

# AN INTERDISCIPLINARY APPROACH FOR UNDERSTANDING AND MANAGING A SUB-TROPICAL COASTAL WETLAND ECOSYSTEM: NATIVE DOG CREEK, SOUTHEAST QUEENSLAND, AUSTRALIA.

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Coastal wetlands in sub-tropical Australia are increasingly under pressures from population growth and development. To understand and manage the complex systems sustainably requires the integration of knowledge from many disciplines about processes and how these operate. The research takes an interdisciplinary approach to understanding a coastal wetland in sub-tropical south-east Queensland and how it has been impacted by management activities. It starts with a conceptual model and explores this in five discrete but interrelated studies: stratigraphy, pollen analysis, climate and meteorology, soil chemistry (acid sulfate soils assessment), and more recent land use changes. The historical development of the area is outlined using long-term information from sediment cores and pollen analysis as well as more recent history from documents relating to European settlement and aerial photographs for the recent past. Climatic and soils data elucidate the effects of weather variability on the system and are used to assess the impact of drainage works on the flood plain and especially on acid sulfate soils. It concludes that human activities in the area, particularly in the last half of the 20<sup>th</sup> century, have led to rapid changes. The major issues are salinisation from tidal intrusion into ditched areas and the oxidation of acid sulfate soils resulting from disturbance of the substrate for development-related purposes. Management recommendations include restoring the hydrology and managing land use.

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## INTRODUCTION

The importance of coastal wetlands is widely recognised. In Australia over 80% of the population live within 50 km of the coast. Coastal wetlands are under considerable development pressure and there have been significant wetland losses (Saintilan & Williams, 2000; Department of Environment and Heritage, Australia, 1996). To avoid the long term degradation of low-lying coastal environments due to development activities, it is critically important to provide relevant and robust scientific information to decision makers on the likely hazards and risks associated with climate change. Sea level rise and the disturbance of coastal acid sulfate soils are particularly relevant. Both issues, if inappropriately managed, have the potential to adversely impact on

biodiversity and water quality. The importance of this is reflected in environmental planning policies (for example, Queensland Government, 2002).

It is difficult to manage coastal wetlands sustainably, as these are complex systems and management needs knowledge of processes from many disciplines, each with its own approach. Integrating knowledge and methods from several disciplines is an interdisciplinary approach defined by Klein (1990) as a process of solving a problem that is too broad or complex to be dealt with adequately by a single discipline or profession. It is thus suited to analysing complex environmental problems, such as understanding wetland ecosystem processes and their management. This paper reports an application of the

interdisciplinary approach to an estuarine system in sub-tropical Australia. The aim is to investigate the factors affecting ecosystem evolution in both the long and short term, using a conceptual model adapted from Maltby et al. (1994). After introducing the model there are five discrete, but interrelated, studies that have been detailed individually in Anorov (2004). First, a geologic/geomorphic investigation provides a framework for understanding how the wetlands evolved during the Holocene Epoch. Second, a palynological study enhances the geological research, examining the directions of ecosystem change evident in the pollen record over some 6000 years. Third, climate and meteorology were linked to hydrology, essential for understanding the risks of the fourth study of acid sulfate soils. Finally, historical research identified the extent of the impact of human activities on the ecosystems. The conceptual model guides the research components. It can aid understanding of the ecosystems as well as potentially informing management about some of the consequences of modifying the wetland system.

## MATERIALS AND METHODS

### STUDY AREA.

The location of the study area is shown in Fig. 1. It is approximately 1km<sup>2</sup> of the lower Native Dog Creek sub-catchment (27° 41' S, 153° 15' E), an ephemeral stream, within the lower Logan River, that joins Moreton Bay some 40 km south of Brisbane. The climate is sub-tropical humid with a summer rainfall maximum. The mean annual rainfall is around 1200 mm. Temperatures range from a mean monthly maximum in July of 21.3°C to 29.6°C in January. The tides are semi-diurnal with an annual range of approximately 2.5 m. The area is underlain by acid sulfate soils (ASS) (Smith et al., 2000). There are four major wetland vegetation types, ranging from freshwater communities of *Melaleuca quinquenervia* (Cav.) ST Blake and *Casuarina glauca* Sieber ex Sprengel above the highest tides, to the intertidal vegetation with saltmarsh towards the landward edge (*Sporobolus virginicus*, (L. Kunth) and *Sarcocornia quinqueflora* (Bunge ex Ung.-Stern)) and with mangroves closer to the tidal source (mainly *Avicennia marina* (Forsk) but with some *Aegiceras corniculatum* (L.) Blanco).

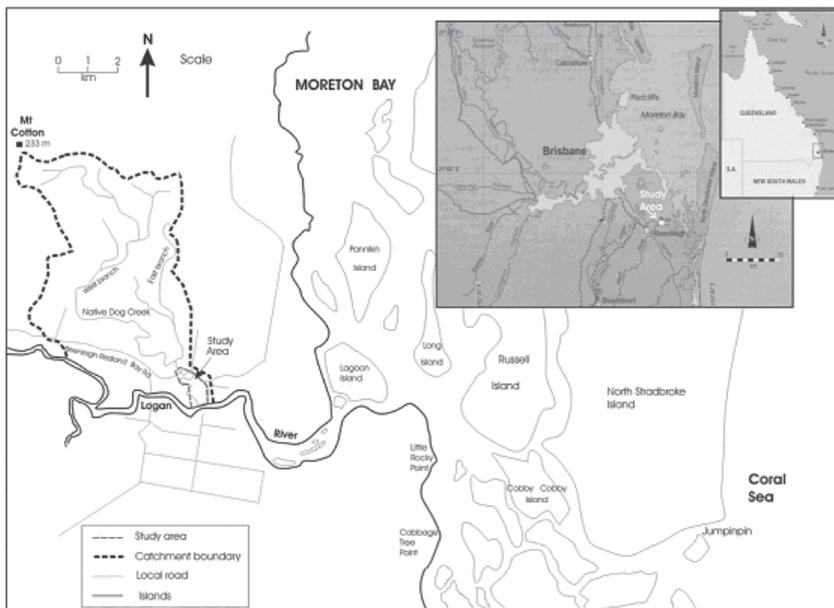


FIG. 1. Location of study area, Native Dog Creek Catchment.

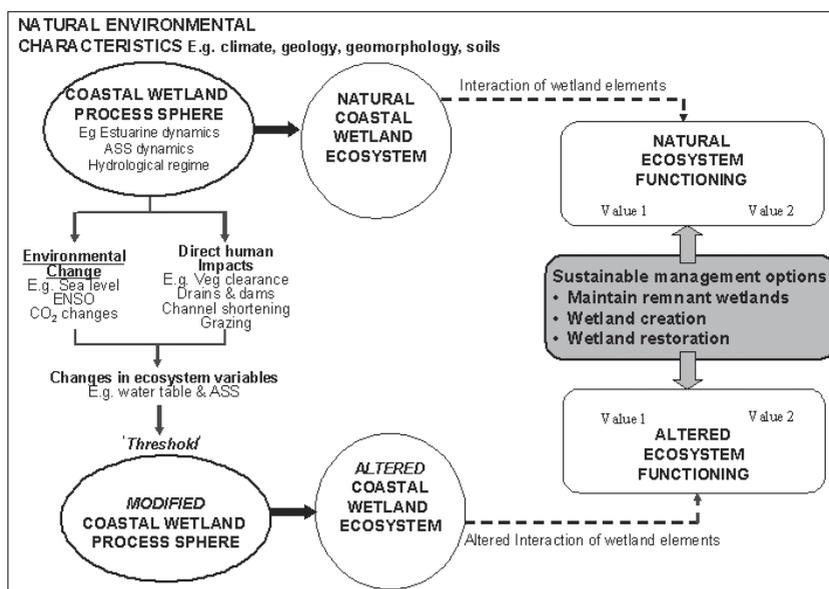


FIG. 2. Conceptual model of interdisciplinary research.

European settlement in the Logan River catchment and associated land clearing since the mid 19<sup>th</sup> century has resulted in the destruction of 99% of Eucalypt forest on the alluvial flats and 85% of freshwater *Melaleuca* forests in the catchment (Society for Growing Australian Plants, 2002). It is estimated that about 23 % of the intertidal wetland vegetation has been lost (Anorov, 2004).

#### METHODS

A conceptual model was modified from Maltby et al. (1994) to show the interactions of factors that influence ecosystem functioning, both from natural processes and anthropogenic ones (Fig. 2). The present research is in the context of the model. The range of disciplines and methods used in this research is shown in Table 1. For some of the research, as indicated in Table 1, published reports and data were consulted and secondary data used: for example for the meteorological information and historical aspects of land use. Primary data (used for stratigraphic modelling, pollen and acid sulfate soil analysis) was obtained from two transects within the study area, with additional field observations to capture elevation data. Elevation data was related to the Australian Height Datum (AHD), with an accuracy of 0.5 cm. Soil and sediment samples were taken from six bore holes up to 18 m deep along one of the two transects that extended

several hundred metres from the intertidal wetlands to the upland (Fig. 3). There were two drill holes each in the *Melaleuca* swamp close to Native Dog Creek, in the backplain and on the intertidal flats.

Acid sulfate soils sampling and laboratory analysis was undertaken in accordance with Ahern et al. (1998). Radiocarbon dating was carried out in accordance with Gupta and Polach (1985). Pollen processing methods used were developed by Dr Mike Macphail specifically for Holocene estuarine sediments and are outlined in Anorov (2004). Pollen taxa were grouped according to their ecology to facilitate identification of past depositional environments and their relative abundance formed the basis for palaeoenvironmental interpretation. Water quality measures in the field were made using standard meters. Aerial photographs were used to map land use changes.

The research began by examining the geological/geomorphological history of the area and similar estuarine environments in eastern Australia and the processes that influenced the evolution of the Logan River floodplain and its coastal tributary, Native Dog Creek. This provided a contextual and practical framework upon which to examine supporting palynological, hydrological, pedological, and more recent historical data.

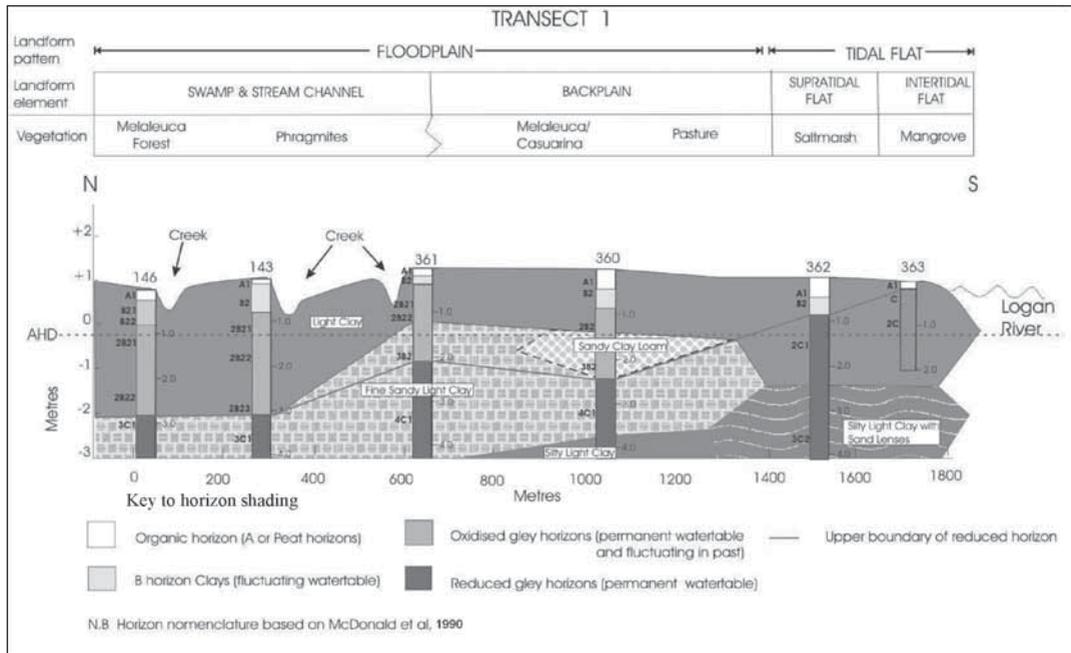


FIG. 3. Stratigraphic cross section of study area showing landform patterns and elements, vegetation and soil morphological data.

The following sections summarise the model and the main findings from each component and show how they relate to the model of wetland characteristics and processes.

## RESULTS

### THE CONCEPTUAL MODEL

The conceptual model shown in Fig. 2 represents a holistic understanding of the coastal wetland environment and of the impact of human-induced changes upon that environment. It is briefly described below and then applied to the results in the discussion.

The model embodies important information and understanding from many relevant disciplines, as indicated in the following route through it. First there is the framework of *natural environmental characteristics*, such as climate, geology, geomorphology and soils. This is the context in which coastal wetland processes operate to create the *coastal wetland process sphere*, comprising dynamic physical, chemical and biological processes. This results in the development of a *natural coastal wetland ecosystem*, its landscapes and associated ecosystem functions.

Ecosystems associated with estuaries and their floodplains evolve naturally in response to processes and events at different time scales: daily (tides), seasonally (river flow), inter-annually (drought periods), extreme events (flood), and at a millennial scale (sea level change). Interactions of the various elements of the natural wetland ecosystem lead to a unique pattern of *ecosystem functioning*, which establishes specific *values* such as land and water quality, and habitat creation. These values are relevant to human, plant and animal communities.

If the *natural coastal wetland ecosystem* is subjected to human activities, *thresholds*, above which the system no longer functions as a natural one, may be exceeded. This leads to a *modified coastal wetland process sphere*. An *altered coastal wetland ecosystem* develops with new and distinctive characteristics, which in turn leads to *altered ecosystem functioning*. To mitigate effects of pressures from, for example coastal development, *sustainable management options* are needed, based on an understanding of the model system.

TABLE 1. Methods and interrelated disciplines used to reconstruct the history of Native Dog Creek and its catchment.

Related discipline/s	Information	Information source	Methods (details in Anorov, 2004)
<b>Geology/geomorphological history</b>			
Geology	Age of depositional environment, sediment accumulation rates	Intact gastropod & bivalve shells	Radiocarbon dating
History Geography	Geomorphological history of the general area	Published research	Description & interpretation
<b>Vegetation history to present</b>			
Palynology	Vegetation history	Samples extracted from cores	Pollen analysis, descriptive statistics & modelling
Botany	Present vegetation	Published literature & local field survey	Description & interpretation
Ecology Geography	Relationship of vegetation to elevation	Vegetation & elevation survey	Quantitative descriptive statistics & qualitative interpretation
<b>Climate, meteorology and hydrology</b>			
Meteorology	Meteorological history	Published data. Bureau of Meteorology	Descriptive statistics & interpretation
Hydrology	Hydrological history	Piezometers, creek levels from field monitoring	Descriptive statistics & interpretation
Surveying	Elevation	Field survey	Description & modelling
<b>Pedology &amp; chemistry of soils</b>			
Pedology/ Soil Science	Substrate (soil & sediment morphology)	Logging of substrate cores in field, particle size analysis	Description, interpretation & Modelling
Chemistry	Soil & water chemistry (including Acid Sulfate Soils)	Sampled in field; tested & analysed in field and laboratory	Descriptive statistics & modelling
<b>Recent land use history and human modification</b>			
History	Recent land use history & environmental condition (since 1826)	Historical records: survey plans, photographs, topographic maps, aerial photos	Description & interpretation

The following sections trace the path through the model for the study area, for its important aspects.

#### GEOLOGICAL/GEOMORPHOLOGICAL HISTORY

The *natural environmental characteristics* of the area are based on its geological and geomorphological history. The coastal bedrock topography of the area north of the Logan River at Carbrook is largely composed of the weakly metamorphosed Neranleigh-Fernvale Beds that extend to the river mouth (Beckmann, 1967). These beds constrain the Logan River to the north and have limited the extent of the flood plain. The early geomorphology evolved as a result of sea level fluctuations and changing estuarine and fluvial regimes during the late Pleistocene and Holocene periods. It consisted of four major phases: Late Pleistocene; Holocene Transgression; Estuary Fill; and Floodplain Development (see Table 2). The

history is preserved in sediments that were deposited in response to Holocene sea level rise under a mesotidal, tide-dominated regime. The Logan River system and its Native Dog Creek sub-catchment have evolved from an infilling estuary since the peak of the Holocene transgression 6500 yrs before present (Table 2).

Changes in sea level influenced the nature of the Logan estuary and the environment in which Native Dog Creek developed. In turn, the connection between Holocene coastal sediments and the formation of sedimentary pyrite strongly influenced the soil properties within the study area. The potential oxidation of pyrite and the subsequent release of sulfuric acid into streams and estuaries related to inappropriate development render these coastal ecosystems vulnerable to environmental degradation if mismanaged. This aspect is examined later.

TABLE 2. Summary of stratigraphy as it affects the study area (adapted from Anorov 2004).

Phase	Time (BP)	Mean Sea Level	Event	Lower Logan River & Native Dog Creek area
FLOODPLAIN DEVELOPMENT	Present	< 0.5 m	Contemporary sea level rise 1 mm/yr during past 40 years	River extends across newly created surface, excavating the top of estuary fill
	1 000			
	2 000			
ESTUARY FILL	3-4 000	+1 to 1.5m	Sea level begins to fall to present levels.	Development of Logan deltaic plain
	6- 6 500		Sea level Stillstand -	Estuarine infilling of Moreton Bay commences
HOLOCENE TRANSGRESSION	10 000	-25 m	Rapid sea invasion of incised river valleys	
LATE PLEISTOCENE	18 000	-130 m	Sea level Lowstand –	Shoreline about 50 km east of Moreton Island
	30 000	-48 m	Several oscillations in sea level	Logan River adjusts to new base level as sea level falls

POLLEN ANALYSIS (VEGETATION HISTORY)

The development of geomorphic features that control the extent of freshwater input, drainage and salinity has influenced the mid-late Holocene vegetation history of the area. Pollen analysis, when considered together with the geomorphic evolution of coastal sedimentary sequences, can make useful contributions to clarifying details of past processes and succession and to the understanding of the evolution of the landscape and the *coastal wetland process sphere* (Fig. 2). In the present study, pollen analysis provided valuable information about rates of ecological change within the study area since sea level stabilised 6500 years before present. An example of the pollen record is shown in Fig. 4 for what is currently a freshwater *Melaleuca* forest. In response to the progradation of the present shoreline after sea level stabilised, the fossil pollen record at the *Melaleuca* forest site showed changes from mangroves and saltmarsh to freshwater wetlands between the early-mid Holocene and the late Holocene, a change that took around 800 years. The estimate of dates was based on the results of radiocarbon dating. In other pollen cores there was evidence of pine tree pollen in the recent past, indicative of introduced species following European settlement. That change has occurred over 170 years.

CLIMATE, METEOROLOGY AND HYDROLOGY

Climate is part of the *natural environmental characteristics* and climate and meteorological processes are part of the *coastal wetland process sphere* shown in Fig. 2. Superimposed on geological processes and sea level changes they help to further explain landscape and ecosystem changes (interaction of wetland elements, Fig. 2). Apart from inferences from stratigraphic and pollen analysis there are no very long-term records for climate variables for the area. The closest recording station, about 10km to the west at Beenleigh, has 130 years of rainfall data. These data showed the periodicity and variability of annual precipitation for the area (Fig. 5). Historically, the region has experienced periods of prolonged wet and dry conditions of 5-20 years duration. These have implications both for the hydrological and acid sulfate soil processes in the *coastal wetland process sphere* (Fig. 2).

In the recent past, the 10-year records from the Logan City Water Treatment station (8 km west of the study area) indicate that the most likely period of moisture deficit, based on mean values, is during the eight months from July to February and that an excess of rainfall over evaporation, on average, occurs only in May (Fig. 6).

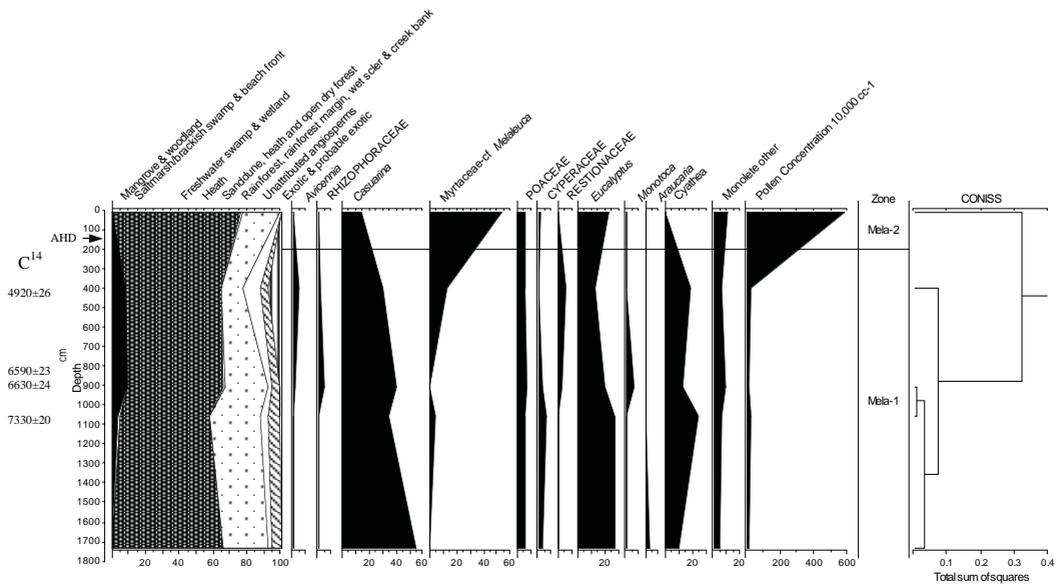


FIG. 4. Summary pollen record of *Melaleuca* wetlands. The x axis shows the percent of total pollen for each of the plant types displayed; the hierarchy on the right is result of a cluster analysis.

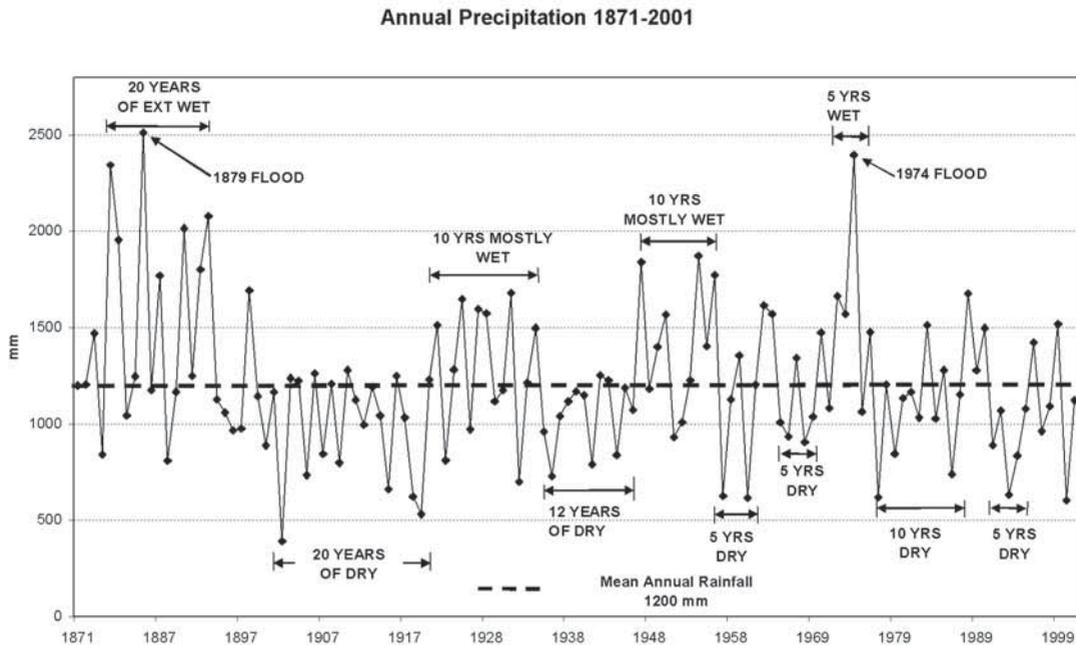


FIG. 5. 130 years of annual rainfall data for Beenleigh Post Office (10km from study area).

The area is also subject to drought. Between 1992 and 2002 the creek completely dried out during five dry periods and there were four flood events when the wetland was inundated for periods of two to nine months as shown in Fig. 7 (M. Greenway (pers. comm.)). Four to five days of heavy rain during January 2001 flooded the *Melaleuca* wetland and nearby *Eucalyptus* forest and these habitats remained flooded for approximately two months (personal observation).

The lower reaches of Native Dog Creek are tidal, though its tidal limit is dynamic and thus salinity is variable. Electrical conductivity (EC) of the creek water in the vicinity of the *Melaleuca* wetland was measured on eight separate occasions between June 2000 and October 2002. The minimum and maximum EC values during this period were 0.3 and 26.0 mS/cm respectively, with a mean of 8.89. Previous studies have shown that, when the creek is flowing, salinity and conductivity levels are generally low (Bradley, 1996; Richards, 1998). However, during extreme high water spring tides, saline waters extend a considerable distance into the *Melaleuca* wetland of the study area. Extreme spring tides combined with localised flooding of the Logan River, force saline waters upstream beyond the Beenleigh-Redland Bay Road (Fig. 1) (Greenway & Kordas, 1994). Saline incursions over

extended periods may lead to the decline and death of freshwater species.

#### PEDOLOGY AND CHEMISTRY OF SOILS

The *natural environmental characteristic* of Humic Gley soils are dominant in the area, using the Great Soil Group classification of Stace et al. (1968). According to the Australian Soil Classification system (Isbell, 1998) all soils in the area are either sulfidic or sulfuric Hydrosols, with the exception of the profiles located within the seasonally dry bed of Native Dog Creek in the *Melaleuca* wetland. Those were

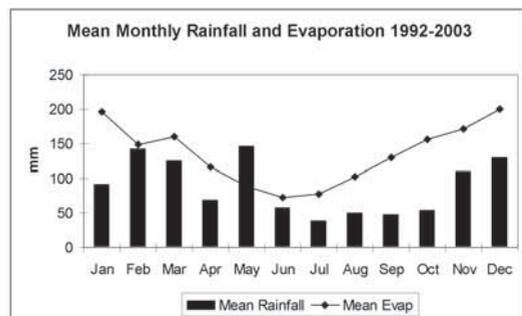


FIG. 6. Mean monthly rainfall and mean monthly evaporation, 1992-2003, Logan City.

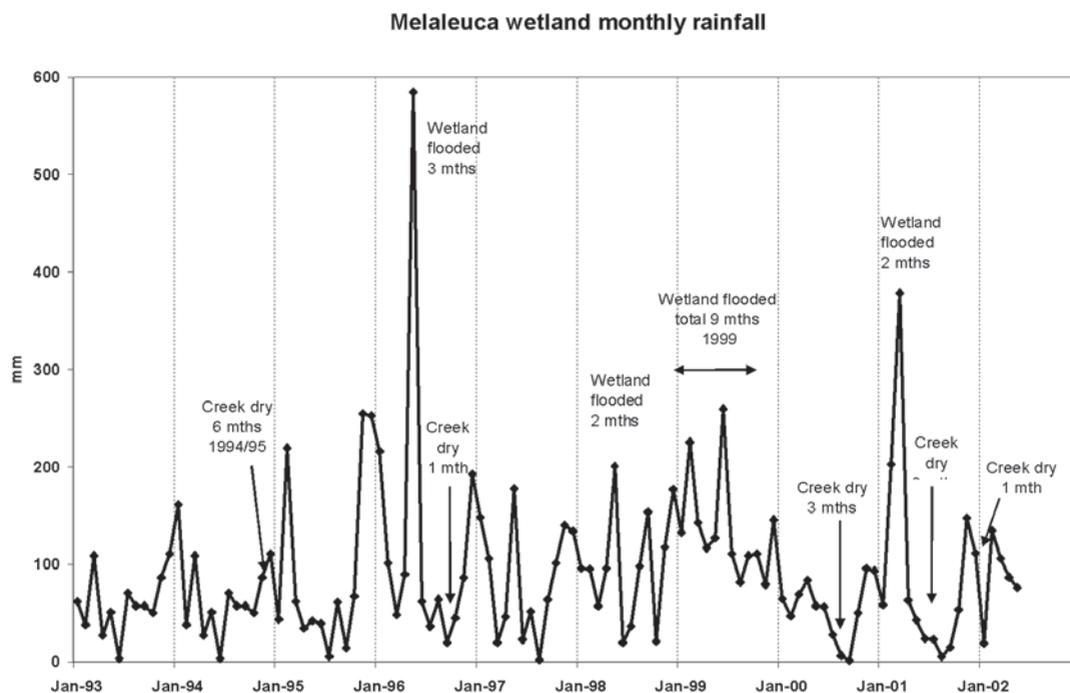


FIG. 7. *Melaleuca* wetland: 10 years of wet and dry periods, Native Dog Creek.

classified as Organosols due to the very high organic carbon content of the peat, with sulfidic subsoils. All soil forms in the wetland are acid sulfate soils as a result of the study area's geomorphic evolution. The original depositional environment of the study area was estuarine, and included sediments that were typical of central basin and fluvial delta environments - environments that were ideal for the accumulation of pyrite. As the estuary infilled, the landward part of the embayment was progressively isolated from estuarine conditions until freshwater/brackish conditions dominated and *Melaleuca* and *Casuarina* wetlands were established. It was during this phase that sulfide oxidation was likely to have occurred, the consequence of which is still evident by the enriched sulfate levels of the ancient soil pore water.

The soils that are not regularly tidally inundated on the Spring tides (that is, those with *Casuarina* and *Melaleuca* vegetation) are typical acid sulfate soils with sulfuric horizons overlying a sulfidic subsoil (Isbell 1998). Table 3 shows some characteristics for those wetlands near the surface and at more than 2.5 m deep. This summarises the distribution and concentration of both actual and potential acid sulfate soils within the study area and assists in identifying

areas that display extreme sulfide content.

The study, based on two transects, found that the alternation of excessively wet and dry conditions over 130 years (as shown in Fig. 5), combined with high organic carbon levels and variations in microtopography, provided ideal conditions for the reformation of pyrite in the stream channel and other low points within the *Melaleuca* wetlands.

Another important factor in the acidification process (*coastal wetland process sphere*) is the moisture balance of the soil profile. Lin & Melville (1993) suggested that upward movement of solutes occurs in response to the evaporation of water from the capillary fringe (the saturated zone of the soil profile above the water table). In the study area a moisture deficit is likely to occur, on average, for up to eight months of the year (from July to February, Fig. 6) and, even in the stream bed, drought conditions (during early 2001) led to low pH (e.g., 2.88) and high EC values (e.g., 23.9 mS/cm) in the remnant pools, accompanied by heavy deposits of iron floc. However there was also a large rain event later in January 2001, and, after this, quantities of iron and aluminium that greatly exceeded ANZECC (2000) Water Quality

TABLE 3. Soil pore water chemical characteristics at 2 sites in the Native Dog Creek wetlands (adapted from Anorov, 2004).

Vegetation		<i>Casuarina</i>		<i>Melaleuca</i>	
Depth (m)		2.8	1.3	3.3	1.5
Acid Sulfate status		PASS	AASS	PASS	AASS
Standard Water Analysis					
pH		4.1	4.1	6	4.6
Conductivity	mS/cm	15	19	15	14
Aluminum	mg/L	0.1	81	0.1	22
Iron	mg/L	440	250	150	3.3
Chloride	mg/L	4800	6400	4400	4600
Chloride:Sulfate ratio		2.6	5.8	2.2	5.7

PASS - Potential Acid Sulfate Soils

AASS - Actual Acid Sulfate Soils

Guidelines were released from the soil into the flooded *Melaleuca* forest (see Fig. 3 for location of *Melaleuca* wetland/swamp). Richards (1998) reported similar observations for this wetland. The groundwater was also strongly acidic with elevated concentrations of soluble iron, aluminium and manganese.

Acid and aluminium affect *natural ecosystem functioning* and can cause severe gill and skin damage in exposed fish causing death, or, under sub-lethal conditions, increasing susceptibility to fungal diseases such as epizootic ulcerative syndrome (Sammut et al., 1999). The effects of estuarine acidification can occur at all trophic levels and cause short- and long-term environmental degradation (Sammut, 1998). To avoid such problems, any disturbance of these areas requires prudent and effective management strategies (*sustainable management options*) that include detailed elevation and acid sulfate soil investigations.

The influence of geomorphic and climate processes, local meteorological events, hydrology and soils is expressed in the existing wetland vegetation as an expression of the *natural coastal wetland ecosystem* (Fig. 2). This has been described earlier, but is augmented by examining the recent land use history and *direct* and *indirect human impacts*. This is summarised in the following paragraphs.

#### RECENT LAND USE HISTORY

Analysing historical records of the local area provided valuable insights into the environmental changes that followed the introduction of European

land management practices more than 170 years ago. However, combining historical data with field assessment of the disturbed *Melaleuca* area, revealed that the impact of human activities on this section of the study area had occurred at a rapid rate, possibly exceeding the *threshold* at which the natural system can function, at least in the short-term, as evidenced by dieback observed in the field during 2001-2004 and on the 1995 aerial photograph (mapped in Fig. 8).

#### HUMAN MODIFICATION OF THE AREA

A chronology of change in the study area was derived from aerial photographs taken between 1944 and 1995, followed by site inspection in 2002 (Anorov, 2004). It has also highlighted the impact of human activities, reflecting the development of this part of Queensland and the demands for services. The 1944 and 1995 maps from the photographs are shown in Fig. 8. The most notable changes (apart from clearing vegetation) have been related to the hydrology, with channel shortening of Native Dog Creek, ditching of the area, and the construction of a golf course with many ponds. Based on aerial photograph interpretation, the development of the golf course in 1989 included the removal of several creek meanders so that by 1990, the original length of the creek had been more than halved. This led to the incursion of saline water into a section of the freshwater *Melaleuca* wetlands identified as '*Melaleuca dieback*' in Fig. 8.

An assessment of the soils, in the '*Melaleuca dieback*' area confirmed the presence of acid sulfate soils throughout the profile (Anorov, 2004). The results

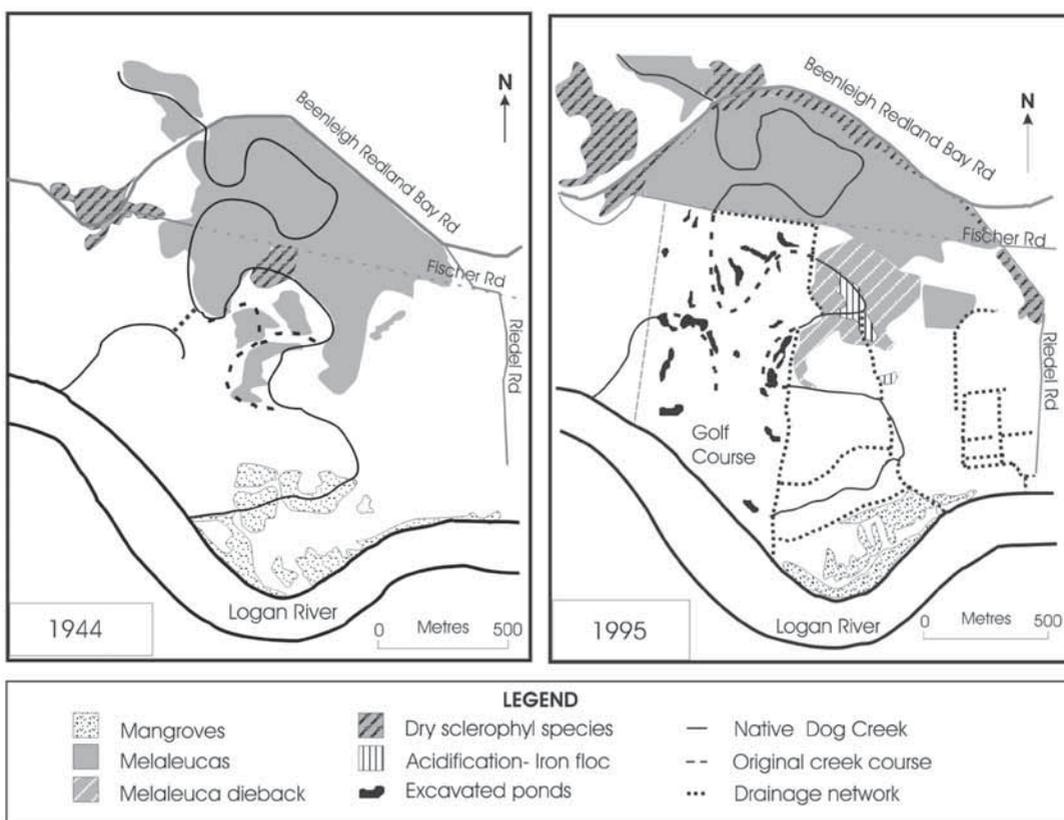


FIG. 8. Changes mapped from aerial photographs 1944 and 1995, Native Dog Creek, Logan River (adapted from Anorov, 2004).

of soil pH before and after field peroxide oxidation are shown in Fig. 9. The greatest reduction in  $\text{pH}_{\text{FOX}}$  occurred at the surface, at 0.75 m (where  $\text{H}_2\text{S}_2$  odour was detected) and below 2.0 m.

Field observations indicated that this area is irregularly inundated with saline tidal water from Native Dog Creek via low points in the creek bank that appear to have been trampled by cattle. These factors, combined with a fluctuating water table, are likely to have influenced subsoil oxidation. The change in hydrological conditions from freshwater to saline conditions resulted in the progressive decline in health and ultimately, the death of this section of *Melaleuca* trees. The dead trees became unstable, falling haphazardly and creating a hummocky microrelief. The hummocks were occupied by *Sporobolus virginicus* or, at slightly lower elevations, there were bare patches (acidic salt scalds)

showing salt efflorescence and coated in iron floc. The processes of salinisation and acidification, followed by vegetation dieback, has resulted in an *altered coastal wetland ecosystem*.

## DISCUSSION

### APPLICATION OF THE BIO-GEOMORPHIC MODEL

The model in Fig. 2 has exemplified the ways in which coastal wetland ecosystems function and how these respond to both natural and anthropogenic processes and pressures. *Natural environmental characteristics* were shown to have provided the context in which the landscape has evolved. Of particular importance in the study area are climate and sea level changes during the Holocene. The *coastal wetland process sphere*, for the Native Dog Creek study area is dominated by its climate and hydrology. Important processes include the formation of acid sulfate soil. Together with its

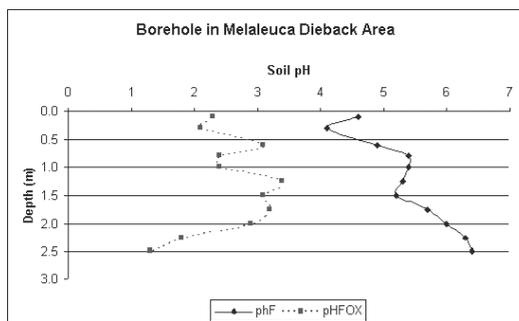


FIG. 9. A comparison of field (pH<sub>f</sub>) and after field oxidation (pH<sub>FOX</sub>) down the soil profile in the *Melaleuca* dieback area.

geomorphology and plant succession the *natural coastal wetland ecosystem* landscapes and associated *natural ecosystem functioning* have developed.

In the more recent past, a variety of human activities have affected the development of the system leading to a *modified coastal wetland process sphere* with alterations of important wetland characteristics. Given sufficient time and depending on the magnitude of modification, an *altered wetland ecosystem* forms and develops new and distinctive structural and functional characteristics. This study identified an altered hydrological regime (drainage and stream channel shortening). The change in hydrodynamic conditions, from freshwater to saline conditions and, especially within the former freshwater systems, resulted in the progressive decline in health, and ultimately, the death of a section of the *Melaleuca* wetlands (Fig. 8). As well there have been chemical transformations of soil and water (acid sulfate soils). These are the key human-induced changes to the coastal lowlands of Native Dog Creek that have disrupted their equilibrium. To minimise these negative impacts, sustainable management options are needed to maintain the natural wetland ecosystems and to restore ecosystem health.

Based on the outcomes of research, management options can be determined. For Native Dog Creek recommendations for the restoration of the wetlands include actions to:

- Re-instate the meanders to mimic the original creek morphology. This would reduce salt water intrusion by shifting the tidal limit seawards thereby providing greater opportunity for the former freshwater wetlands to once again experience extended periods of inundation due to seasonal flooding.

- Avoid any further disturbance of Acid Sulfate Soils.
- Neutralise any existing acidity through the application of lime.
- Remove cattle from the freshwater backswamps and backplains of NDC to minimise erosion of creek banks due to trampling.

In future, the land use planning process should assess the risk of disturbing acid sulfate environments and ensure that effective environment management plans are in place to mitigate impacts of any disturbance.

#### EVALUATION OF THE RESEARCH

The strength of the research lies in its interdisciplinary nature, integrating the morphostratigraphic, hydrologic, pedogenic and vegetation history of the coastal lowlands of Native Dog Creek to clarify its dynamic and complex history in the context of a model that reflects that dynamism (Anorov, 2004). It should be recognised that altered hydrological regimes, introduced animal and plant species, acidification and salinisation and various land uses are all components and conditions that need to be considered in any management strategy.

The research has contributed valuable information in several areas. It has integrated pollen analysis with stratigraphic modelling to provide an enhanced understanding of long-term processes; it has also shown that pollen analysis reflects the advent of European settlement, with the introduction of exotic plants; it has provided important insights into rates of natural ecological change in response to evolutionary changes in the physical environment that will serve as a reference for comparison with rates of change imposed on the existing coastal wetland ecosystem within the last 170 years. An important outcome from the broader pollen study has been the compilation of a pollen reference collection for estuarine south east Queensland, a region that previously lacked such information.

#### FURTHER RESEARCH

Issues that warrant further research include: vegetation dynamics from the late Holocene to the present-day, by high resolution pollen analysis and radiocarbon dating, to provide an enhanced understanding of the effects of post-European land practices and activities on the natural coastal wetland ecosystem; an accurate reconstruction of the palaeoenvironment using diatom analysis to indicate palaeosalinity levels and integrated with pollen analysis and geomorphic research. For example, Tibby (1996) found that the use of diatom

analysis to investigate changing salinity patterns in the Tuross Lake system (south eastern New South Wales) was a powerful tool in elucidating the cause of some changes in the pollen record by indicating the relative importance of influences such as geomorphic change and climate. This is particularly important as the climate change issue becomes more acute.

#### CONCLUSIONS

The research reported here has significance at both the local level and more generally. At the local level its value has been in developing an understanding of the changes that have occurred in the past in the study area. As well it has developed an appreciation of the interaction of many factors, each the focus of different areas of research, including natural processes and events and the impacts of human activities. It was concluded that these wetlands are particularly vulnerable to sea level changes and inappropriate land use. This research found that the greatest risk to the environment from human activities was from the disturbance of acid sulfate soils and specific management strategies were suggested to mitigate such impacts.

More generally, this interdisciplinary study has incorporated a range of processes and methods, from several perspectives, into a conceptual model that could be expected to apply broadly to many coastal wetland environments. Based on the findings of, and integration between the various areas of the research, it is suggested that future coastal management strategies should be intimately linked to a knowledge of their past. It is also vitally important to investigate the hydrological status of coastal tidal creeks (and rivers) in detail, especially as modifications to coastal creeks can result in problems associated with saltwater incursion and wetland drainage of the coastal floodplain. Hydrological modification of coastal tributaries is an important management consideration, particularly as acid sulfate soils are known to exist in many coastal settings in Australia and represent a significant environmental hazard if mismanaged.

The natural environment is continually adapting to altered hydrological conditions. It is apparent that human induced changes over the past 170 years in the study area have occurred at a rate that exceeds rates of change normally experienced in natural systems. Hence the current environment is experiencing degradation through both decline in health (as indicated by *Melaleuca* die-back observed in the field) and loss of indigenous plant species.

The development and implementation of sustainable management options must be informed by robust and relevant scientific information, if ecosystems and the services they provide are to be sustainable.

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