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Major achievements of the Comparative Geomorphology of Estuaries project

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Brendan Brooke
Catherine Ticehurst
Emma Murray**

June 2006



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Australian Government
Geoscience Australia



**CRC for Coastal Zone
Estuary & Waterway Management**

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June 2006

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Introduction

What are near-pristine estuaries?

Roughly half of Australia's estuaries were classified as 'near-pristine' during the National Land and Water Resources Audit (NLWRA 2002). Near-pristine estuaries are estuaries that have not been significantly impacted upon by humans, and are considered to exist in an essentially natural state. This means that the estuaries are not used for aquaculture, that fishing is limited and sustainable and that the water movements through the estuaries and fringing wetlands have not been altered by roads or engineering structures (e.g. training walls, causeways and barrages). In addition, the catchments of near-pristine estuaries retain most of their natural vegetation cover (Table 1).

Table 1. Criteria used by the NLWRA to define a near-pristine estuary (NLWRA 2002)

Physical characteristics	Condition
Catchment natural cover	>90%
Land use	Limited roads and disturbance to natural conditions and processes
Catchment hydrology	No dams or impoundments, virtually nil abstraction
Tidal regime	No impediments to tidal flow, changes from natural morphology (e.g. training walls, barrages, bridges and causeways)
Floodplain	Wetlands intact in vegetation and hydrology, no alterations to flood pattern
Estuary use	Extractive activities limited to Indigenous or limited and sustainable commercial and recreational fishing, no aquaculture
Pests and weeds	Minimal impact on estuary from catchment weeds and limited pests and weeds within estuary
Estuarine ecology	Ecological systems and processes intact (e.g. benthic flora and fauna)

Because the catchments of near-pristine estuaries are not heavily urbanised nor used for large-scale farming, we assume that the amounts of sediment and nutrients that are delivered to these estuaries in stream flow are near the levels they would be if European settlement of Australia had not occurred. By implication, near-pristine estuaries tend to be located along the most remote and inaccessible parts of the coastline. We know relatively little about Australia's near-pristine estuaries because they are mainly found in out of the way places

(Figure 1) and most studies have focussed on estuaries with identified environmental problems.

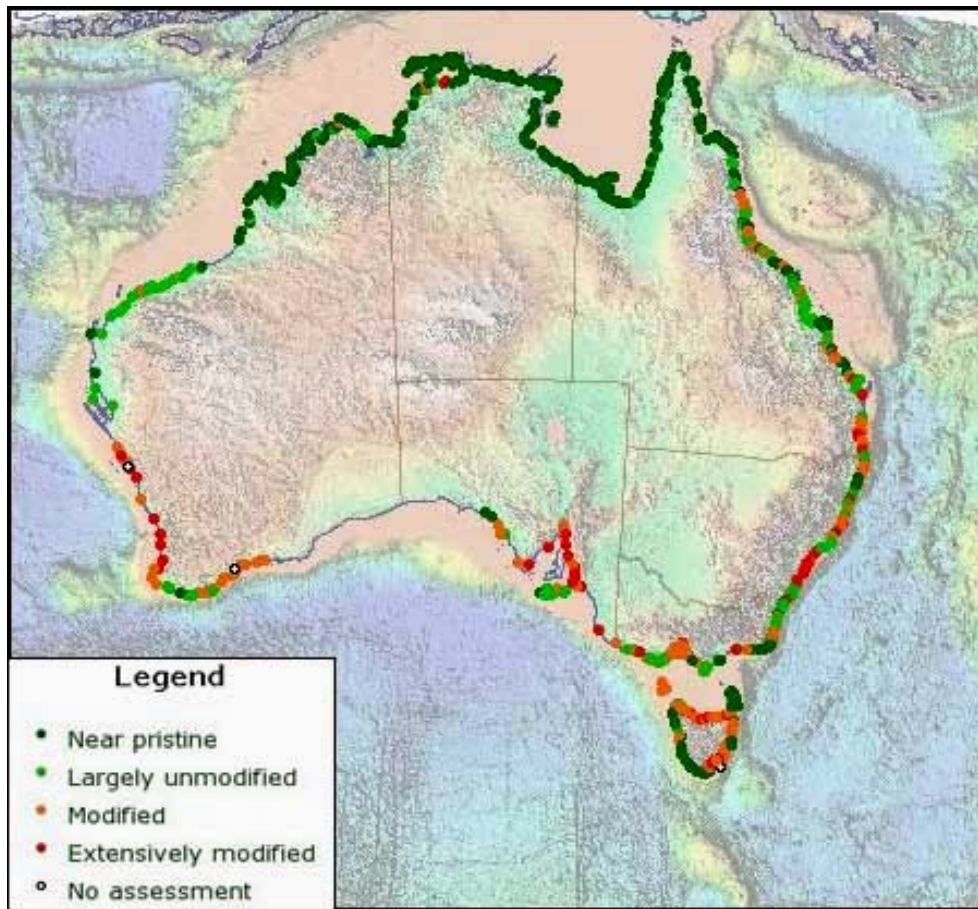


Figure 1. Condition of estuaries around Australia based on NLWRA assessment (NLWRA 2002)

Why the interest in Australia's near-pristine estuaries?

Australia's near-pristine estuaries are some of our most valuable natural assets, with many natural and cultural heritage values. They are important as undisturbed habitat for native plants and animals, for biodiversity conservation, as Indigenous lands and for tourism. They also support near-shore fisheries. In addition, by studying near-pristine estuaries, scientists can learn more about the way humans have changed natural systems. This information then feeds into natural resource management because it constitutes benchmark or baseline information against which similar information from more modified estuaries can be compared.

It is also worth noting that most countries do not have nearly as many near-pristine estuaries as Australia does, and therefore may lack this important opportunity for conservation of biodiversity and scientific inquiry.

Aims and context of the Comparative Geomorphology of Estuaries Project

The central aim of this Coastal CRC project was to improve understanding of Australia's near-pristine estuaries. As the title implies, the project had a geomorphic focus in that a major output was mapping of geomorphic habitats of a representative selection of near-pristine estuaries from around Australia. In the coastal context, geomorphic habitats are landforms ('geo' = land, 'morph' = shape) such as salt marshes and intertidal flats whose shape and position in the landscape are strongly governed by the effect of physical and biological forces on sediments. The mapping follows on from similar work undertaken during the first National Land and Water Resources Audit (NLWRA 2002), when the geomorphic habitats of 540 of Australia's estuaries were mapped. However, near-pristine estuaries were poorly represented in the NLWRA (2002) process. This occurred because the NLWRA targeted estuaries that were clearly altered by developments around and within these waterways and by the clearance of native vegetation and other activities in their catchments, rather than the well-preserved estuaries that require conservation. Consequently, only 41 near-pristine estuaries were mapped.

In addition to the generation of new information on near-pristine estuaries in the form of images, maps and measured habitat areas, the Comparative Geomorphology of Estuaries Project has:

- collated existing information of Australia's near-pristine estuaries in the form of a literature review (Murray *et al.* 2006);
- highlighted remote sensing techniques (satellite-based or airborne sensors) and related new methods of image classification for their potential in mapping and monitoring the habitats and water quality of near-pristine estuaries (Creasey *et al.* 2006); and
- scoped the development of easily measured geomorphic indicators based on estuary habitat areas, which give insight into catchment and estuary condition, and the degree of change to estuaries caused by historical and modern catchment land-use practices (Radke *et al.* 2006).

Project achievements and findings

Geomorphic habitat mapping

The geomorphic habitats of 158 near-pristine estuaries were mapped in the Comparative Geomorphology of Estuaries Project by methods outlined in Creasey *et al.* (2006). The maps comprise industry-standard ARC GIS files consisting of a base map of the estuary boundary, and vector layers showing the extent of sub-aerial, tidal and sub-tidal habitats. The maps are available for download on the OzEstuaries website (<www.ozestuaries.org>). This website also contains the maps of near-pristine and modified estuaries generated during the NLWRA (2002). An example of a new geomorphic habitat map is provided in Figure 2.

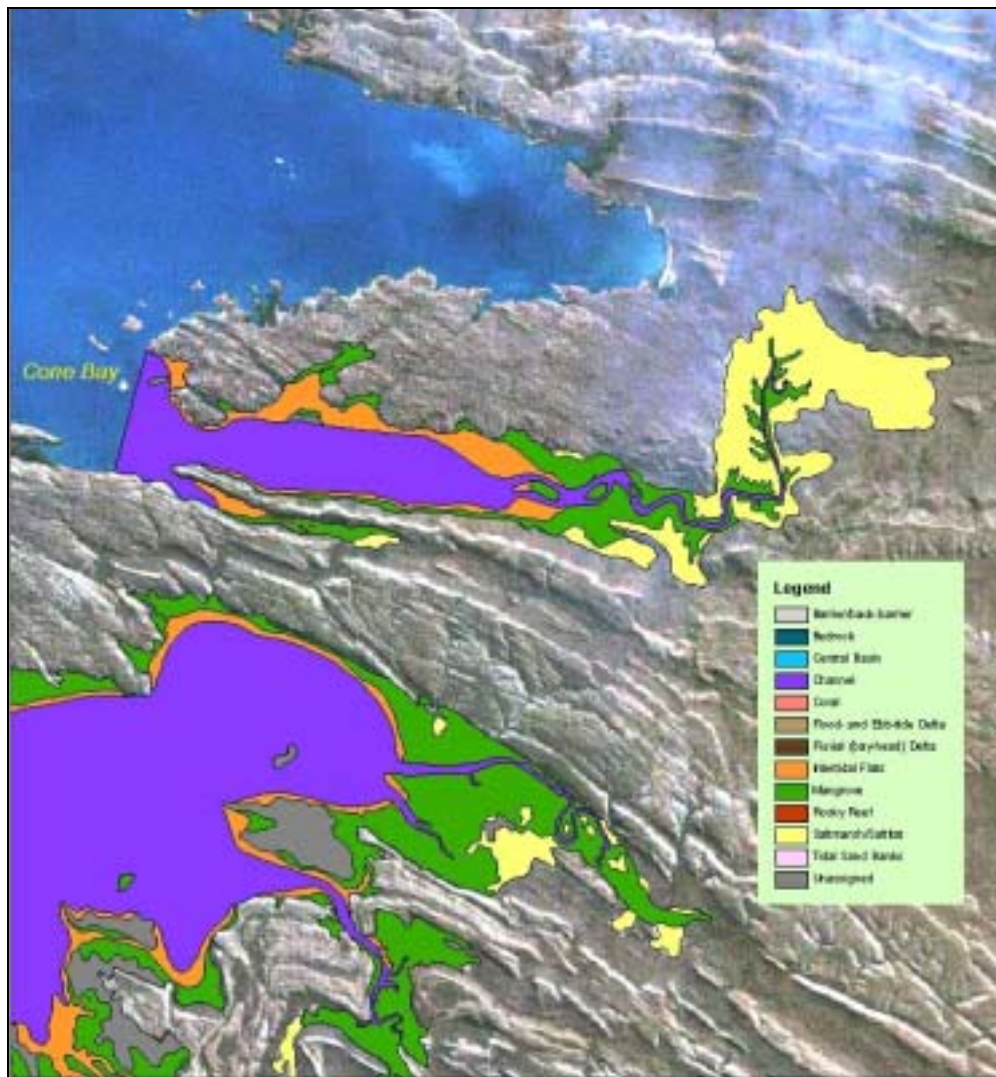


Figure 2. Geomorphic habitat map of Cone Bay (-16 28°S, 123 32°W) on the southern Kimberley coast of Western Australia. Indicated habitats are typical for estuaries in this section of the Kimberley region where habitat areas are often constrained by surrounding bedrock valleys.

The near-pristine estuaries that were mapped in this project were chosen to reflect, as far as possible, the full range of geomorphic variability in Australia. A statistically significant number of the different types of estuaries (between 16 and 26) were chosen, and these were spread as far as practicable around the Australian coastline. These estuaries are located in all the coastal geomorphic regions of Australia (Harris *et al.* 2002). Within this context, state government preferences and the availability of suitable images and photographs were also taken into account. By 'estuary types', we refer to the major kinds of coastal waterways (i.e. wave- and tide-dominated estuaries and deltas, tidal creeks, strandplains and embayments) which experience differing amounts of wave, tide and river energy (Heap *et al.* 2001). By coastal geomorphic regions (Harris *et al.* 2002) we refer to the Northwest Coast, Gulf of Carpentaria, Northeast Coast, Southeast Coast and Southwest Coast.

The national set of habitat maps in OzEstuaries now includes near-pristine examples of Australia's diverse estuaries and coastal waterways. Near-pristine estuaries from Queensland and the Northern Territory comprised by far the largest proportion of the estuaries mapped during the project, accounting for 46% and 30% respectively. Significantly fewer estuaries were mapped in Tasmania (9%), New South Wales (2%) and Victoria (<1%). This was mainly because there are far fewer near-pristine estuaries in these southern states, and many of them had already been mapped during the NLWRA. There were some important observations made about the estuaries during the mapping process that might have a bearing on the established coastal geomorphic regionalisation. For example, it was suggested that the Northwest Region should be divided into two regions to recognise the unique bedrock-controlled coastal waterways of the Kimberley (Figure 2). Near-pristine estuaries in the south and west Gulf of Carpentaria were also found to be distinct from those of the east Gulf of Carpentaria, where habitats extended further inland and there is a greater abundance of mangroves and salt flats.

Literature review

The purpose of the literature review (Murray *et al.* 2006) was to collate previously disparate information on near-pristine estuaries, and make it widely available for use by managers, researchers and the general public. This information was acquired through scientific articles, reports, conference proceedings, government agencies, grey literature, websites, expert advice and anecdotal observation, and was summarised both on a state-by-state basis and at the national level, with emphasis on current knowledge and management. The extent and availability of information pertaining to near-pristine estuaries was generally good at the catchment level in most states. Information at the individual estuary level was sparse, although important geomorphic, water quality and ecological studies have been undertaken in some areas (e.g. Tasmania).

An unfortunate finding of the literature review was that a reasonably large percentage of the estuaries deemed to be in near-pristine condition during the NLWRA will likely have to be reclassified to account for modification in either the catchment or in the estuary itself. The reclassification is required because either (i) inaccurate information was used during the initial assessment; or (ii) there has been a change in the catchment or estuary condition since the initial assessment. The occurrence of aquaculture was often cited as the cause for reclassification of estuaries in the southern states, while overlooked catchment modification was the main reason for changes to classifications in Northern Australia. The downstream impact of cattle grazing on the near-pristine estuaries in northern Australia, in particular, is unknown and could be quite extensive.

Coastal catchment and waterway land management practices were found to vary greatly across Australia. The catchments of near-pristine estuaries in the southern states are often fully contained within national parks, while there was a mixture of land tenure in the northern catchments (Indigenous, pastoral lease, crown land and freehold) and fewer national parks. Inclusion of the catchments of near-pristine estuaries in national parks affords the estuaries a certain degree of protection against catchment developments which can have large impacts on estuaries. However, to fully protect an estuary, both the catchment and direct use (e.g. fisheries and other extraction activities) must be managed. With this purpose in mind, tables were provided in each state chapter in which the near-pristine estuaries were assigned to their corresponding coastal IMCRA (interim marine and coastal regionalisation for Australia) regions. It is envisaged that this information will help with future national representative system of marine protected areas (NRSMPA) programs (Figure 3).

All IMCRA regions in Queensland, the Northern Territory and northern Western Australia include near-pristine estuaries, and the IMCRA regions of Tasmania were reasonably represented by near-pristine estuaries (Figure 3). There are 14 IMCRA regions with no near-pristine coastal waterways along the New South Wales, Victorian, South Australian and southern Western Australian coastlines, however (Figure 3).

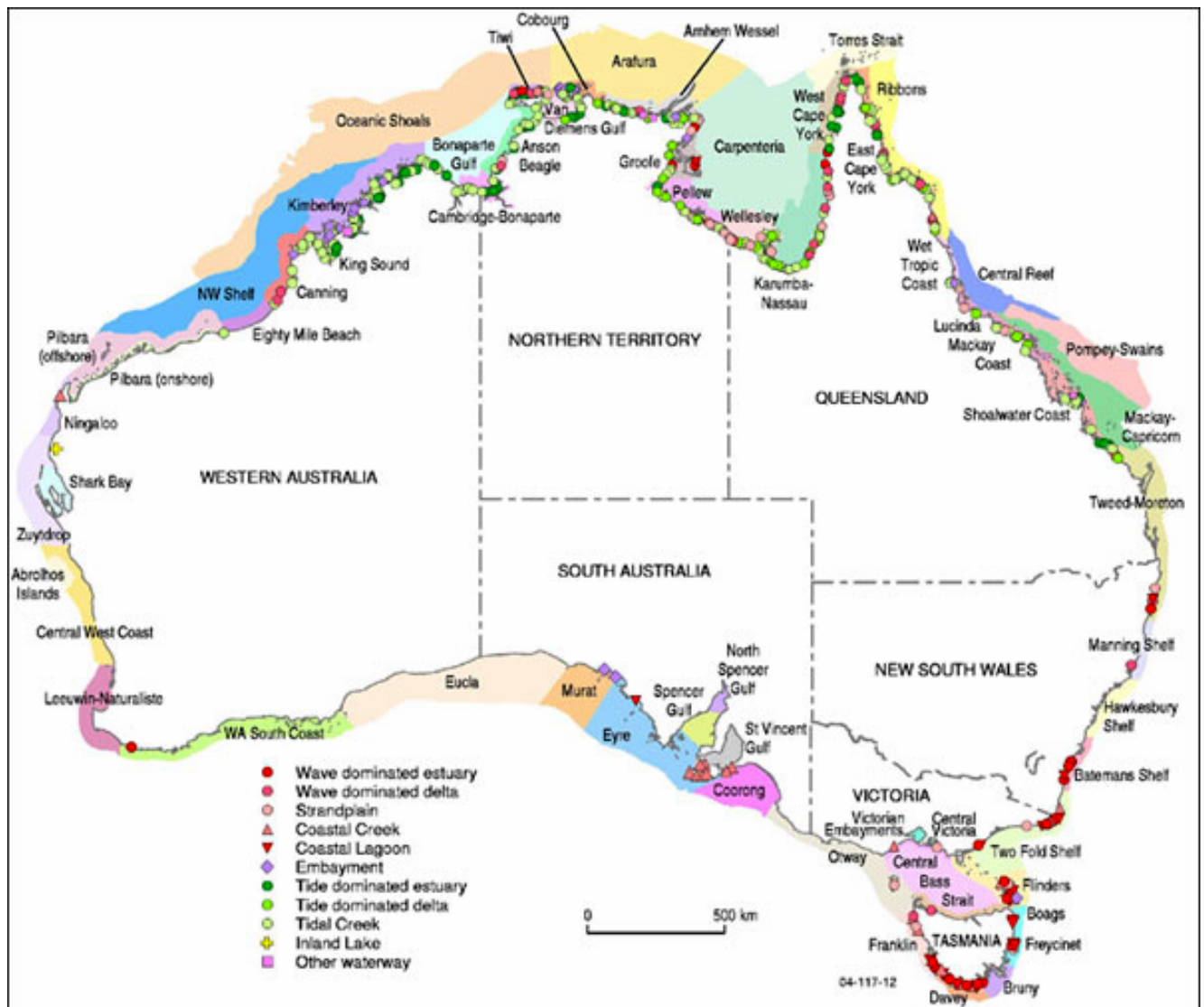


Figure 3. IMCRA bioregions based on IMCRA Technical Group (1998) and the geomorphic type of near-pristine estuaries around Australia according to the NLWRA assessment (Heap *et al.* 2001)

Remote sensing techniques and applications to near-pristine estuaries

As mentioned previously, near-pristine estuaries tend to be located along the most remote and inaccessible parts of the coastline, making them difficult to study. This is why remote sensing techniques were scoped for their potential use in monitoring and gathering further information on the habitats and water quality of near-pristine estuaries. Remote sensing involves the collection of information about the earth's surface using sensors mounted on satellites or aeroplanes. The result of remote sensing is an image from which the spatial distribution of different landscape characteristics (e.g. mangrove forests and seagrass beds) can be mapped (see example in Figure 4).

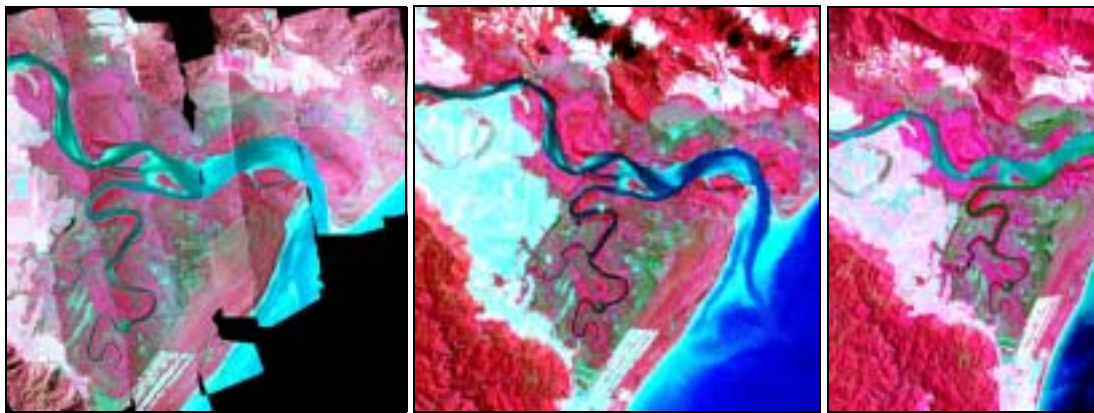


Figure 4. A comparison of three false-colour remote sensing images of the Daintree River (Queensland) region showing a variety of land-cover types

*Left: May 1996 airborne Casi image, Middle: September 1999 Landsat image;
Right: March 2001 Hyperion image (Creasey et al. 2006)*

Remote sensing has been used for many years to map the coastal zone both for research and for management purposes. One relevant example was the use of aerial photography to map Australia's coastal geomorphic habitats during the NLWRA and in this project. However, it was underscored in the remote sensing methods and applications portion of the Comparative Geomorphology of Estuaries mapping report (Creasey *et al.* 2006) that more advanced satellite and/or airborne remote sensing instruments are now available, and these can be even more cost-effective and objective than aerial photo interpretation. This is because the imagery can be collected at larger spatial scales (regional) and because computer software is now available that can help automate the process by which land-cover and water quality maps are made from the images. For example, the eCognition™ software package is designed to produce maps from remote sensing images by grouping similar adjacent features (e.g. water body or forest patches) in the landscape. A case study from the near-pristine Wildman River in the Northern Territory demonstrated that maps made from remotely

sensed images using eCognition™ are comparable to or better than maps based on manual digitisation (Figure 5).

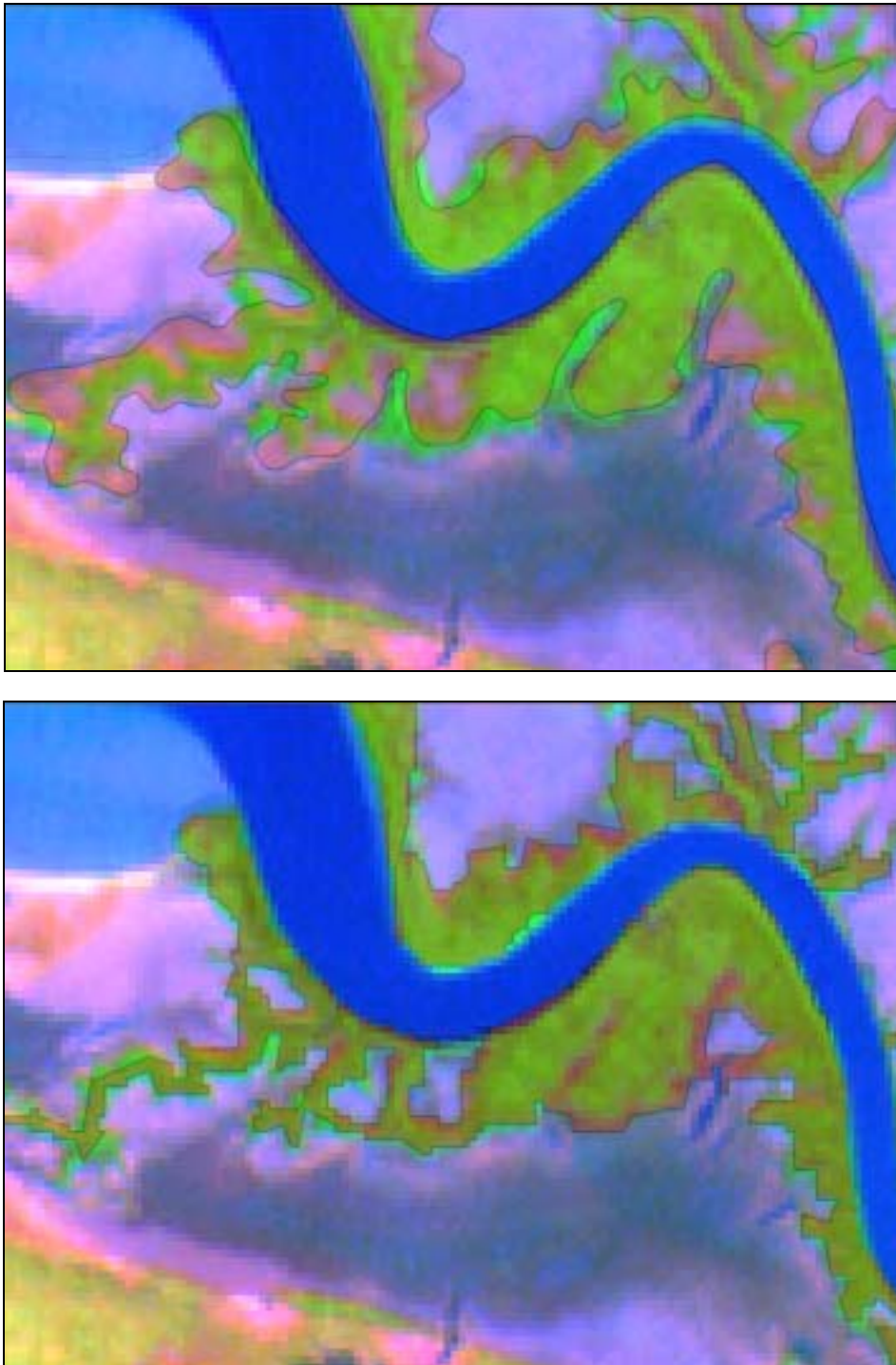


Figure 5. Mangrove areas at the mouth of the Wildman River based on manual assessment (top) and eCognition™ classification (bottom)

Although both methods produce similar results, the eCognition™ classification is better constrained to just the mangrove pixels (green) (Creasey *et al.* 2006).

The level of detail and number of physical properties that can be mapped using remote sensing imagery largely depends on the characteristics and availability of the remote sensing instruments. In a second case study on near-pristine estuaries in tropical northern Queensland, different types of imagery and computer algorithms were investigated for their ability to differentiate between the dominant vegetation types in an estuarine environment.

An automated mapping routine was then developed and applied to widely available satellite data (Landsat ETM) to produce maps of the Daintree River, Cooper Creek and Noah Creek. These maps were then compared to aerial photo interpretations. Although slightly different land-cover types were used, the results were comparable for the common vegetation classes (see Daintree example in Figure 4). The advantage in using Landsat ETM data in an automatic mapping routine over manual interpretation of aerial photographs is that it is fast and can cover large regions. The disadvantage is that user knowledge and experience cannot be applied at the same level of detail.

It can be summarised that remote sensing, especially when it incorporates new automated image classification techniques, can reduce the time and effort required for routine monitoring and mapping of Australia's near-pristine estuaries. This can enable environmental managers and researchers to regularly up-date habitat maps to monitor changes through time.

Indicators of estuary environmental condition based on the GIS maps of estuary geomorphic habitats

An important goal of the Comparative Geomorphology of Estuaries Project was to explore the development of indicators based on spatial information derived from the new habitat maps of near-pristine estuaries produced in this project, in combination with existing similar maps of other estuaries provided by the NLWRA (2002). The new maps provide baseline information on key geomorphic attributes of the near-pristine systems that may be used as benchmarks, against which to quantify changes to more modified estuaries. They can thus help us understand how modifications to coastal catchment, such as land clearing, may affect habitats in estuaries.

In a preliminary study, we compared the areas of different habitats of the various types of Australian estuaries on the basis of the NLWRA environmental condition classifications (Radke *et al.* 2006). The results are very encouraging. We found systematic changes in estuary geomorphic indicators with diminishing estuary

environmental condition (i.e. from near-pristine, through largely unmodified and modified to severely-modified) for most types of estuaries (e.g. Figure 6). The estuaries that were more disturbed by native vegetation clearance in catchments and development in and around the estuaries had higher levels of geomorphic maturity.

This finding indicates that these types of environmental disturbances appear to result in a relatively greater load of sediment moving into the estuary. This was evidenced in apparent increases in the areas of tidal sand banks, intertidal flats and mangroves in tide-dominated estuaries, and in intertidal flats in wave-dominated estuaries. The wave-dominated estuaries also appear to have experienced a marked reduction in saltmarsh areas. Our results suggest that higher sediment loads resulting from land clearing have led to premature infilling of some Australian estuaries. However, a more thorough vetting of the data is needed to confirm these initial results.

The results of this study thus highlight the potential of the national estuary geomorphic habitat area dataset for providing new insights into the way estuaries react to changes in catchment land use. This is especially the case for many estuaries for which there is a lack of useful historical records.

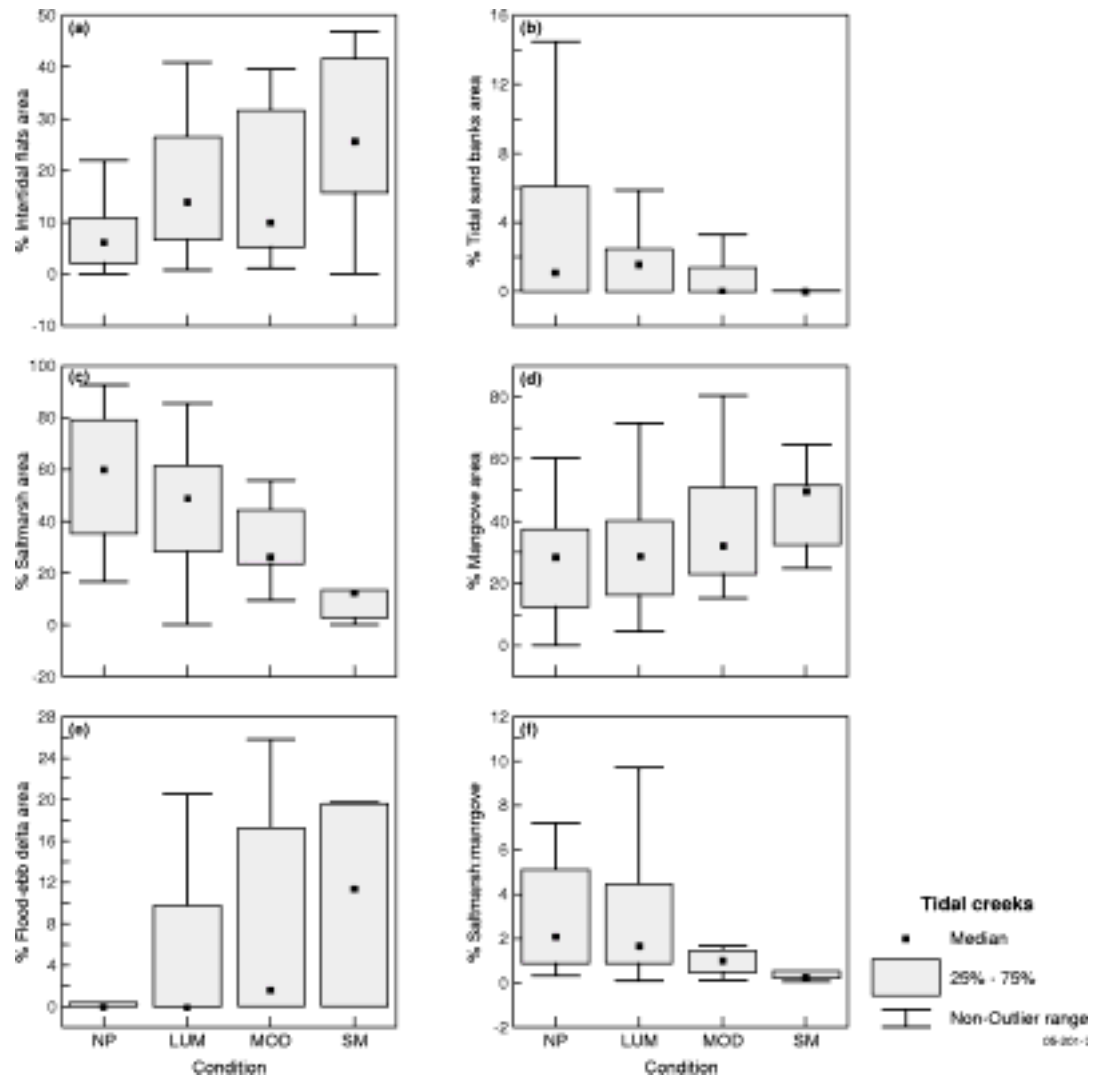


Figure 6. Some preliminary results for the geomorphic indicator analysis of tidal creeks

These box and whisker diagrams show medians, 25th and 75th percentiles and ranges for the relative area data of the various geomorphic habitats. Environmental condition classifications are: near-pristine (NP); largely unmodified (LM); modified (MOD); and severely modified (SM). Note there are reasonable trends in most of the data.

Conclusions

The Comparative Geomorphology of Estuaries Project has delivered a range of new estuary data and information that provide a unique national overview of the location, environmental condition, biophysical characteristics and management of Australia's near-pristine estuaries. These estuaries represent highly valuable natural assets in terms of biodiversity and natural and cultural heritage values. Significantly, this is the first national study of these environments and the information and insights generated provide a solid information base for improving the management of these systems and for the development of a national policy framework to help in their conservation.

The project's review of methods of mapping estuarine habitats using remote sensing techniques represents an important reference document that describes and demonstrates a range of established and new techniques that can be used to more effectively manage these environments. Another major outcome of the project is the added value the near-pristine estuary geomorphic habitat data has brought to the national dataset generated by the NLWRA. By combining the new near-pristine estuaries data with this dataset, we now have a unique, robust national set of biophysical data that covers all the types of estuaries, the full spectrum of environmental conditions and, indeed, includes most of Australia's estuaries. As we have shown in the preliminary analysis of the geomorphic habitat data, new information can be generated from the dataset that improves our understanding of how the disturbance of coastal catchments and estuaries impacts on estuarine habitats. This knowledge can in turn better inform the management of estuaries and enhance the potential for the conservation of Australia's coastal biodiversity.

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