Towards an understanding of mangrove diversity in Australia

Ian David Cresswell
B Sc (Hons) Murdoch University

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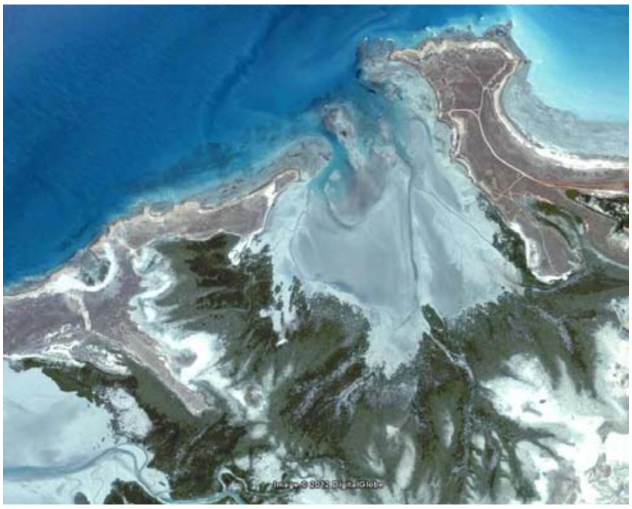
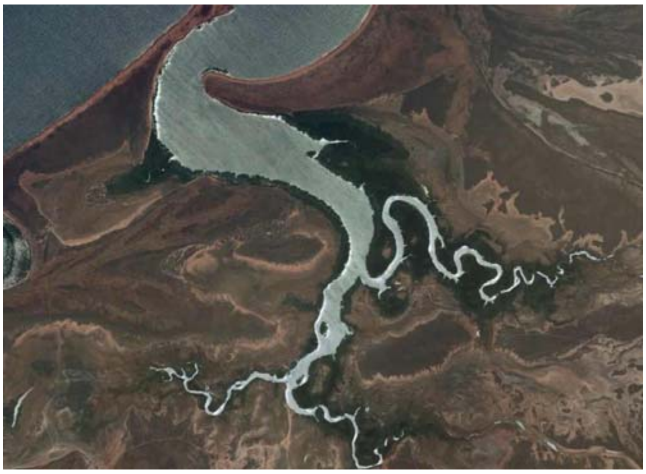
An internationally significant mangrove fringe in an open embayment (with spits at the headlands), Mitchell Plateau, WA



Nationally significant mangrove tidal creeks behind mangrove fringed tidal flats and tidal creeks partially protected by a limestone barrier, Cape Keraudren, WA



A regionally significant mangrove lined tidal creek complex and tidal flats leeward of a limestone barrier, Port Hedland, WA

Dedication

This work is dedicated to my mother Rose Lilian Cresswell

(14 March 1921 – 18 May 2010)

whose unwavering belief in me and support is the bedrock upon

which everything else is built.

Declaration

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

Ian David Cresswell

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Acknowledgements

Firstly I would like to express my deepest thanks for the ongoing support (over more years than I care to acknowledge) of my three supervisors, Peter Bridgewater, Bernie Dell and Vic Semeniuk. Without their guidance and encouragement this would not have been possible. I am particularly grateful for their help in the final year in providing unqualified and generous support in helping to 'close me down'. It has been an interesting journey and I couldn't have chosen three more able gentlemen to guide me.

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To all who have helped me in large or small ways I wish to express my gratitude.

Abstract

The key findings of this thesis link mangrove diversity with the diversity of abiotic environments and, for the first time, provides a consistent method for the development of a comprehensive scientific framework for the management of mangrove ecosystems at national level. In Australia (and globally) a lack of information on the different mangrove habitats that support the diverse range of mangrove ecosystems has inhibited both management and conservation of mangrove ecosystems. Currently there is no agreed and commonly used national classification scheme for mangrove information. This gap weakens future conservation and sustainable development of the Australian coastline. This thesis addresses that gap in knowledge.

The physical framework of the Australian coast forms the habitat template in which mangrove diversity develops. The key hypothesis examined is that an understanding of the abiotic setting within which mangroves are found markedly improves an understanding of the distribution and diversity of mangrove ecosystems.

To test that hypothesis, detailed examination of the four overarching physical drivers that shape the Australian continental edge: geology, physiography, climate and oceanography, was undertaken to create a comprehensive picture of the abiotic coastal environment. This showed that coastal, fluvial, and hydrological processes that lead to coastal landform development form the basis for understanding the various coastal landforms and mangrove habitats developed along the Australian coast. The results demonstrate that physical drivers and coastal process do shape the distribution of mangrove species, and how mangrove vegetation is developed, maintained, changed or lost. Inter-relationships between these overarching physical drivers provide a classification of Australia's coast into major coastal sectors, including those which do

not support mangroves. To elaborate the results, a description of each sector containing mangroves and the types of mangrove habitats present is provided.

Mangrove diversity is not simply variation in floristics (species richness) but also must include structural and physiognomy diversity. An individual species of mangrove may perform various ecosystem roles in different physical settings. This concept is elaborated through constructing eight hypothetical expressions of mangrove diversity examining the changes in mangrove habitats under increasing complexity of tidal and climate influence, showing how the interaction between tidal, climate and environmental gradients results in different mangrove expression around the Australian coast.

Building on the interactions between abiotic and biotic diversity, seeking ways and means to improve mangrove conservation in Australia, lead to ideas for the development of a mangrove-focused national conservation strategy. A set of three criteria is put forward to identify the significance of mangrove sites globally, nationally and/or regionally (sub-nationally). Besides these practical approaches, an assessment of each State and Territory's mangrove management and conservation mechanisms shows the scope of existing policies and conservation strategies, and reveals little coordination of mangrove conservation or management issues at the national level, or between the jurisdictions. Building on these findings, and in the framework of the proposed national conservation strategy, a series of recommendations are made to improve the collection and access to mangrove information, including through the implementation of a national level data and information plan providing standards for biophysical and management information on mangroves.

Abbreviations

BoM	Bureau of Meteorology
^{o}C	Degrees Celsius
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CRC	Cooperative Research Centre
GA	Geoscience Australia
HAT	Highest Astronomical tide
HST	High spring tide
M	Million
MHWN	Mean high water neap
MHWS	Mean high water spring
m/s	Metres per second
MSL	Mean Sea Level
PPT	Parts per thousand
PPM	Parts per million

Scale Terminology

The use of Scale terminology follows that set out in a series of classification papers on coastal and wetland landforms by Semeniuk and co-workers (Semeniuk 1986, C.A. Semeniuk 1987, Semeniuk et al. 1989). The coastal landforms in this thesis are described in frames of reference of fixed sizes, using terms for frames of reference such as continental, regional, large, medium, small and fine (Semeniuk 1986, Semeniuk et al. 1989), and megascale, macroscale, mesoscale, (C. A. Semeniuk 1987).

Salinity Terminology

The use of salinity classes in this thesis follows that of Hammer (1986) and C. A. Semeniuk (1987). Salinity is measured in parts per million (ppm) of total dissolved solids within freestanding water near the mangroves.

Salinity category	**Salinity in ppm**
Fresh	< 1000
Brackish	1000 – 20000
Saline	>20000 – 35000
Hypersaline	>35000

Glossary

Literature dealing with mangroves has used an elaborate terminology to describe the physical appearance, distribution and diversity of mangroves; however that terminology is often inconsistent between studies. Therefore, to be clear as to the meaning used throughout this thesis, definitions are provided for all of the major terms used. The major terms are: diversity, estuary, floristics, mangrove, mangrove assemblage, mangrove ecosystem, mangrove fringe, mangrove habitat, mangrove physiognomy, mangrove structure, species richness and zonation.

Diversity is used in this thesis in two ways, firstly to refer to the diversity of vascular plant species in terms of their floristics *(q.v.)* (following the traditional use of the term α-diversity from Whittaker 1972), and secondly to refer to the diversity of structure and of physiognomy. Thus, for a location with a single species of mangrove, there may be structural diversity with variation in the mangrove formation from forest to scrub to shrubland to dwarf forest (Specht 1970) or there may be physiognomic variation. In this thesis, the type of diversity is specifically described as floristic diversity *or* structural diversity *or* physiognomic diversity as defined above. If not specifically noted then diversity refers to the total floristic, structural, and physiognomic diversity within a formation or a zone.

Estuary is used to refer to any semi-enclosed coastal body of water, which is connected to the open sea, and within which sea water is measurably diluted with freshwater derived from land sources, as defined by Cameron & Pritchard (1963), Pritchard (1967), Dyer (1973), and Perillo (1996).

Floristics refers to the plant species composition of any area, identified to the species level.

Mangrove is used to refer to the tree or tall shrub plant species that form the dominant visual structural component of vegetation growing between High Spring Tide (HST) and Mean Sea Level (MSL), and is consistent with the now well established use of the term, as defined by MacNae (1968) and adopted by Tomlinson (1986). Several Australian studies and other global studies include a wider range of species, including ferns, grasses and Chenopods; however in this thesis the earlier stricter definition of MacNae is used in order to have clarity over a very large geographic range of the obligate tree and shrub species found in the intertidal zone that have adapted to that environment and are not found (or very rarely found) elsewhere. Mangrove species considered in this thesis are based on numerous previous authors (MacNae 1968, Chapman 1977, Semeniuk et al. 1978, Hutchings & Saenger 1987, Tomlinson 1986, Duke et al. 1998, Duke 2006) but modified to include only species recognised by the Australian Plant Census (*http://www.anbg.gov.au/chah/apc/*). The list of Australian mangroves considered in this thesis is found in Appendix 1a.

Mangrove assemblage is used to describe the aggregate of plant species (as defined from the list in Appendix 1a) within a zone or within the entire mangrove fringe. It is a non-scalar term that can refer to the vascular plant species composition of the entire fringe, or the composition of a specific mangrove zone or habitat. *Mangrove assemblage* covers all the variation within a particular habitat and the term is used to denote floristic/ structural combinations of mangrove types; this usage also is synonymous with the term "community" or "association", or the broader term 'mangal'.

Mangrove ecosystem refers to the physical extent of the full set of all species to be found in a specific area of mangroves interacting together and with the abiotic environment, and is the physical expression of the concept of mangrove functioning described above. A mangrove ecosystem may be relatively small and localised, being simple due to the simple interaction of a limited number of physical processes with a finite number of biological organisms occupying that space; or it may be a complex suite of mangrove habitats functioning in different ways along large expanses of coast. This term is not scale dependent, rather it is holistic and encompassing of all the terms above.

Mangrove fringe is the "development" of mangrove along the coast. It is the term used to refer to any belt, patch, or band of mangrove along the coast be it located within an estuary associated with a river, along the shoreline, or in areas with irregular inundation. It is the term applied to the overall physical unit of mangroves at any given locality, without further subdivision by floristic, structural, or physiognomic attributes. A mangrove fringe can be floristically, structurally and physiognomically simple, as expressed through one or two dominant plant species (such as the ubiquitous *Avicennia marina*), or it can be complex, comprised of many species showing complex mixes of floristic, structural and physiognomic attributes. In this thesis, the term 'mangrove fringe' encompasses all structural, physiognomic, and floristic variation within any areas of mangroves, and is not consistent with the similar term coined by Gilmore & Snedaker (1993).

Mangrove habitat refers to the abiotic space that mangroves occupy that has been developed by smaller scale geomorphology, substrate, groundwater and soilwater salinity, or hydrological interface (Semeniuk 1993a). It is the sum of the physicochemical factors that determine whether a given location is inhabitable by mangroves. In this thesis it is used solely to refer to the abiotic "environmental space" which is then utilised by a common recurring set of plants and animals. In this thesis the term is largely synonymous with a small-scale geomorphic unit with a specific tidal level and hydrochemistry.

Mangrove physiognomy refers to the shape of individual plants within an area of mangroves. The plants may be trees (> 3-5 m in height) or shrubs (≤ 3-5 m in height). The plants may be columnar trees or shrubs that are broadly branched or forked along the main trunk, multistemmed plants (equivalent in form to “mallee eucalypts” or copsed species in the northern hemisphere), gnarled and recumbent trees or shrubs.

Mangrove structure refers to the spatial arrangement of mangroves in terms of size of plant and vegetation spacing (canopy cover). The most commonly used structural classification in Australia is that of Specht (1970) which ascribes structure into forests, woodland, scrub, shrubland, and heath. The term “dwarf forest” has been used in the literature for mangrove forest that is small in height (Lugo & Snedaker 1974, Hutchings & Saenger 1987) and is used to refer to formations of mangrove comprised of small woody plants ≤ 1.5 m in height.

Species richness is a measure of the number of species within a prescribed area or location. In this thesis it refers to the number of mangrove species within a prescribed area or location (the list of mangrove species considered by this thesis is contained in Appendix 1a). For instance the species richness in the humid tropical zone of northern Queensland and Northern Territory is between 25-30, while the species richness in Exmouth Gulf in Western Australia is 6 and the species richness in Leschenault Inlet, Western Australia is 1.

Zonation refers to the occurrence of bands, or belts (or strips) of variation in the mangrove fringe. These bands or belts may be floristic, or structural, or physiognomic, and are often expressed as colour variations in the mangrove fringe (as seen from aerial photography). This variation is typically expressed as bands or belts parallel to the shore or to habitat margin (*e.g.* the margin of a chenier or a tidal creek), and usually reflect some shore- or habitat-parallel pattern such as frequency of inundation, a salinity gradient, a substrate gradient, or an energy gradient.