercial scallop (*Pecten fumatus*) and the queen scallop (*Equichlamys bifrons*). The introduced New Zealand screwshell (*Maoriculpus roseus*) is also present in varying numbers throughout the soft sediment habitats of this region (Probst, 2005, unpublished data). This species is now commonly found on soft sediment habitats from Bass Strait and throughout eastern and southern Tasmania.

4. Map Series

4.1 Map Legend and definitions

Table 1. Map Legend and definitions of substrate types and habitat categories used in this study-

Reef
Reef The term "reef" applied to any consolidated substrate, though typically consists of rocky outcroppings. It may be of any profile or rugosity.
Medium profile reef The term medium relief referred to areas where the bottom was hard bedrock and the relief changed regularly. Changes in depth are usually from 1-4 m over short distances.
Low profile reef This definition referred to hard bedrock bottom type when there was very little change in the relief. This category occasionally overlapped with the patchy reef and hard sand categories.
Cobble This definition referred to a hard bottom type consisting of small rocks. This category was usually found in the main channel areas with high flow rates, either tidal or fluvial and occasionally overlapped with the hard sand categories.
Unconsolidated Substrates
Hard sand Hard sand referred to unconsolidated substrates containing elements that cause the signal to appear either harder and rougher than would be expected from that substrate, due to firmly compacted sand, large grain size, shell matter (either whole shells or shell grit) or biological material. Generally, hard sand was found in the bottoms of the main channels.
Sand Sand was the most commonly encountered unconsolidated substrate. Sand was common on the flood and ebb tide deltas and the intertidal flats and subtidal shallows. It represents the coarser end of a scale of sediments from silt to sand, though was mostly found to be fine sand.
Silty sand Silty sand was most common in the main central basins. Broadly, silty sand is either sand with more than 20% silt or silt with more than 20% sand.
Silt Silt substrate was only found in the deepest and largest central basins. This habitat category represents the finest unconsolidated substrate.

Vegetated unconsolidated substrate

Vegetated

This category covers all the vegetated areas that are either unclear as to their species or community assemblage, or are vegetation that is not being mapped for this project. Almost all of the "vegetated" category mapped for this project consisted of saltmarsh.

Seagrass

The "seagrass" category referred to the "dense" areas of seagrass where the substrate, usually sand, was completely covered by seagrass and the patch size is greater than 20 m wide. Note, however, the division of the seagrass areas by density was indicative only.

The dominant seagrass type mapped in the estuaries was *Heterozostera tasmanica*. Another common species, *Zostera muelleri*, often occurred in conjunction with *Heterozostera*, though it is difficult to distinguish these species without microscopic inspection. The main functional difference is that only *Zostera muelleri* can survive regular exposure to the air by the tide. In waters subject to freshwater influence the seagrass species *Ruppia megacarpa* was often present. The habitat mapping presented here, details the extent of the larger beds of these species.

Patchy seagrass

"Patchy seagrass" represented areas where the patch size of "seagrass" (i.e., "dense seagrass") varied from less than 1 m up to 20 m in width.

Sparse seagrass

In "sparse seagrass" areas, the substrate beneath the seagrass was easily visible, often consisting of more than 50% of the field of view within a reference area 1 m^2, such as that formed by a quadrat.

This category usually applied to seagrass that occurred in waters that are either in the intertidal zone (and thus exposed at low tide to the desiccating effect of the air and/or browsing) or in areas of high water flow rates and turbulence. While the density of the shoots of the seagrass was low, the beds could cover extensive areas.

Sparse patchy seagrass

Similar to "patchy seagrass", the definition "sparse patchy seagrass" represented areas where the patch size of sparse seagrass varied from less than 1 m up to 20 m in width.

Macroalgae

This category refers mainly to the areas of low growing macroalgae occurring on unconsolidated substrates, especially in Southport Lagoon and Cloudy Bay Lagoon.

4.2 The Southern Estuaries map series

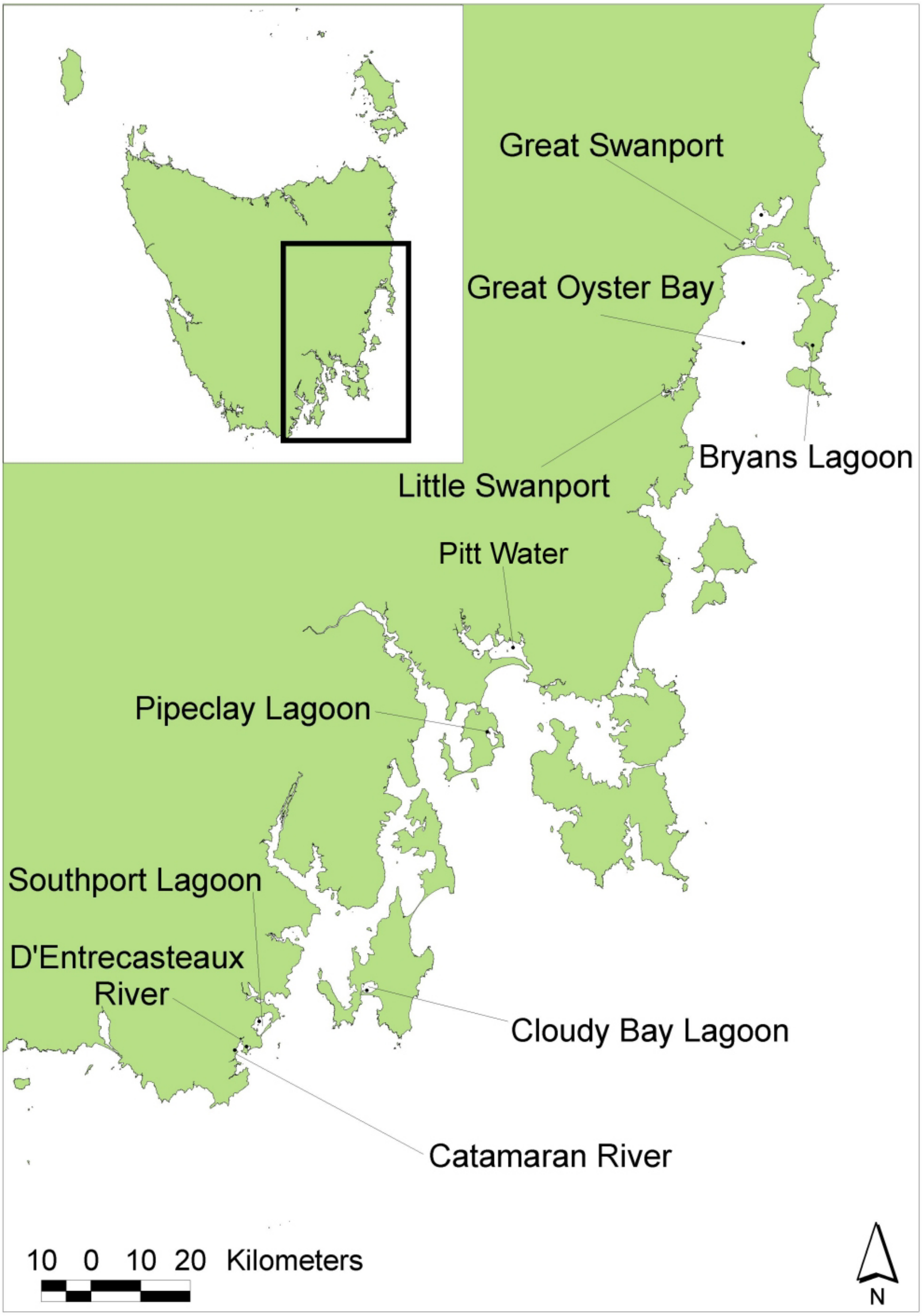

Figure 4-1. Overview of the estuary and marine area locations across south-eastern Tasmania.

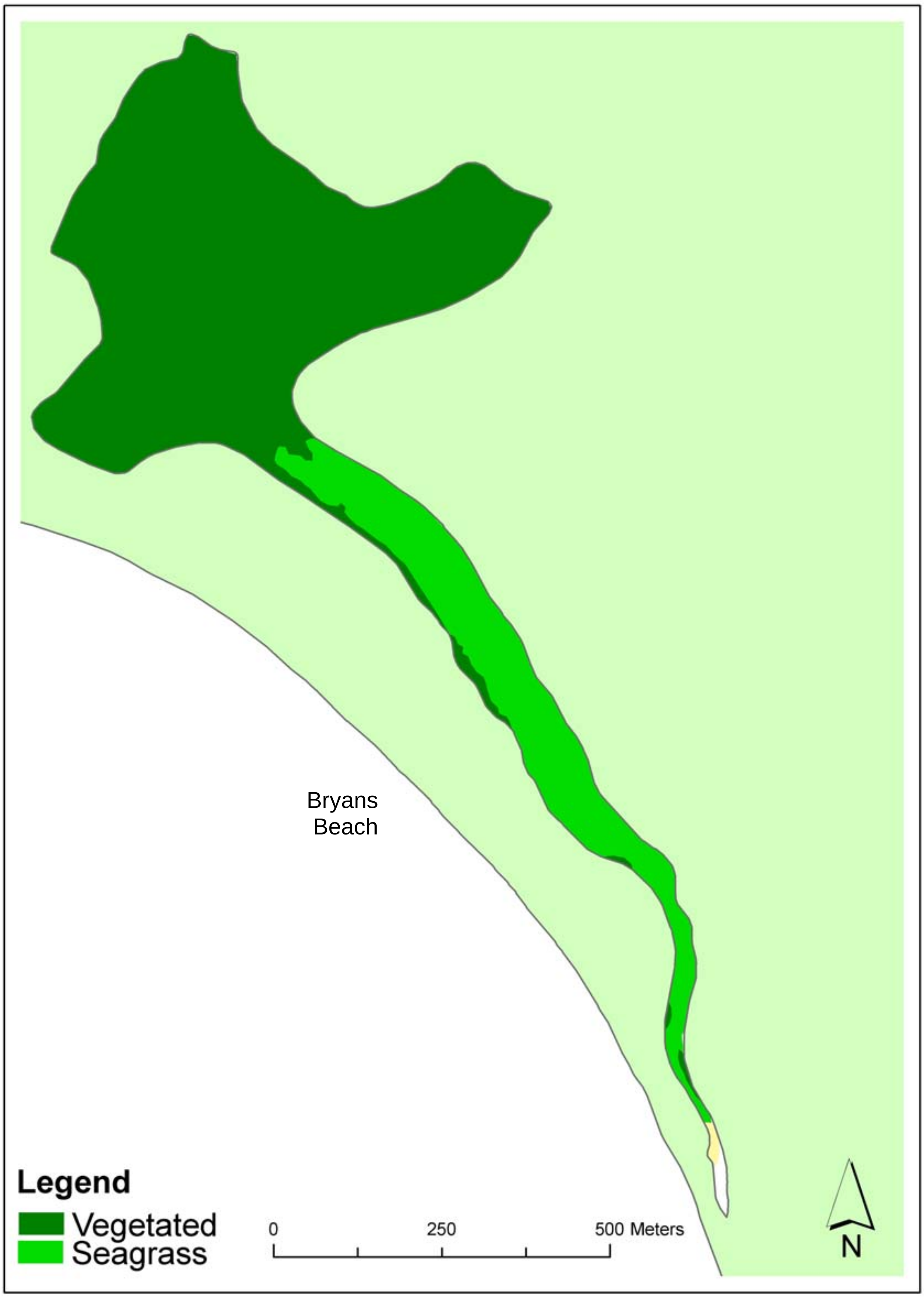

Figure 4-2. Bryans Lagoon habitat map.

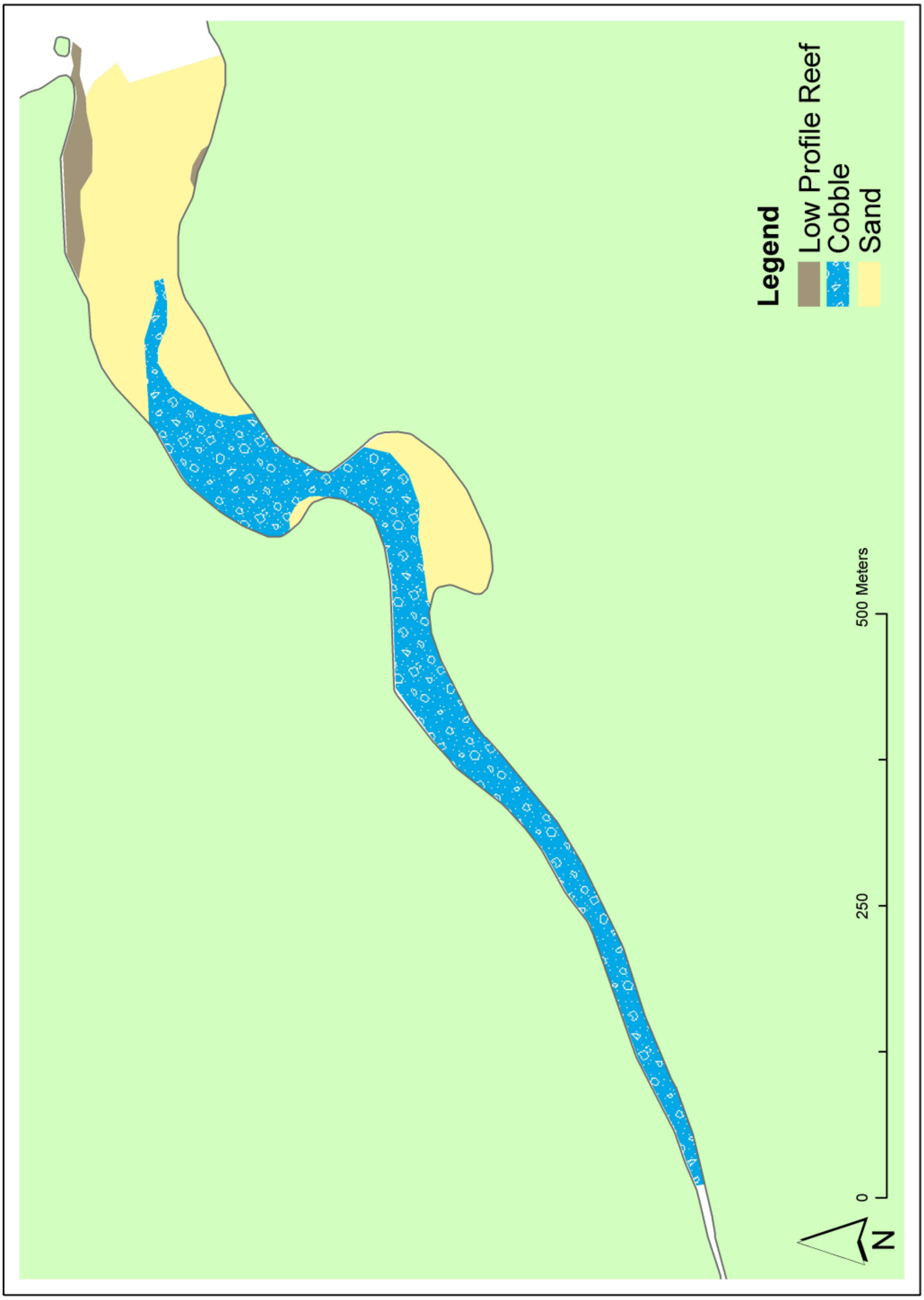

Figure 4-3. Catamaran River estuary habitat map.

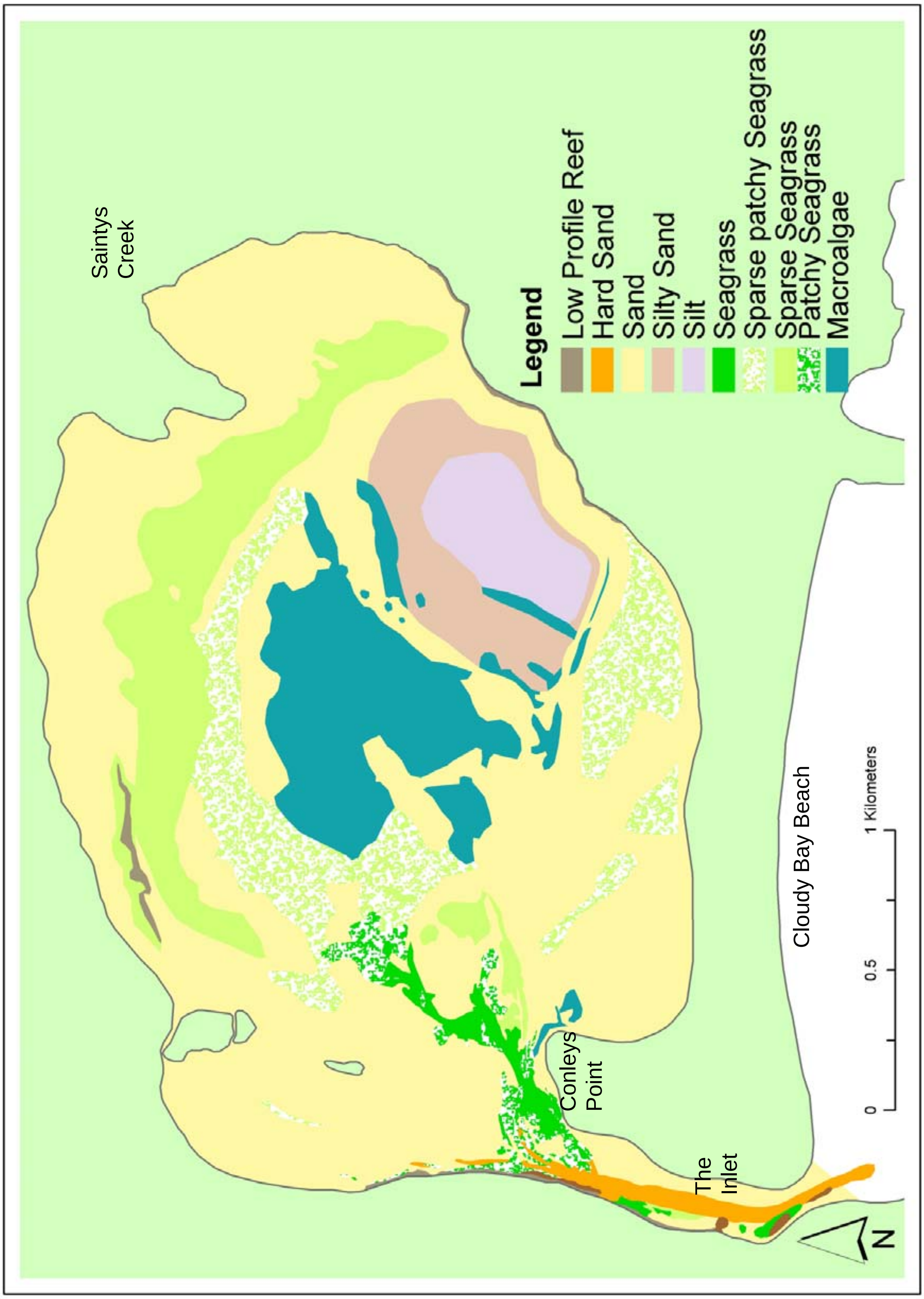

Figure 4-4. Cloudy Bay Lagoon habitat map

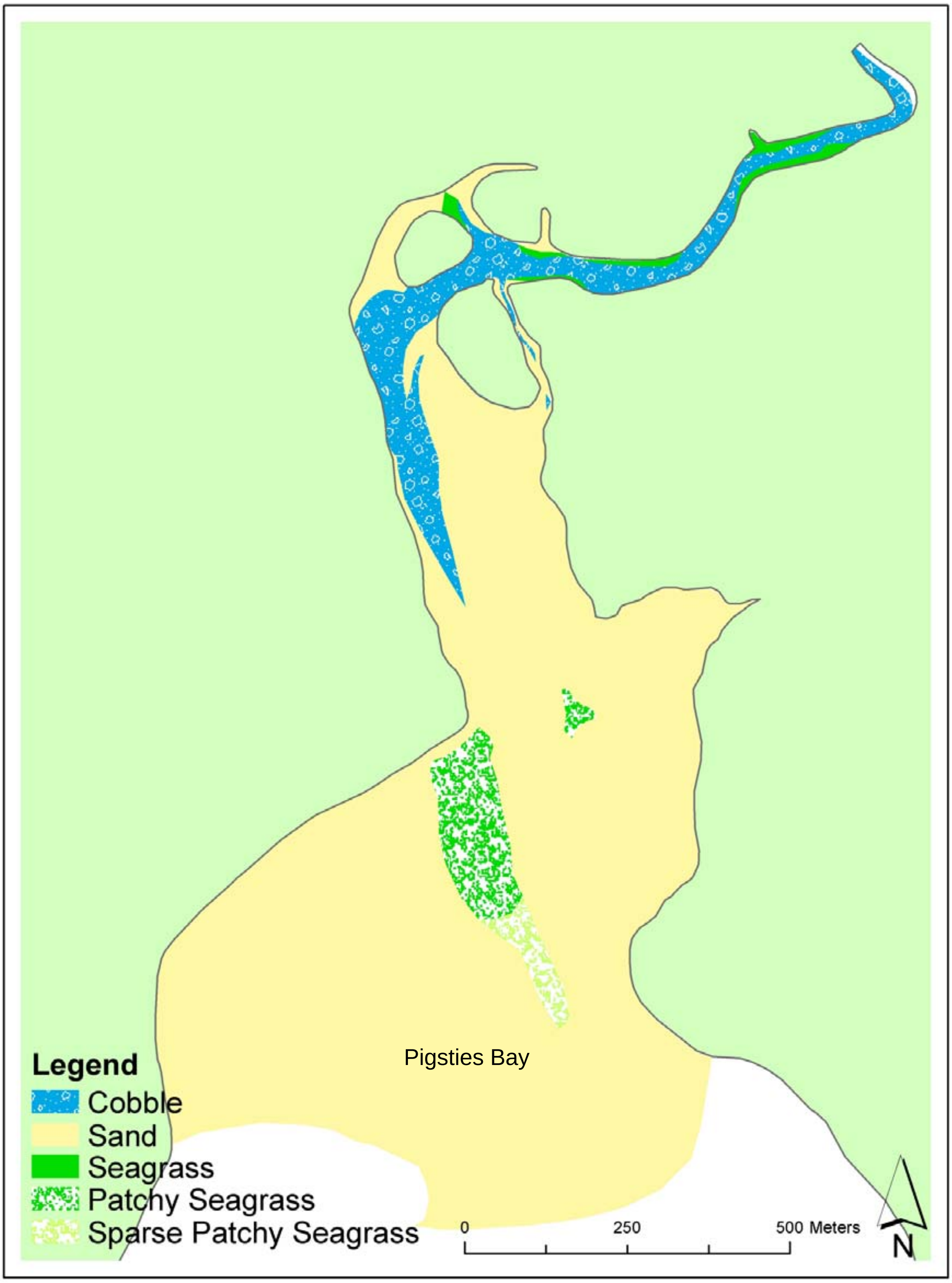

Figure 4-5. D'Entrecasteaux River estuary habitat map.

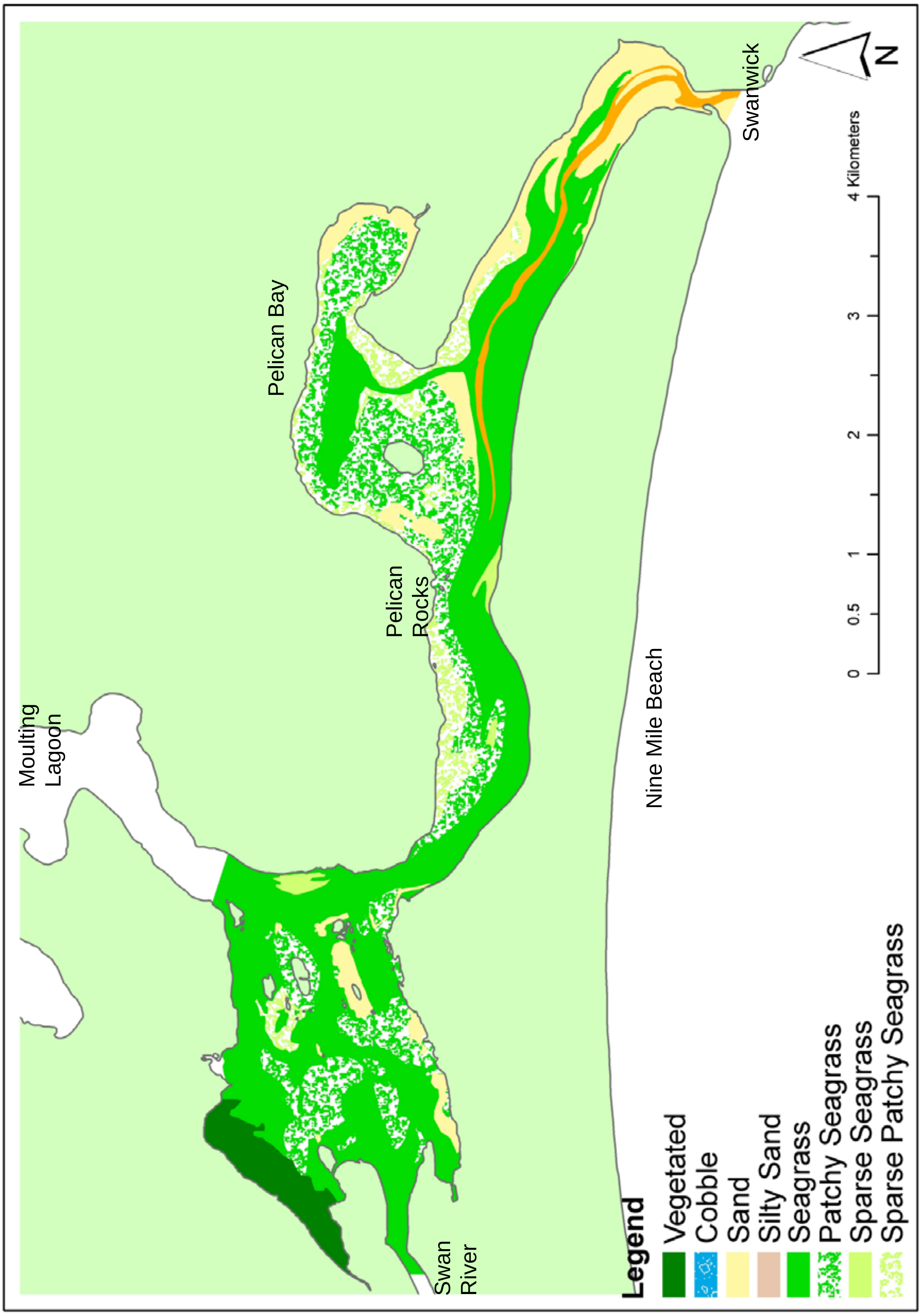

Figure 4-6. Great Swanport habitat map.

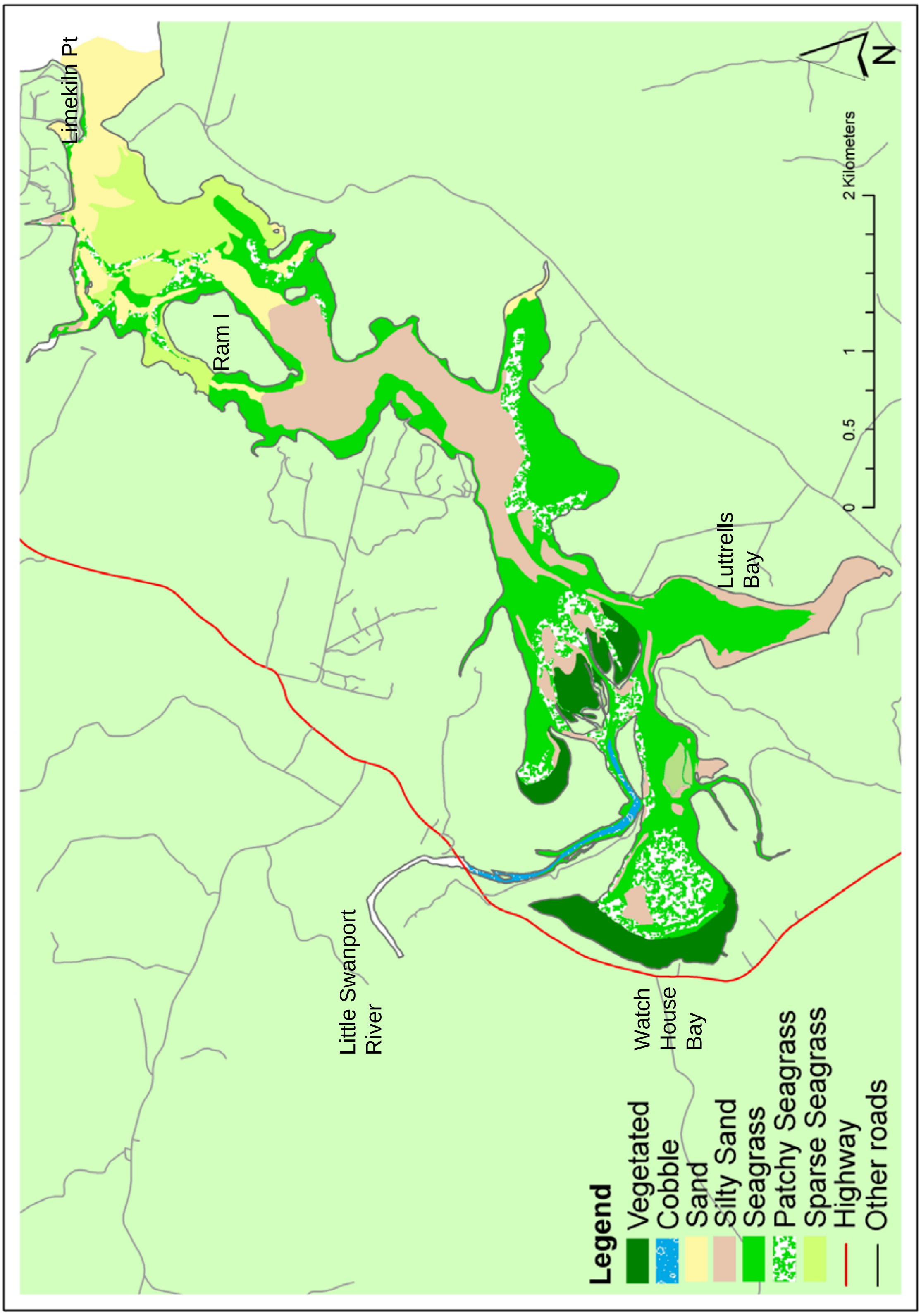

Figure 4-7. Little Swanport habitat map.

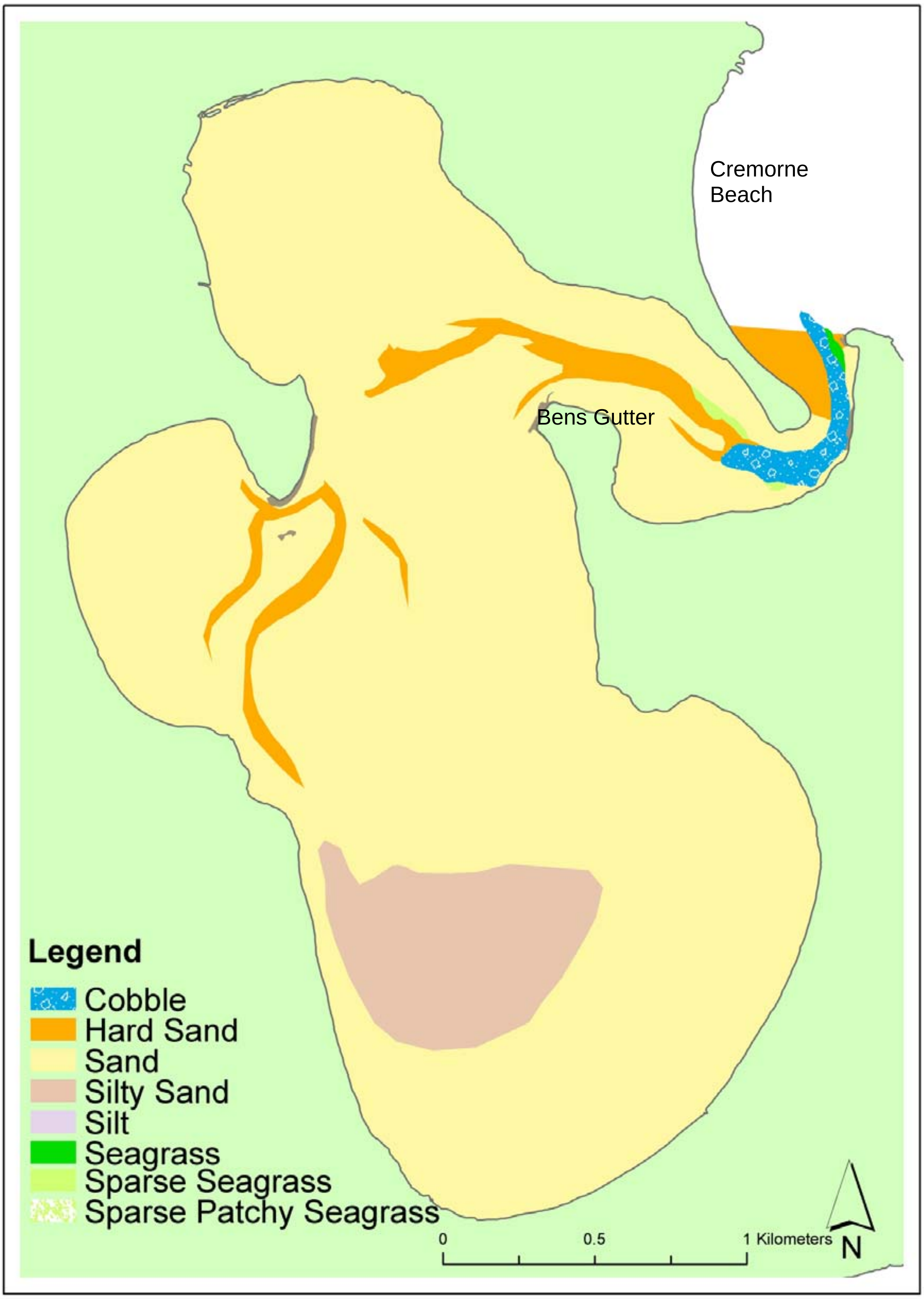

Figure 4-8. Pipeclay Lagoon habitat map.

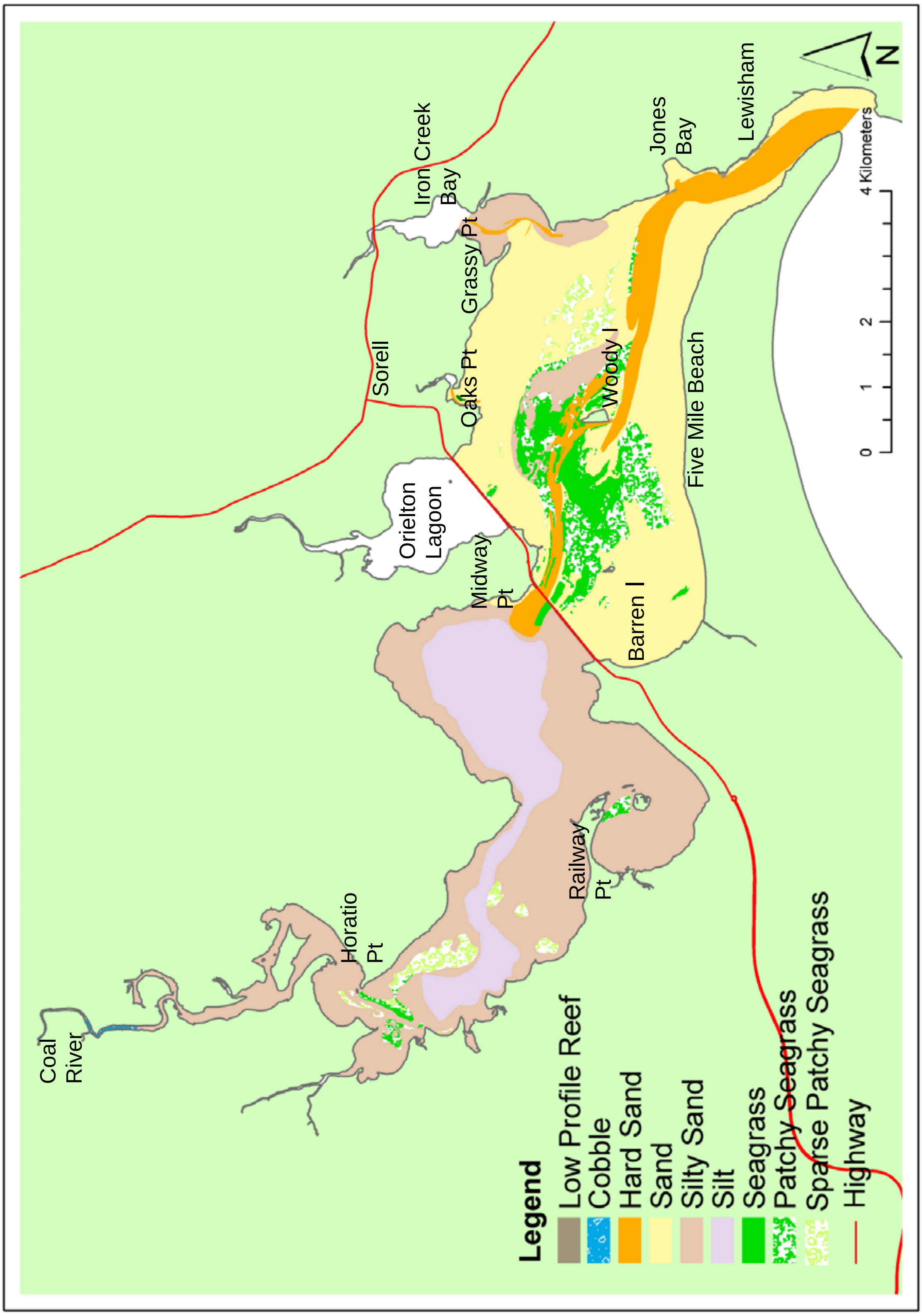

Figure 4-9. Pitt Water habitat map.

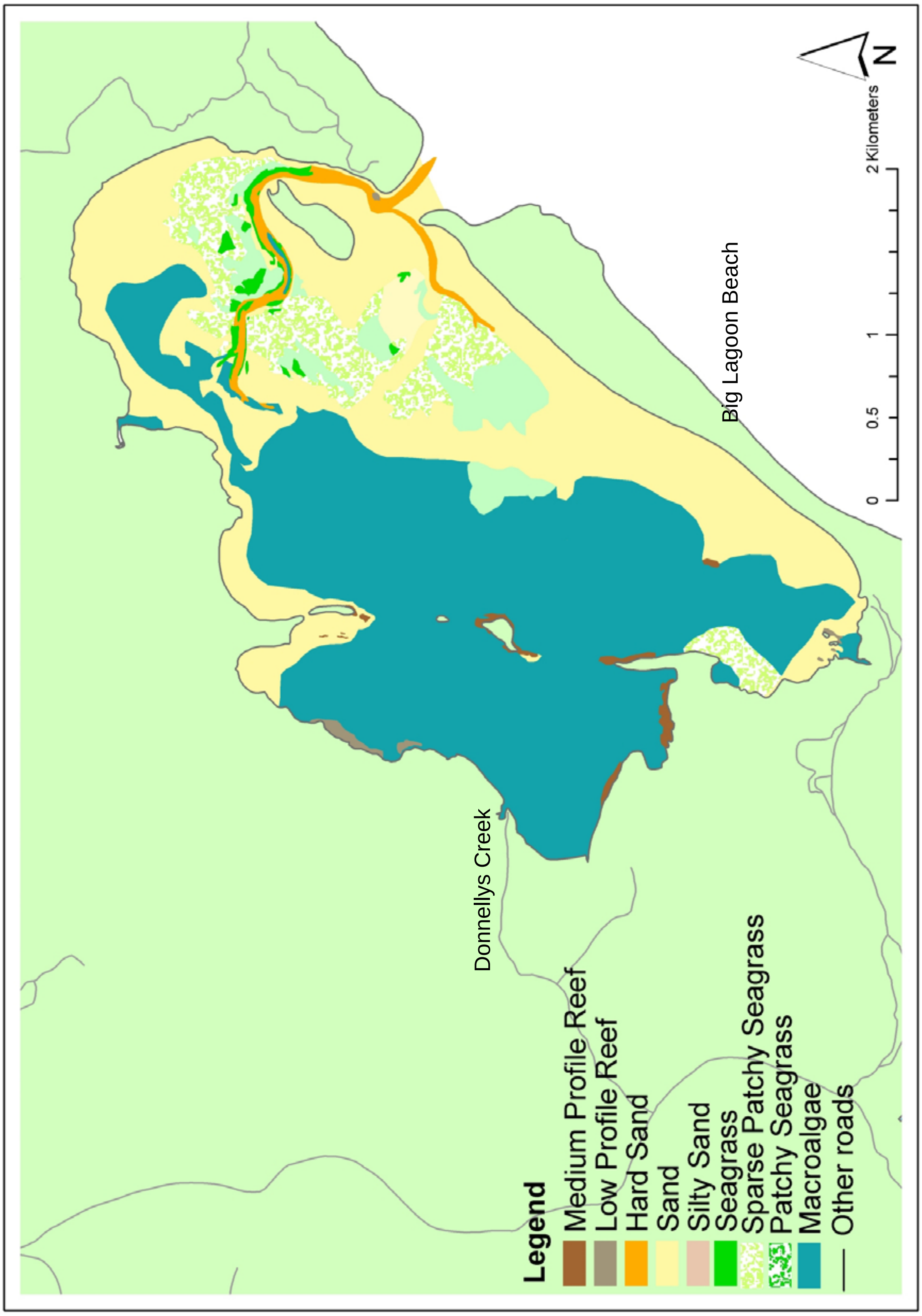

Figure 4-10. Southport Lagoon habitat map.

4.3 The Great Oyster Bay map series

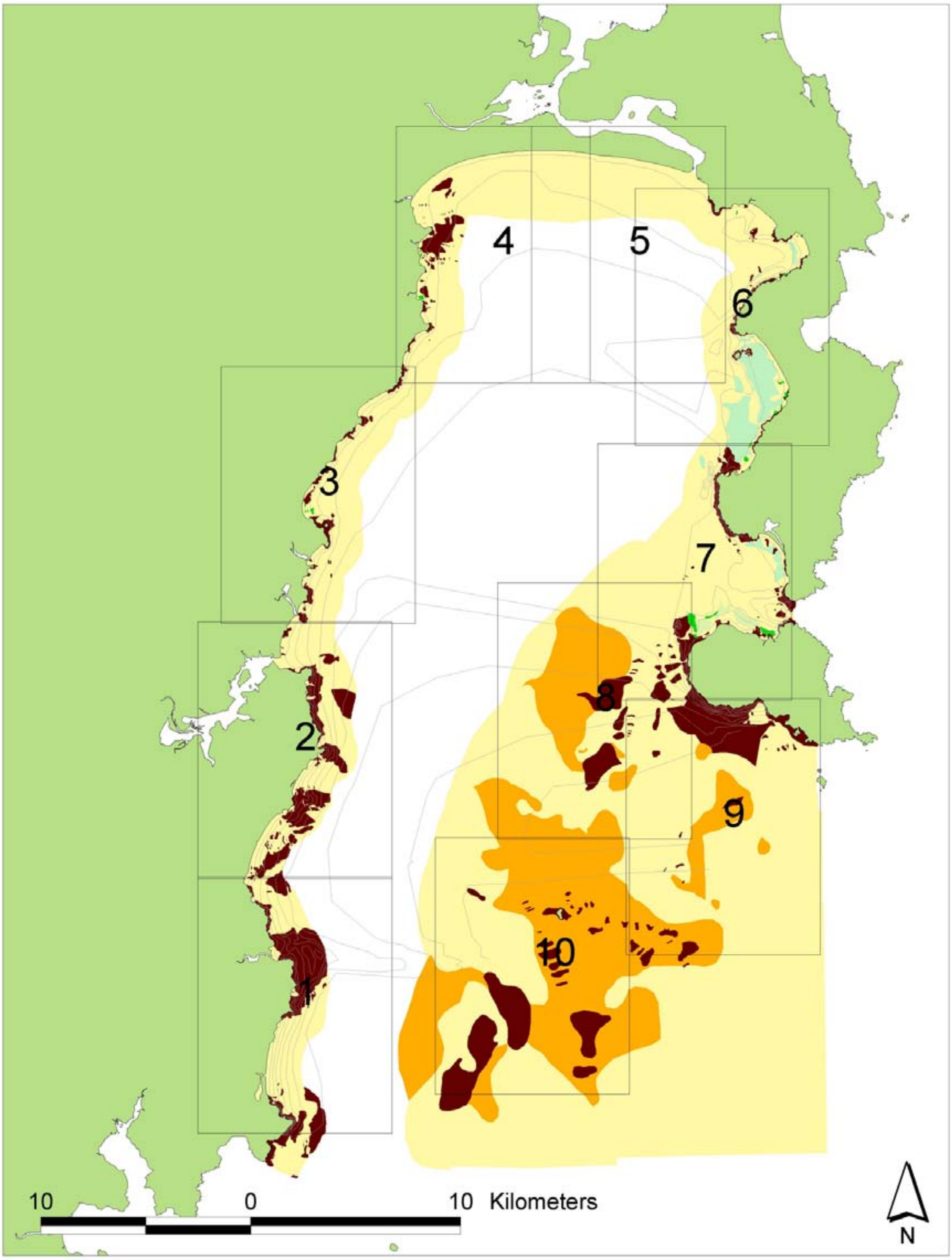

Figure 4-11. Index map to the Great Oyster Bay map series.

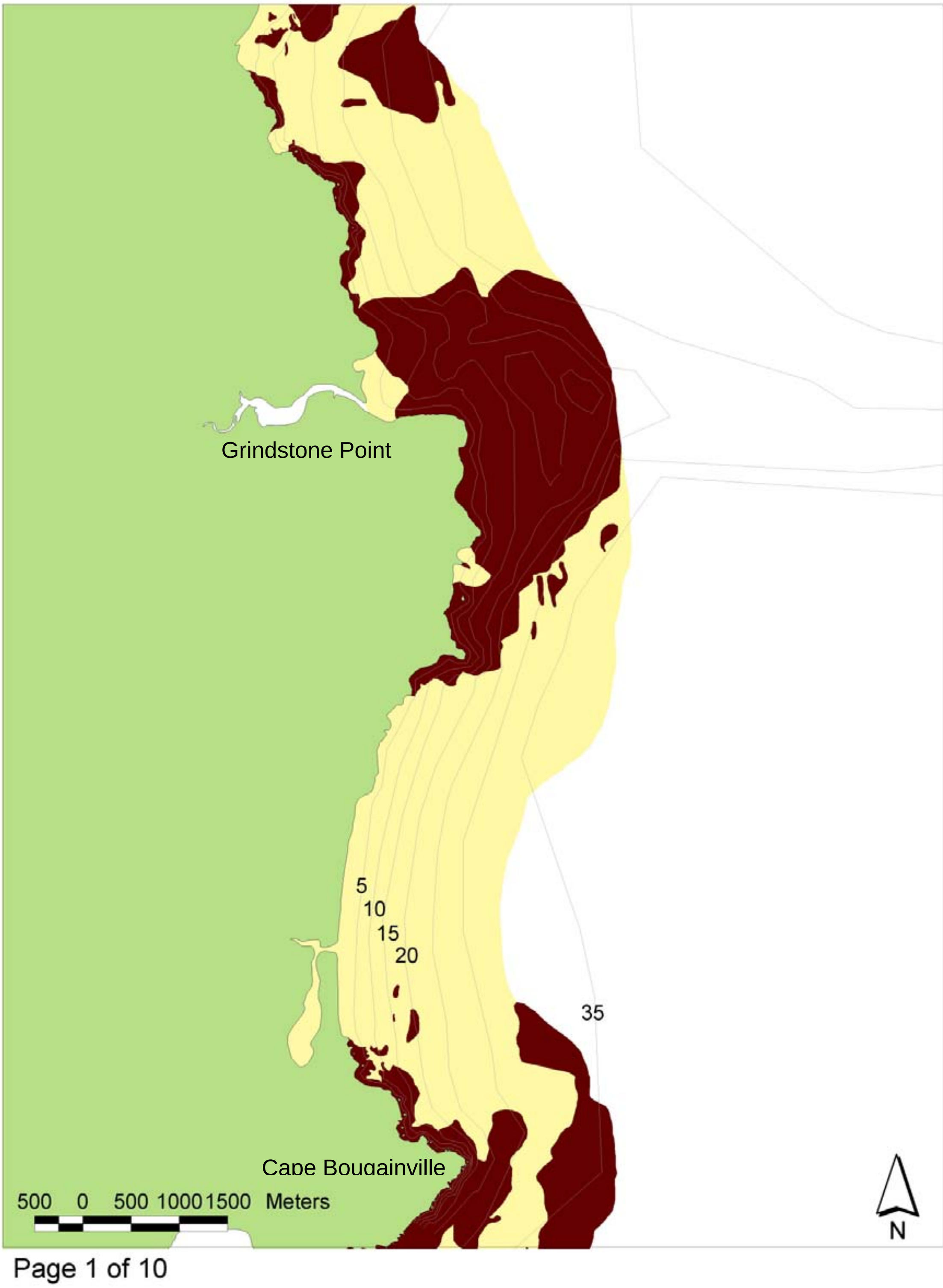

Figure 4-12. Map 1 of 10: Great Oyster Bay map series

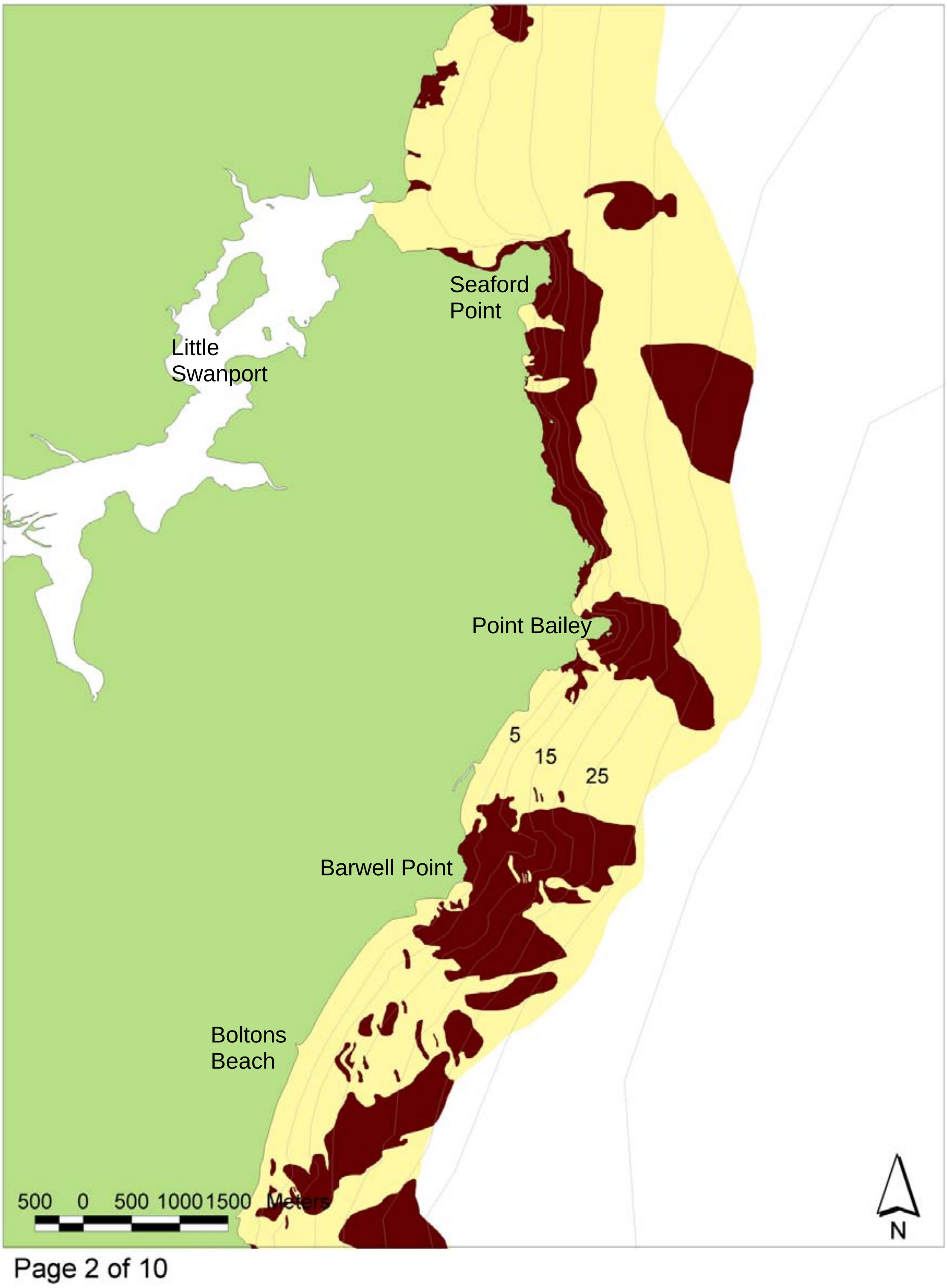

Figure 4-13. Map 2 of 10: Great Oyster Bay map series

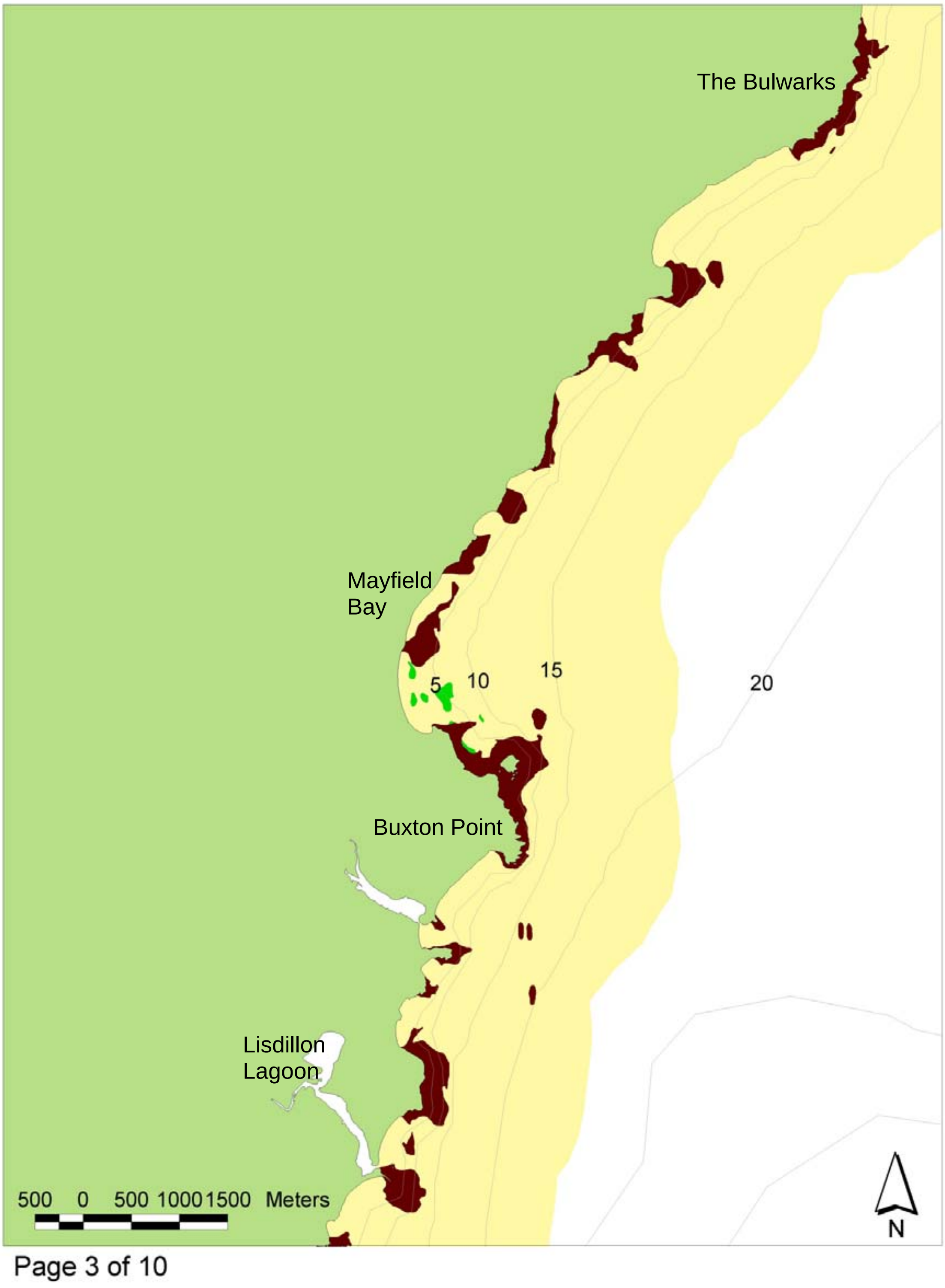

Figure 4-14. Map 3 of 10: Great Oyster Bay map series

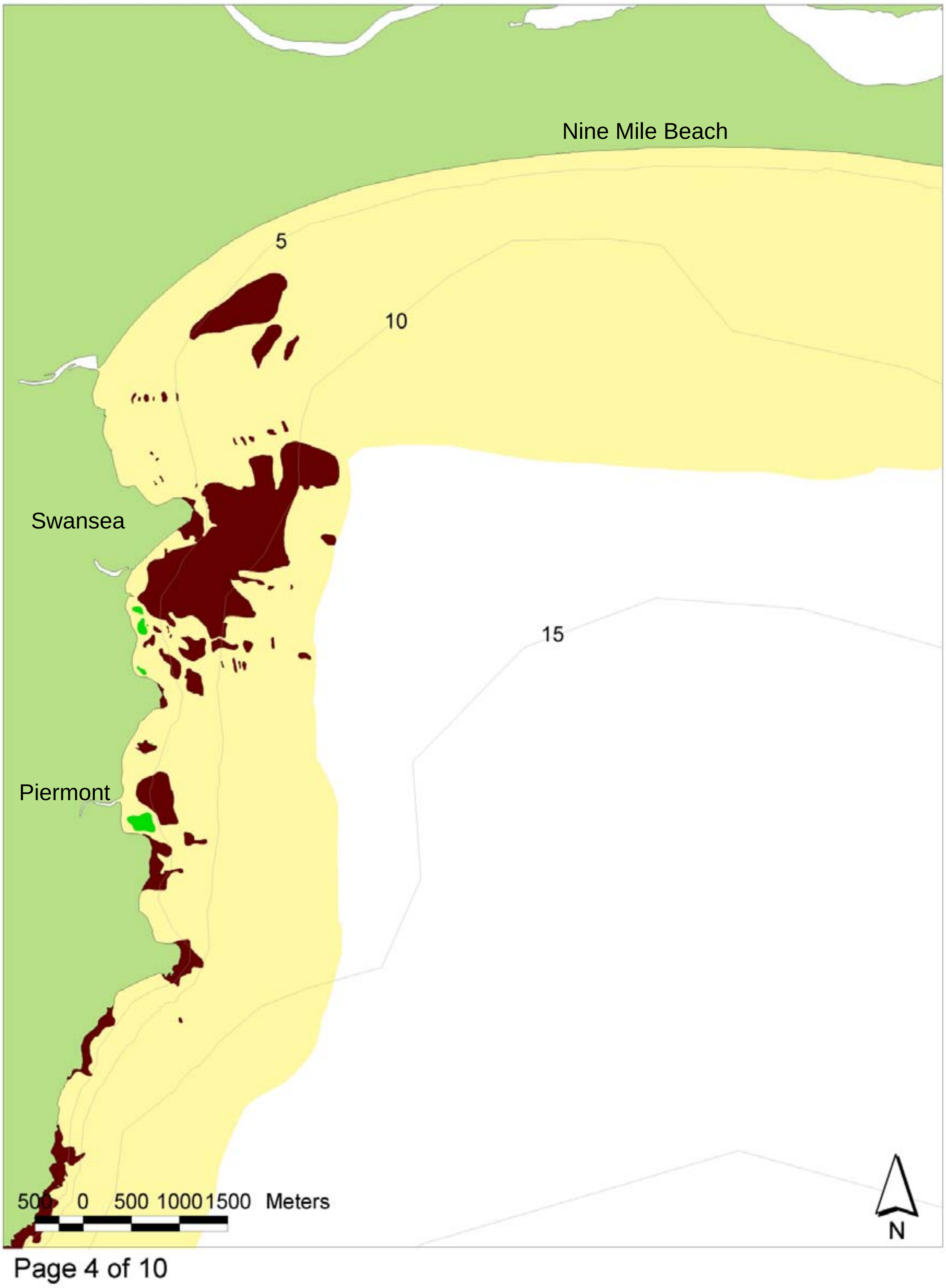

Figure 4-15. Map 4 of 10: Great Oyster Bay map series

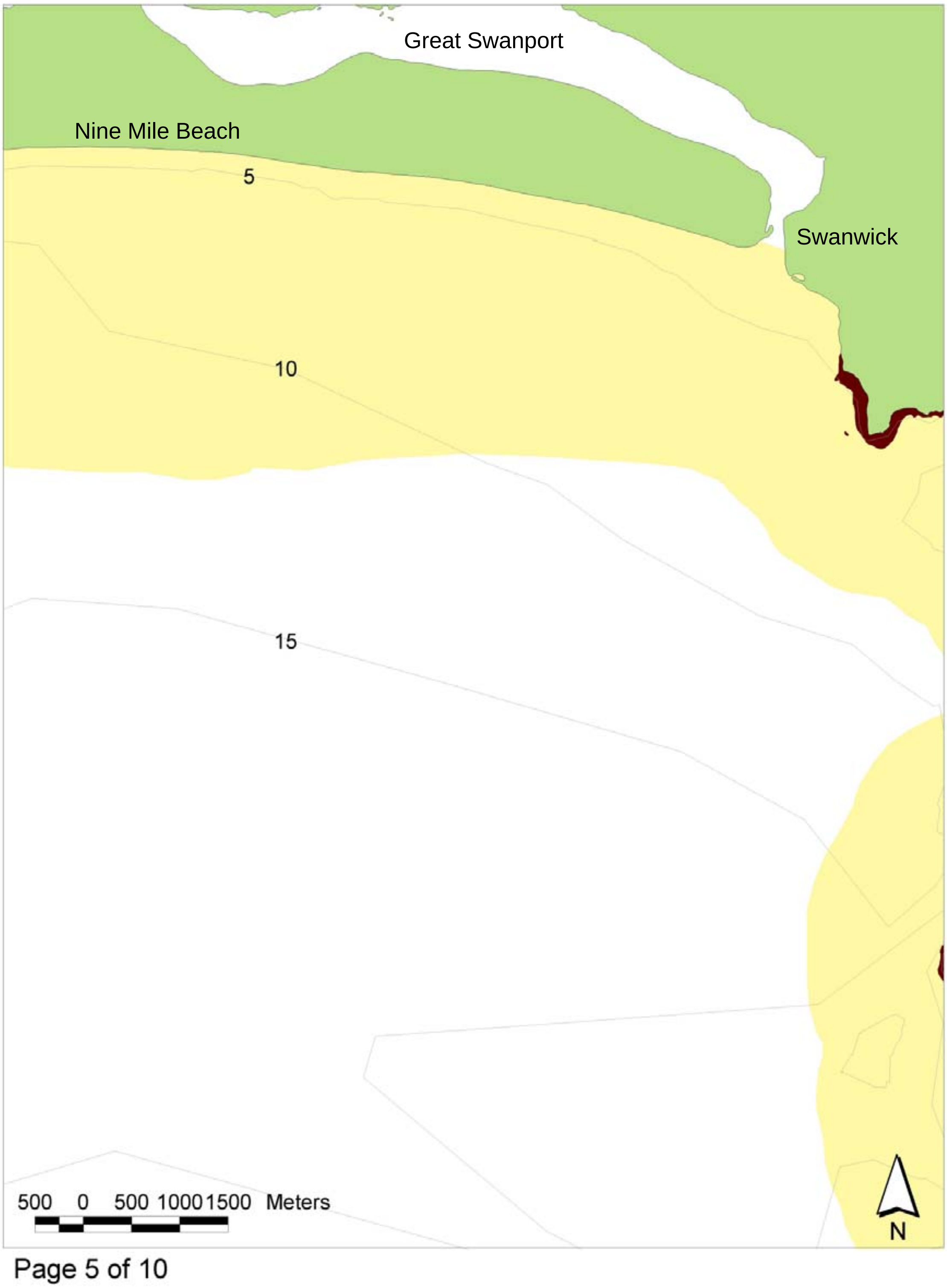

Figure 4-16. Map 5 of 10: Great Oyster Bay map series

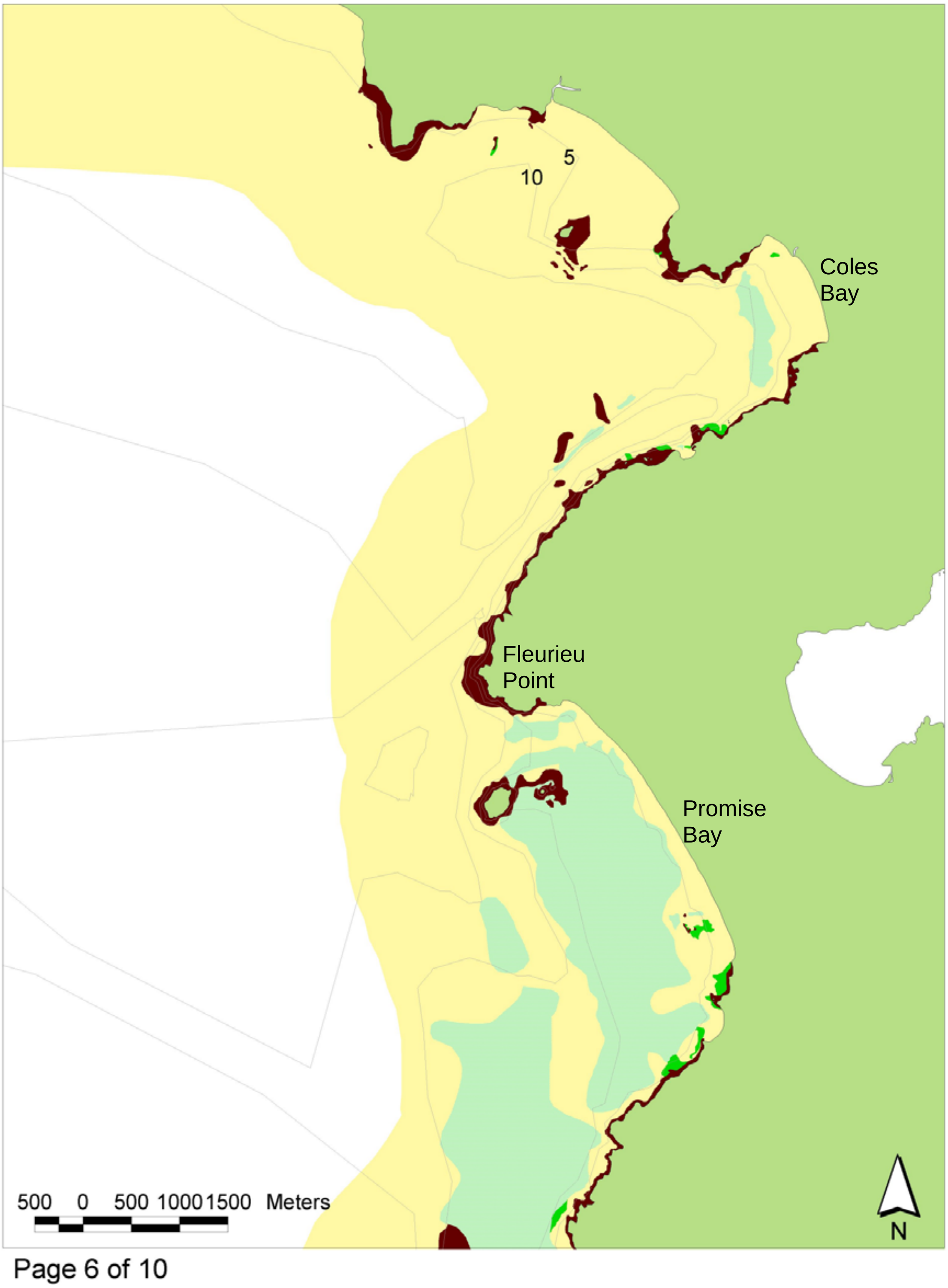

Figure 4-17. Map 6 of 10: Great Oyster Bay map series

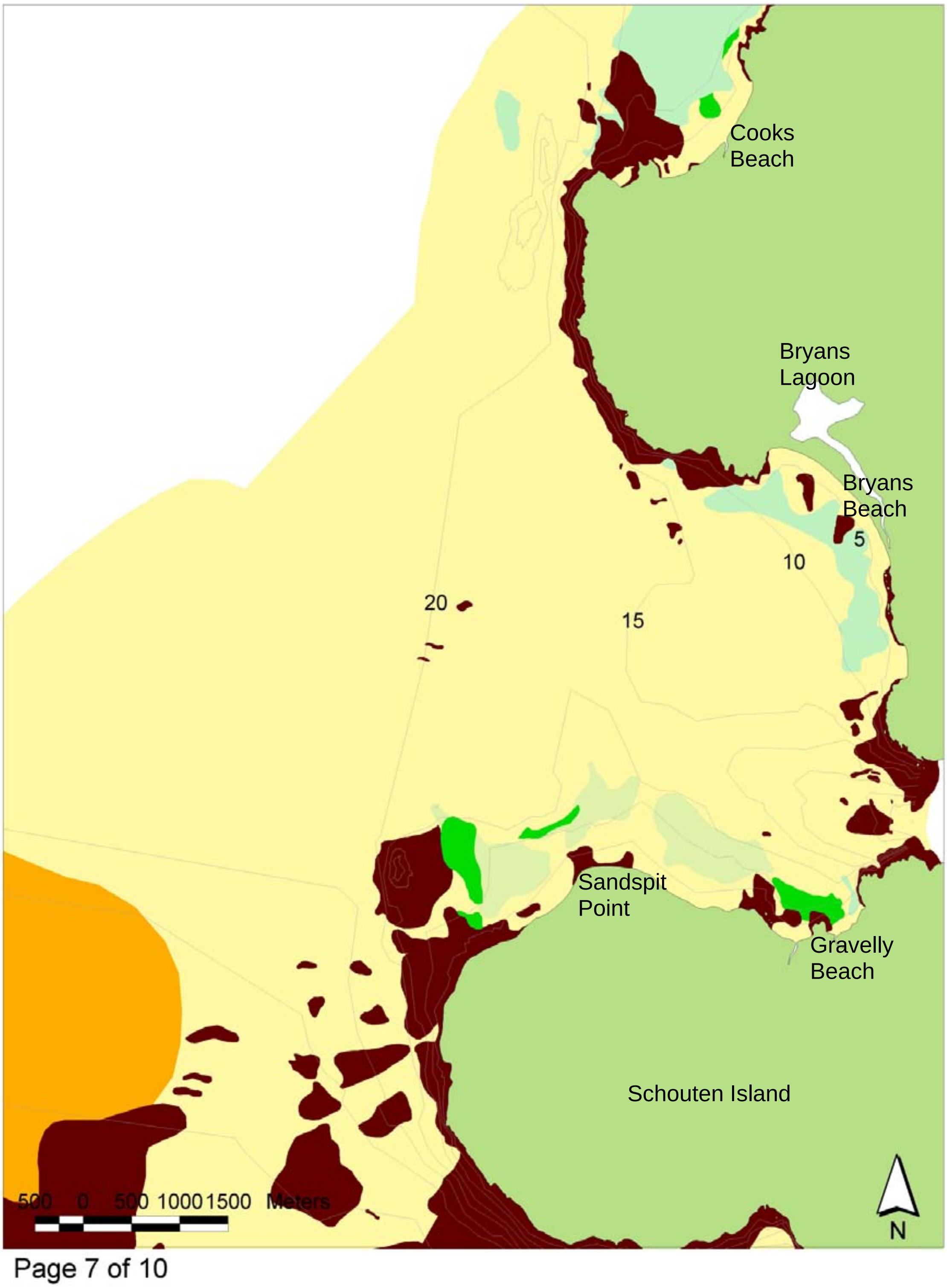

Figure 4-18. Map 7 of 10: Great Oyster Bay map series

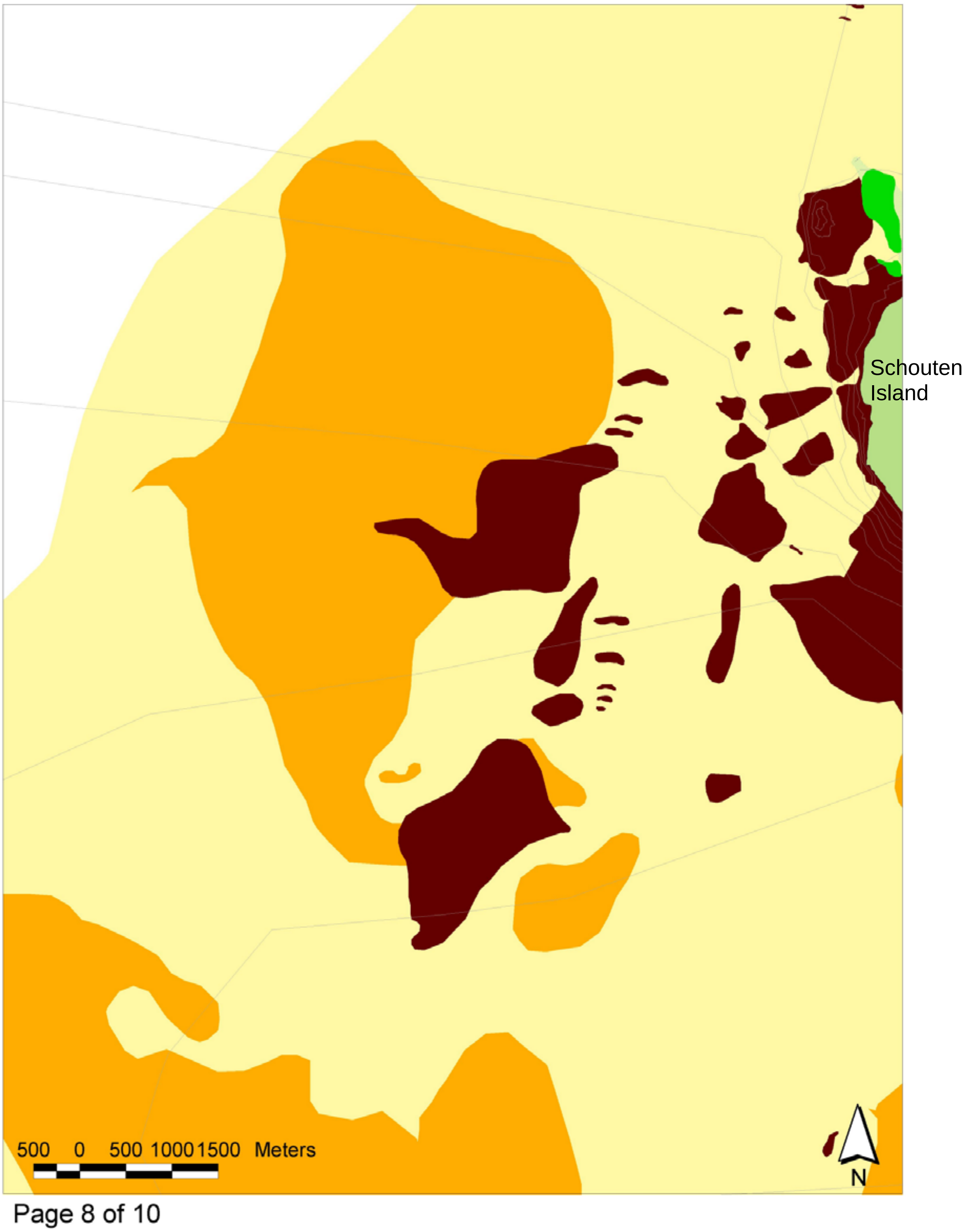

Figure 4-19. Map 8 of 10: Great Oyster Bay map series

Figure 4-20. Map 9 of 10: Great Oyster Bay map series

Figure 4-21. Map 10 of 10: Great Oyster Bay map series

5. Discussion

The main purpose of this report is to provide detailed habitat information and mapping for the estuaries (Bryans Lagoon, Catamaran River, Cloudy Bay Lagoon, D'Entrecasteaux River, Great Swanport, Little Swanport, Pipeclay Lagoon, Pitt Water and Southport Lagoon) and Great Oyster Bay. The inclusion of two additional areas, Little Swanport and upper Pitt Water, provide an almost complete coverage of estuaries in the Southern NRM region. The following discussion synthesises the findings of the report and addresses the ways in which the estuaries are similar and dissimilar. It is recognised that estuaries are relatively independent of each other and do not easily fall into regional grouping such as bioregions (Edgar *et al.*, 1999; Hirst, 2004). Each estuary is unique, both in terms of its physical development and the ongoing processes that drive the geophysical and biological forms and interactions taking place today. These factors include rainfall, wind, geology, catchment size, local marine wave climate, temperature, salinity, nutrient availability and tidal range. The Bruny Bioregion report (Barrett *et al*., 2001) presents similar findings for the highly indented coastline of southeastern Tasmania, including identifying the oceanographical influences on the region such as swell, currents and the variable nutrient levels periodically flushing through the system. They also identify the extremely high levels of biological endemism and biodiversity, with several marine species included on the Tasmanian threatened species lists. Previous studies (e.g., Moverley and Jordan, 1996; Jordan *et al*, 1998) have shown that a high proportion of bays have unique assemblages of fish in both the seagrass and unvegetated habitats.

The estuaries studied exhibit a great diversity in form and function. There are some interesting parallels that can be drawn between particular estuaries. For example, some estuaries possess similar characteristics, such as Southport Lagoon and Cloudy Bay Lagoon. These two estuaries have similar areas (~10 km^2 versus ~6 km^2), catchment sizes (~27.2 km^2 versus 42.7 km^2) and geomorphological facies, including long sinuous main channels, well-developed flood tide deltas, large intertidal flats and extensive central basins. Both have low freshwater inputs and are well-mixed estuaries, usually dominated by marine waters. They both have the majority of their dense seagrass beds, and substantial populations of filter feeders, clustering on the flood tide delta and along the main channel. They have almost identical total areas of seagrass (~145 Ha) and large beds of macroalgae are present on the shallow (~2-3 m) unconsolidated substrates of the central basin. However, Southport Lagoon currently has much larger areas of macroalgal beds (~500 Ha versus ~65 Ha) and preliminary observations of archival aerial photography of Southport Lagoon suggests that this area has been much greater in the past. Cloudy Bay Lagoon also has extensive intertidal seagrass beds (most likely *Zostera muelleri*), which appear to be largely absent in Southport Lagoon.

A second pairing of characteristics can be made between Catamaran River estuary and the D'Entrecasteaux River estuary. Both of these systems have high fluvial inputs (see Table 14), narrow cobbled channels and insubstantial or absent central basins. They have very small amounts of seagrass surviving on the fringes of the main channel or on parts of the delta that are more sheltered from the high energy fluvial discharges. Rocky headlands protect both estuaries from the full force of the swells, and even substantial wind waves.

A third pairing can be made between Little Swanport and Great Swanport, though the parallels are more limited, partly due the size disparity, but also because a major component of Great Swanport was not mapped for this project, namely Moulting Lagoon. Both estuaries have very high levels of seagrass, especially when the area of seagrass is related to the overall area of the estuary. This is particularly clear when they are compared to all the other estuaries on this basis. Great Swanport has ~78% of its area covered in seagrass and Little Swanport has ~56%. The proportion of seagrass for the other estuaries with sizeable seagrass beds is: Cloudy Bay Lagoon 24%, Southport Lagoon 14% and Pitt Water 12%. Furthermore, while seagrass density and patchiness is a fairly imprecise measure and there can be seasonal variation (Bulthuis and Woelkerling, 1983), there is also clear hierarchy of in terms of seagrass density. When the area of dense continuous seagrass beds are compared to the total area of seagrass (that is, against all densities of seagrass including dense, patchy, sparse and sparse patchy seagrass), Great Swanport and Little Swanport have by far the highest proportions at 61% and 57%, respectively. This ratio for the other estuaries is: Pitt Water 30%, Southport Lagoon 7% and Cloudy Bay Lagoon 5%. The exception for this measure is Bryans Lagoon with 100% dense cover. Great Swanport and Little Swanport also have strong fluvial influences with the highest and second highest total annual runoff at ~172.2 and 88.4 gigalitres, respectively. The strong freshwater influence is reflected in the large depositional fluvial deltas and also, biologically, by the presence of extensive *Ruppia megacarpa* beds in the upper reaches of both estuaries. *R. megacarpa* is generally much more prominent than other seagrasses in brackish waters (Edgar, 1997).

Pitt Water is an exceptionally large and complex system that cannot be readily paired with other estuaries, although it shares very low freshwater inputs with Southport Lagoon, Cloudy Bay Lagoon and Pipeclay Lagoon. For Pitt Water, this is partly due to extraction of water for agriculture and horticulture. This estuary currently has the second highest amount of seagrass at ~500 Ha and a sizeable proportion of that is dense seagrass (30%). The main seagrass beds occur around the end of the main channel at the flood tide delta near Woody Island (see Figure 3-21). This is also true for Southport Lagoon and Cloudy Bay Lagoon, with sparser and patchier beds tending to occur further upstream. In contrast, the two large estuaries with large fluvial inputs (Great Swanport and Little Swanport) have large very dense beds of seagrass (dominated by *R. megacarpa*) in extensive shallow bays in the upper reaches, in addition to beds of seagrass in the middle reaches. The small estuary of Bryans Lagoon is unique in that it is closed to marine influences and also has very low fluvial inputs due to its small basin and low rainfall. It has almost complete coverage of seagrass with uniformly high densities.

In terms of habitats, extensive areas of sandy shallows with sparsely distributed ascidians are notable. While they were not explicitly mapped, they were found in most estuaries. The estuaries of the central east coast appear to support very high levels of seagrass, while the southeastern estuaries have substantially lesser areas and densities of seagrass. This is consistent with recent work in mapping the habitats of Georges Bay that also shows historically high levels of seagrass distribution (Mount *et al.*, 2005).

5.1 Conservation significance

The unique and variable environments that constitute the estuaries of southeastern Tasmania need to be included in any considerations for marine protected area status. Substantial benefits have accrued from the larger marine protected areas declared in Tasmania (Edgar and Barrett, 1999). While the MPA process is largely structured around the Interim Marine and Coastal Regionalisation of Australia (IMCRA)(Edgar *et al*., 1995; ANZECC, 1998a, 1998b, 1998c; Marine and Marine Industries Council, 2001), Tasmanian estuaries do not neatly fall into these bioregions. It is important, when considering reservation status for the estuaries, to compare and contrast the various estuaries within the region. Although this is difficult to achieve with the current level of information, increasing material is available on which to base informed decisions. It is also important to place each estuary in the broader context, both in terms of its own catchment and fluvial systems and also in the context of the adjacent coastal region. Given the strong interactions, it is reasonable to consider each estuary to be fully and actively integrated with the wider environment. Furthermore, while habitat classifications are convenient, especially in the absence of more detailed information, care must be exercised when using habitats as a surrogate for biodiversity because broad substrata classes may not capture highly complex biological relationships (Ward *et al.*, 1999).

Another factor potentially affecting the conservation status of estuaries is their geo-conservation status. The Tasmanian State of Environment Report 2003 (RPDC, 2003) states, "Geodiversity is the natural diversity of geological, landform and soil features, and processes (Eberhard, 1997)." Future research could address these issues more fully by applying the ideas of geodiversity (see Household *et al*., 1997). The following table shows some of the geomorphological features that have been identified for inclusion in the Tasmanian Geoconservation Database (DPIWE, 2000) from the estuaries covered by this report.

Table 24. Geodiversity information from the Tasmanian Geoconservation Database V2 (DPIWE, 2000).

GIS_CODE	NAME	Comments
DCX04	Cloudy Bay Mid-bay Spit (Cloudy Bay Lagoon)	Impressive mid-bay spit, with slightly recurved tip, impounding large, shallow (partly infilled) lagoon.
FRE07	Bryans Lagoon and Beach (Bryans Lagoon)	A fine example of mid-bay spit and dune barred lagoon. While this landform is relatively common, most are degraded by roading or other development.
FRE08	Moulting Lagoon - Great Oyster Bay (Great Swanport)	Long-lived graben system possibly related to Gondwanan break up. Geomorphologically (and possibly structurally) still active.
PRO12	Lumeah Point Quaternary Deposits (Pipeclay Lagoon)	Various Quaternary aeolian, freshwater and marine deposits with associated palaeosols have been used to determine palaeoenvironment. Several fossil coastal landforms.
PRO03	Seven Mile Beach Spit (Pitt Water)	Type section for last interglacial and post last glacial period high sea levels (Davies 1960). Well developed mid bay spit with extraordinarily abundant Holocene beach ridges.

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 the extraordinary range of habitats within this region.

5.2 Monitoring of estuarine habitats, especially including seagrass, in the Southern NRM region

5.2.1 Monitoring protocols for estuarine habitats

This section discusses monitoring protocols that range from further scientific expert habitat mapping and monitoring to methods that encourage community participation in seagrass data collection. Monitoring of estuaries presents many scientific challenges, mostly as a result of the wide variety of abiotic and biotic variables interacting on often highly variable time scales. For example, a major effort to develop a predictive model to support monitoring was attempted using benthic macrofaunal assemblages in southeastern Australia, but was inhibited by existing data sets and approaches (Hirst, 2004). This was largely due to the difficulty of finding close correlations between the constitution of the sampled assemblages and more easily collected physical variables. This was partly explained by the general paucity of species numbers in estuaries and the ability of the species present to survive widely varying environmental conditions. Critical variables affecting the assemblage structuring that were identified included changes in salinity and changes in estuarine morphology at broad geographic scales.

This project, however, has focussed on mapping the extent and condition of broad habitat classes, underlying geomorphic structures and salinity profiles. This allows initial assessments of the estuaries and comparisons with similar mapping efforts in the future. It also contributes to the existing estuarine knowledge base created by Edgar *et al*. (1999). This knowledge base is continuing to be developed by projects such as the "Biodiversity and degradation in North West Tasmanian Estuaries" (Hirst *et al*., 2005), the work in Little Swanport (Crawford, Neira *et al*., 2005), and the reports on Georges Bay (Mount *et al*., 2005), the Derwent (Jordan *et al*., 2001) and North West Bay (Jordan *et al*., 2002). The mapping of habitats and geomorphic structures also supports improved spatial targeting for finer scale sampling in future monitoring programs.

In general terms, there are many potential habitats to monitor in estuaries. However, while the monitoring of unvegetated habitats are becoming well established by the scientific community, protocols designed for the wider community are not well established and so the focus here is on relatively easily observed seagrass beds. Seagrass is a key component of many estuarine ecosystems and is known to fluctuate in abundance on decadal time scales, though it is not yet clear how much the beds are responding to natural forcing factors or to human impacts. There are a very large number of ways in which seagrass can be monitored, however, the monitoring program should reflect both the objectives for monitoring and the resources available. Three complementary options are desirable.

The first option is to repeat this mapping exercise at 5 yearly intervals, using similar (or improved) methods and precision. Given the accuracy of the current maps and the seagrass condition sampling program, this would enable both an assessment of the distribution and density of the seagrass beds and associated epiphytic algae throughout the estuaries at the time, as well as allow changes over the five year period to be described and quantified.

The second option is to annually conduct small-format digital aerial photography runs to obtain four to five sample "quadrats" of approximately 250 x 250 m at targeted locations within each estuary or bay. Marine and Freshwater Research Institute (MAFRI) are currently applying a similar methodology in Port Phillip Bay, Western Port Bay and Corner Inlet in Victoria. This is a lower cost, rapid sampling approach compared to option 1, which can be used to quantitatively follow trends in seagrass extents across broad areas without requiring comprehensive mapping each time. The method enables changes in seagrass extent, density and epiphytic loading to be monitored (Dekker *et al*., 2005; Mount, 2003, 2005a, 2005b).

The third option is to initiate targeted community-based monitoring based on international best practice, which would produce ongoing results useful to management. Excellent programs have already been developed, documented and implemented within Australia. The recently prepared Parks Victoria Technical Guide (See Appendix 3 on the CD-ROM) is a particularly good resource in this regard as it not only deals with the same species present in Tasmania, but it also enables participation in Seagrass-Watch. This is the largest community-based seagrass monitoring program in the world, with over 150 monitoring sites in the Western Pacific to date – mostly in tropical waters (http://www.seagrasswatch.org/). While it is ideal to obtain regular samples, the frequency of monitoring depends on the commitment and resources of those involved. Annual monitoring is usually more likely to succeed than seasonal (3 monthly) monitoring.

5.2.2 Habitat monitoring recommendation

A seagrass monitoring program should be established that involves:

1. Mapping at five yearly intervals using boats with subsurface detection equipment, such as video and sounders, in combination with expertly selected and interpreted remote sensing.
2. Monitoring estuaries on an annual basis with large imagery-based "quadrats" obtained with small-format digital aerial photography.
3. Promoting community seagrass monitoring based on the Seagrass Watch protocols as presented by Parks Victoria with a frequency of 3 to 12 months depending on the commitment of volunteers.

5.2.3 Habitat monitoring locations

The following maps (over page) show the location of appropriate representative sampling sites, with a focus on seagrass monitoring. Baseline information for most of these sites was obtained during the present project; however, additional sites are also identified for Little Swanport and Southport Lagoon.

6. Conclusions

This study enhances the shallow marine habitat mapping inventory of southeastern Tasmania. The extraordinary variability of estuarine systems through time is becoming clearer and the provision of a snapshot of the broad habitats found within a selection of them is a small but important addition to the development of these understandings. It is also important to recognise the complexity concealed by the broad categories used for mapping.

Many of these maps are important for establishing the current extent of estuarine and marine habitat types. They will assist the development of measurable natural resource and management action targets. 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 found within 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 for finer-scale biological inventories.

Figure 6-1. Bryans Lagoon

Figure 6-2. Pitt Water

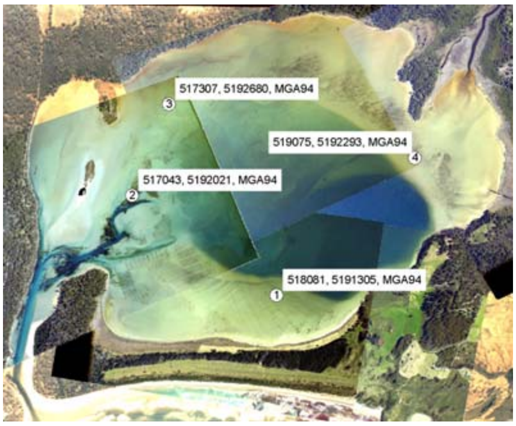

Figure 6-3. Cloudy Bay Lagoon

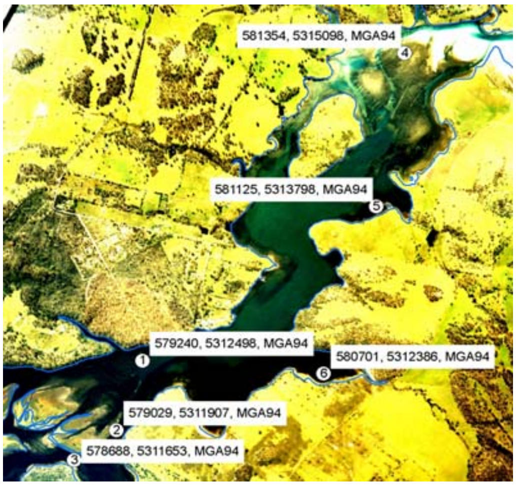

Figure 6-4. Little Swanport

Figure 6-5. Great Swanport

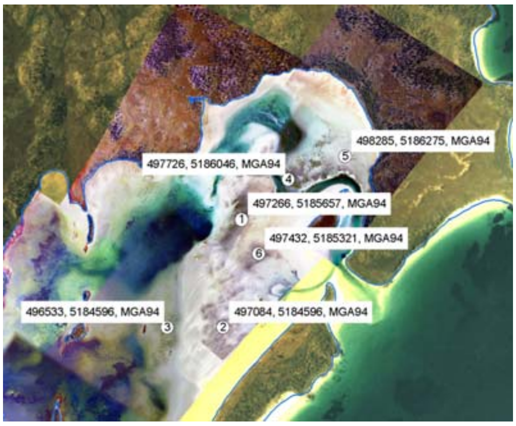

Figure 6-6. Southport Lagoon

Acknowledgments

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Appendix 1. **Catalogue of aerial photographs**

Project	Film	Photo	Film-Frame	Date	Estuary	Scale	Run	FltHt (feet)	FltHt (m)	Time (EST)	Color?	Sun Glint?
M914	1286	21	1286-21	16/01/1998	Bryans	52000	1	26,000	7,925	12:02	yes	yes
A118	1356	182	1356-182	5/03/2002	Bryans	42000	27E		0	1:55	yes	some
A110	1345	221	1345-221	1/02/2001	Catamaran	42000	49	22,500	6,858	3:31	yes(limited)	no
M863	1142	9	1142-9	5/12/1989	Cloudy Bay Lagoon	42000	46	22,500	6,858	9:20	yes	no
A086	1249	119	1249-119	23/02/1996	Cloudy Bay Lagoon	20000	93	21,500	6,553	10:48	yes	no
1104_TAFI	stills	vertical	RGB	26/11/2004	Cloudy Bay Lagoon/Southport Lagoon/ Catamaran/D'Entrecasteaux River			7,500	2,300		yes	No
1104_TAFI	video	vertical	RGB	26/11/2004	Cloudy Bay Lagoon/Southport Lagoon/ Catamaran/D'Entrecasteaux River			7,500	2,300		yes	no
A086	1357	9	1357-9	5/03/2002	D'Entrecasteaux River	20000	96	22,000	6,706	2:55	yes	no
A118	1356	197	1356-197	5/03/2002	Great Swanport	42000	24E	22,500	6,858	2:12	yes	yes
A135	1374	219	1374-219	29/11/2003	Great Swanport	24000	1	12,200	3,719	2:29	yes	yes
A135	1374	220	1374-220	29/11/2003	Great Swanport	24000	1	12,200	3,719	2:29	yes	yes
A135	1374	221	1374-221	29/11/2003	Great Swanport	24000	1	12,200	3,719	2:30	yes	yes
A135	1374	222	1374-222	29/11/2003	Great Swanport	24000	1	12,200	3,719	2:30	yes	yes
A135	1374	223	1374-223	29/11/2003	Great Swanport	24000	1	12,200	3,719	2:30	yes	yes
A135	1374	224	1374-224	29/11/2003	Great Swanport	24000	1	12,200	3,719	2:31	yes	yes
A137LS	1382	92	1382-92	22/03/2004	Little Swanport	22500	PP	11,250	3,429	13:04	yes	no
A135HD	1383	49	1383-49	28/03/2004	Pipeclay Lagoon	24000	15	12,200	3,719	1:36	yes	no
A135HD	1383	58	1383-58	28/03/2004	Pitt Water	24000	15	12,200	3,719	1:40	yes	yes
A135HD	1383	64	1383-64	28/03/2004	Pitt Water	24000	16	12,100	3,688	1:46	yes	some
A135HD	1383	69	1383-69	28/03/2004	Pitt Water	24000	17	12,200	3,719	1:52	yes	yes
M742	1124	137	1124-137	15/12/1988	Southport Lagoon	42000	47	22,500	6,858		yes	Yes

Quickbird satellite imagery © Digital Globe (courtesy Sinclair Knight Merz) from Greater Hobart Project, March 2004 (Pan Sharpened RGB 0.6 m): Pitt Water

Appendix 2. MDL Codes for Estuaries

MDL Codes for Estuaries

SUBCE - Single unconstricted mouth, branched channel with off-channel embayment
SUBCN - Single unconstricted mouth, branched channel with no off-channel embayment
SUBBE - Single unconstricted mouth, branched bay with off-channel embayment
SUBBN - Single unconstricted mouth, branched bay with no off-channel embayment
SUUCE - Single unconstricted mouth, unbranched channel with off-channel embayment
SUUCN - Single unconstricted mouth, unbranched channel with no off-channel embayment
SUUBE - Single unconstricted mouth, unbranched bay with off-channel embayment
SUUBN - Single unconstricted mouth, unbranched bay with no off-channel embayment
SCBCE - Single constricted mouth, branched channel with off-channel embayment
SCBCN - Single constricted mouth, branched channel with no off-channel embayment
SCBBE - Single constricted mouth, branched bay with off-channel embayment
SCBBN - Single constricted mouth, branched bay with no off-channel embayment
SCUCE - Single constricted mouth, unbranched channel with off-channel embayment
SCUCN - Single constricted mouth, unbranched channel with no off-channel embayment
SCUBE - Single constricted mouth, unbranched bay with off-channel embayment
SCUBN - Single constricted mouth, unbranched bay with no off-channel embayment
MUBCE - Multiple unconstricted mouth, branched channel with off-channel embayment
MUBCN - Multiple unconstricted mouth, branched channel with no off-channel embayment
MUBBE - Multiple unconstricted mouth, branched bay with off-channel embayment
MUBBN - Multiple unconstricted mouth, branched bay with no off-channel embayment
MUUCE - Multiple unconstricted mouth, unbranched channel with off-channel embayment
MUUCN - Multiple unconstricted mouth, unbranched channel with no off-channel embayment
MUUBE - Multiple unconstricted mouth, unbranched bay with off-channel embayment
MUUBN - Multiple unconstricted mouth, unbranched bay with no off-channel embayment
MCBCE - Multiple constricted mouth, branched channel with off-channel embayment
MCBCN - Multiple constricted mouth, branched channel with no off-channel embayment
MCBBE - Multiple constricted mouth, branched bay with off-channel embayment
MCBBN - Multiple constricted mouth, branched bay with no off-channel embayment
MCUCE - Multiple constricted mouth, unbranched channel with off-channel embayment
MCUCN - Multiple constricted mouth, unbranched channel with no off-channel embayment
MCUBE - Multiple constricted mouth, unbranched bay with off-channel embayment
MCUBN - Multiple constricted mouth, unbranched bay with no off-channel embayment

Appendix 3. CD-ROM

Habitat maps of the selected Lagoons, Estuaries and Great Oyster Bay with linked video and images of representative biological communities. See attached CD-ROM.

Appendix 4. Sediment Particle Size Analysis

Sediment particles are categorised into size classes as follows:

Description	Particle Size (microns)	Particle Size (phi)
Silt and clays	<63	>4
Very fine sand	63 - 125	4
Fine sand	125 - 250	3
Sand	250 – 500	2
Coarse sand	500 – 1000	1
Very coarse sand	1000 – 2000	0
Granules	2000 – 4000	-1
Gravel	4000 – 8000	-2

Note: 1 micron is 1 thousandth of a millimetre and phi is a standardised measure of the Wentworth scale.

Sediment samples are also categorised according to their frequency distribution across the size classes above. Samples typically may be unimodal (one peak) or bimodal (two peaks). The degree of particle size sorting is also recorded ranging from very well sorted, through well sorted, moderately well sorted to poorly sorted and very poorly sorted. These categories inform the observer about the energetic, hydrological and biological processes that were operating when the sediment was deposited (Woodroffe, 2003).