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Saltwater intrusion and mangrove encroachment of coastal wetlands in the Alligator Rivers Region, Northern Territory, Australia

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Executive summary

The aim of research reported here was to determine the spatial extent and rate of saltwater intrusion in the Alligator Rivers Region, in the eastern half of Van Diemen Gulf in Northern Australia, and link the findings to similar surveys of the western Gulf. This required examination of the tidal creek networks to identify their network patterns and growth rates. An additional aim was to identify and describe morphology in the vicinity of the headwaters of the tidal creeks to determine their potential association with parts of the estuarine reaches of rivers subject to different tide versus flood discharge relationships. The potential for interplay between large magnitude meteorological and oceanographic physical processes to drive changes on the floodplains is also briefly examined.

The rate, spatial extent and geomorphological character of saltwater intrusion in the Alligator Rivers Region have been determined from an interpretation of aerial photography available at the time the research was undertaken in 1998. The research documents coastal change associated with saltwater intrusion of the Alligator Rivers Region, and completes descriptions of tidal creek and mangrove growth in streams debouching into the southern waters of Van Diemen Gulf. The progress of tidal creek extension and mangrove encroachment of the Wildman, West Alligator, South Alligator and East Alligator Rivers of the Alligator Rivers Region was reconstructed from aerial photographs for the years 1950, 1975, 1984 and 1991 and mapped at a scale of 1:100 000.

Growth of tidal creek networks occurred in the eastern rivers of the Alligator Rivers Region, particularly the Wildman River and South Alligator River. Changes in the spatial characteristics and distribution of the tidal creeks and mangroves indicate that the saltwater reach has significantly expanded along extending creeks since 1950 in a manner similar to that reported from the western Gulf coast. Expansion of tidal creek networks occurred through a combination of headward extension and tributary development. The most vigorous rates of extension were along the low-lying palaeochannel swamps of the South Alligator and East Alligator Rivers. Mangrove colonisation in an upstream direction has increased for the four river systems examined.

It is possible the semi-enclosed basin of Van Diemen Gulf, with its deep basin and broad nearshore shallows along the southern coast, amplifies the effects of northerly monsoonal winds, particularly strong northwesterlies, on water levels along the southern shore. Drier than average wet seasons with strong onshore north westerly winds would be associated with above average water levels in the southeastern Gulf and enhancement of tidal activity on the flood plain surface. If this is so, then the changes observed along the southern shore would be geographically restricted and subject to reversal with a return to more average and higher rainfall conditions. The gradual, sustained increase in northerly winds over the historical period supports this argument. Additionally, areas of saltwater intrusion at Point Farewell and Kapalga show evidence of *Melaleuca* spp regrowth. This may indicate that saltwater intrusion has occurred as part of the natural variability of the wetlands and the processes driving it are contributing to raising the elevation of the floodplains through splay deposition at the headwaters of the tidal creeks. However, these propositions cannot be tested without detailed analysis of the post 1991 satellite imagery and aerial photography now available coupled with long-term sea level observations from the Gulf, closer identification of the processes involved and examination of the patterns of vegetation regrowth at a site level.

Key words: Alligator Rivers Region, saltwater intrusion, mangrove encroachment, tidal creek, sea level

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Saltwater intrusion and mangrove encroachment of coastal wetlands in the Alligator Rivers Region, Northern Territory, Australia

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1 Introduction and background

The aim of research reported here was to determine the spatial extent and rate of saltwater intrusion in the Alligator Rivers Region which occupies the eastern half of Van Diemen Gulf in Northern Australia (Fig 1). A subsidiary aim was to link the research findings with similar, previously reported, surveys of saltwater intrusion of freshwater floodplains in the western Gulf to improve understanding of geographic variation in geomorphologic processes and saltwater intrusion. The aims required examination of the growth rates and distribution patterns of tidal creek networks associated with the estuarine rivers of the region.

As a basis for further investigation, an additional aim was to identify and describe the headwater morphology of tidal creeks. This aim was adopted to determine whether hydrodynamically dissimilar parts of riverine estuaries in the region (see Figure 14), with different tide versus flood discharge relationships, are associated with depositional fans or erosional gullies at the heads of tidal creeks (Woodroffe et al, 1987; Vertessy 1990). The potential for interplay between large magnitude meteorological and oceanographic physical processes to drive changes on the floodplains was also briefly examined.

Broad, low-lying coastal floodplains flank the southern shores of Van Diemen Gulf (Fig 1). The elevation of the floodplains is very close to mean high water spring tide level (Vertessy 1990; Wasson 1992) such that substantial inundation occurs when ocean or river water levels in the estuaries exceed the highest astronomical tide. The floodplains comprise contrasting landscapes in the western and eastern parts of the Gulf. In the west, at Chambers Bay (Fig 1) particularly, and along Finke Bay to the Wildman River, there are no rivers with well-developed tide-dominated estuarine components. Here the floodplains are dominated by extensive tracts of freshwater meadows, with billabongs and palaeochannels. Further east, the lowlands of the Alligator Rivers Region are comprised of floodplains adjoining large river systems. The largest is the South Alligator River with a catchment area of approximately 11 878 km^2 and a tidal reach extending up to 105 km inland of the coast.

During the past 50 years, freshwater meadows and billabongs of the floodplains in Van Diemen Gulf increasingly have been subject to saltwater intrusion, principally through landward extension of tidal creeks (Chappell 1988, Bayliss et al 1997). The problem has been especially apparent on pastoral leases in the vicinity of the Mary River (Knighton et al 1991, 1992, Woodroffe & Mulrennan 1993) and has been attributed to the impact of buffalo in tracking across low levees along tidal creeks and linking the creeks to palaeochannels. However, interactions between very large magnitude meteorological and oceanographic processes are more likely to be major drivers of floodplain development (Winn et al 2006).

The character and regional extent of saltwater intrusion around the shores of Van Diemen Gulf and elsewhere in the wet-dry tropics of Australia is largely unknown. Incursion of tidal creeks into freshwater meadows on the floodplains of Chambers Bay is apparently driven by wet and dry season differences in the relative intensities of sea-level, tide and flood conditions, with flood channels scoured in the wet season and subsequently dominated by tidal flows in the dry season. This is arguably not different from the Alligator Rivers Region although effects on superficial landforms may be very different. For example, markedly different tide versus flood discharge relationships and morphologies occur along the estuarine reaches of rivers in the Alligator Rivers Region compared with the tidal creeks of Chambers Bay (Chappell 1988). As a result the manner in which tidal networks have expanded apparently differs for disparate reaches of the river estuary.

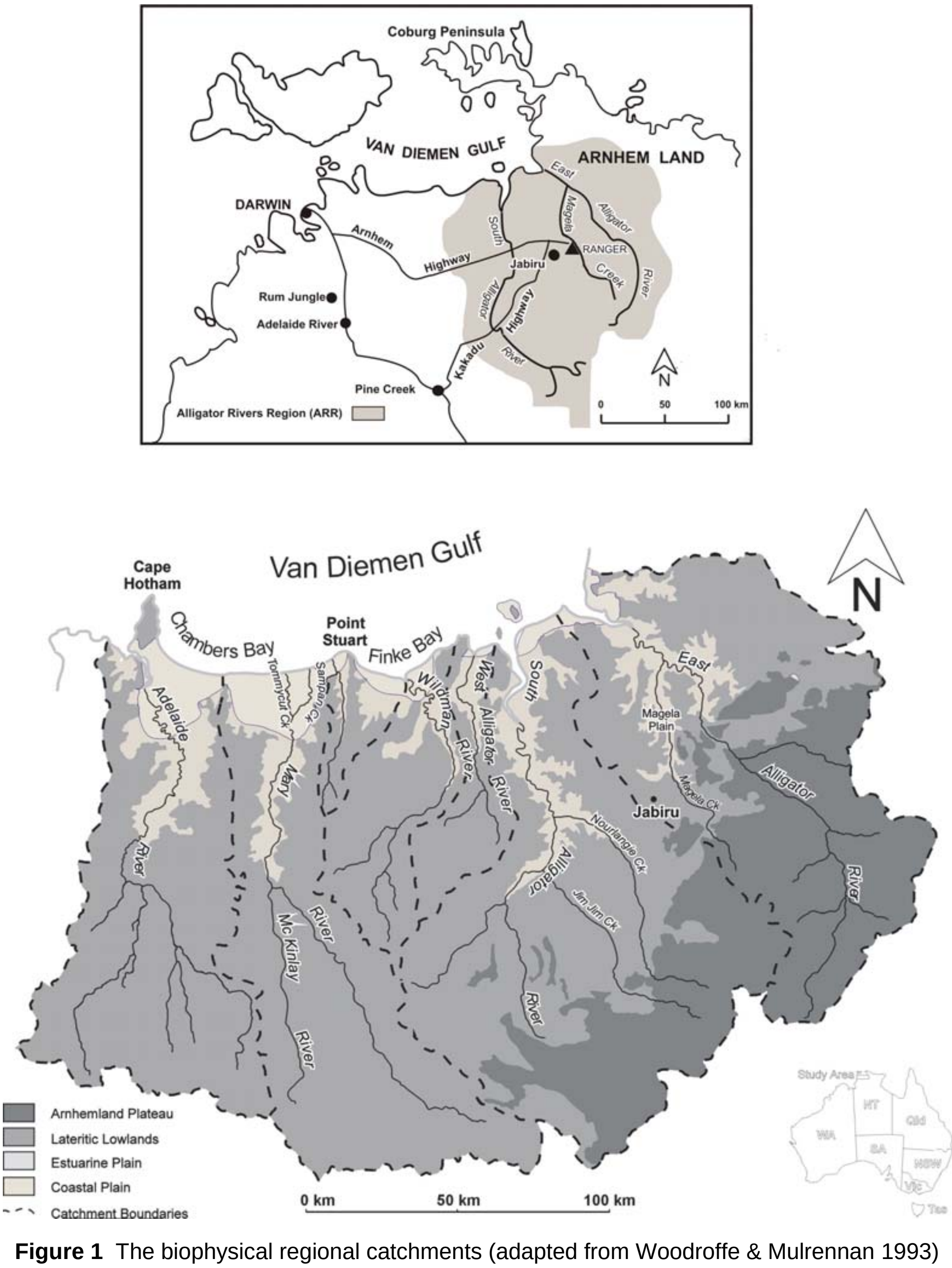

Figure 1 The biophysical regional catchments (adapted from Woodroffe & Mulrennan 1993)

1.1 Research context

The Alligator Rivers Region encompasses the catchments of rivers draining into Van Diemen Gulf between Point Stuart and the eastern bank of the mouth of the East Alligator River (Fig 2). It lies to the east of Darwin (Fig 1); includes all of Kakadu National Park – a reserve of World Heritage significance; and is part of a biophysical region encompassing all coastal wetlands from Cape Hotham to the western flank of the Coburg Peninsula. Rivers with long tidal reaches include the Wildman, West Alligator (Marangarrayu), South Alligator and East Alligator Rivers. Evidence of recent tidal creek extension and problems associated with intrusion of saltwater into freshwater environments has been observed and described within the literature for a number of rivers debouching into Van Diemen Gulf, including the Mary and South Alligator Rivers.

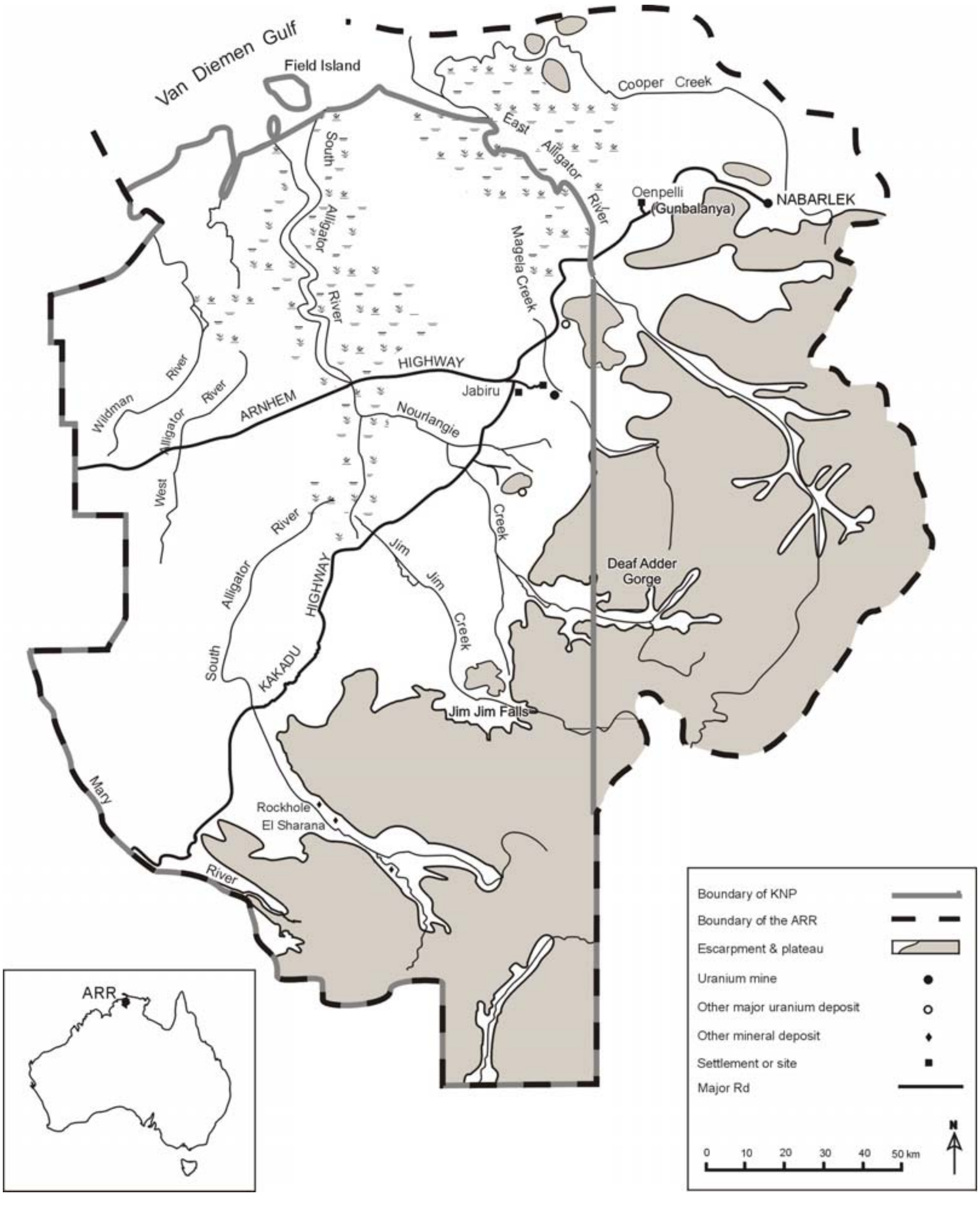

Figure 2 The Alligator Rivers Region (ARR) including Kakadu National Park

Knighton et al (1991) have documented dramatic changes to the lower Mary River floodplains associated with upstream expansion of the dendritic tidal creek network since 1950. Tidal creek expansion has resulted in the reimposition of a saltwater influence on the floodplains (Knighton et al 1991). Saltwater has invaded low-lying freshwater wetlands, destroying the associated vegetation and causing dieback of large areas of *Melaleuca* (paperbark) spp.

From a comparison of 1950 and 1983 aerial photography, Woodroffe et al (1986), Fogarty (1982) and O'Neil (1983) identified evidence of recent tidal creek extension and saltwater intrusion on the South Alligator River floodplains in the Alligator Rivers Region. Several tidal creeks have extended headward towards freshwater wetlands of the floodplains. Mangroves have encroached on creeks that have become more tidally active. Areas of upper intertidal higher level mudflats have expanded apparently due to more frequent tidal inundation. Woodroffe et al (1986) noted areas of dead *Melaleuca* spp swamp as evidence of saltwater intrusion into freshwater billabongs and swamps via the extending creeks.

Similar observations of *Melaleuca* spp dieback have been observed on the Magela Creek system of the East Alligator River (Williams 1984). From comparison of aerial photographs taken in 1950 and 1976, 38% of the perennial freshwater forest, dominantly *Melaleuca* spp that covered almost 60% of the floodplain in 1950, suffered significant loss. The changes in *Melaleuca* spp forest density was attributed to factors other than plant succession and sediment accumulation in the swamp, although saltwater intrusion was not specifically identified as a causal effect. Lowry & Riley (2004) subsequently found a further 21% decrease in the overall density of *Melaleuca* spp between 1976 and 1996.

2 Factors contributing to saltwater intrusion

Several very large magnitude physical factors determine biophysical changes on the floodplains and contribute substantially to the estuarine processes driving intrusion of salt water into the coastal lowlands and formation of the coastal plains. They include variability of climate, fluctuation in sea level, stream hydrology and morphology of the coastal plain. In turn, these contribute to secondary processes affecting the stability of tidal creeks, such as the distribution of vegetation communities and human use of the coastal plain. All factors require further field survey and closer examination. In particular, evaluation and modelling of the fresh and saline water interface requires a well surveyed long profile as well as surveyed channel cross-sections to identify channel width and depth in a manner similar to the surveys conducted by Vertessy (1990) in the South Alligator River for numerical modelling and a fuller appreciation of processes affecting the development of tidal creeks.

2.1 Wind and weather

Three features of the regional climate are of direct relevance to the hydrology of tidal streams: the seasonal rainfall pattern; changes in wind direction, including the frequency and the incidence of tropical cyclones and associated storm surge. Rainfall relates to run-off from the floodplains as well as water level within the main river systems. Winds, including those generated by tropical cyclones, affect waves, water levels at the coast and currents in the estuarine reaches of the rivers. Unfortunately, no wave statistics are available for the southeastern part of Van Diemen Gulf. However, the wave regime is unlikely to be a significant factor in the narrow riverine estuaries of the Gulf. In the sheltered waters of the Gulf, and especially because the shore is flanked by a broad, shallow sub-tidal terrace, the most significant processes affecting salt water intrusion of the coastal lowlands are those