PHOTOGRAMMETRIC SURVEY OF THE TWEED RIVER WETLANDS

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ABSTRACT

Air photographic records of the Tweed River Estuary were compiled for 1930, 1948, 1962, 1978, 1985 and 1994. The distribution of mangrove and saltmarsh was mapped from all photographs for all areas common to all photographs. The survey revealed a substantial increase in the area of intertidal wetland, particularly mangrove, in the period 1930-1994. The increase in wetland area occurred throughout the estuary, including the Fluvial Channel, the Tidal Channel and the Broadwaters. Factors responsible for the changes are suggested.

INTRODUCTION

Tweed River Wetlands

Concern over the potential impacts of renewed dredging has prompted a detailed long-term assessment of changes in the distribution of mangrove and saltmarsh on the Tweed Estuary, and the geomorphological context of these changes. To this end a comprehensive air photographic record was compiled for the Tweed Estuary, covering decadal time intervals from the earliest air photographs taken in 1930.

The distribution of mangroves and saltmarsh on the Tweed River has been mapped on two previous occasions. West *et al.* 1985 produced ***An Estuarine Inventory for New South Wales, Australia*** in which the distributions of estuarine wetland plant communities were mapped between 1981 and 1984. More recently, Australian Water and Coastal Studies (AWACS) completed the Tweed River Wetland Monitoring program (AWACS 1996) at the request of the NSW Department of Land and Water Conservation Tweed River Project. AWACS (1996) mapped the distribution of mangrove and saltmarsh at five sites (three in the Tweed River Estuary, and control sites at Brunswick Heads and Jabiru Island, Queensland) using infra-red photography, flown from 17-19 April 1995. The intent of this data was to serve as a benchmark against which change in the distribution of wetlands might be measured following the impact of renewed dredging.

The photogrammetric survey described in this paper extends the survey of the Tweed saline wetlands both spatially and temporally. This provides a context for the interpretation of monitoring sites and reveals long-term processes shaping the distribution and extent of intertidal wetlands in the estuary.

METHODOLOGY

Geomorphic Setting

The Tweed River drains 1,100 sq.km of humid subtropical catchment, in which the Neranleigh Fernvale Group and the Lamington Volcanics are the dominant geological units (Chestnut 1975). The Tweed River Estuary is a drowned river valley in an intermediate stage infill in the Roy (1984) model (West *et al.* 1985). Three geomorphic settings have been defined for the purposes of this report, each being environments in which intertidal wetlands are subject to particular interactions of hydrological and sedimentological processes. These settings are the Fluvial Channel, the Tidal Channel and the Broadwaters (Figure 1). The geomorphological features of each are described in turn.

The Fluvial Channel

The Fluvial Channel is defined as the estuarine segment from the tidal head to Fingal Point, where estuarine muds and clays give way to marine sands. the intertidal environments are dominated by silts and clays derived from the catchment, and shaped by flood discharge. There is little in the way of marine sedimentation, though reworked marine sand extends in the channel as far upstream as Chinderah Island. The combination of seawater dilution and fluvially deposited clays are

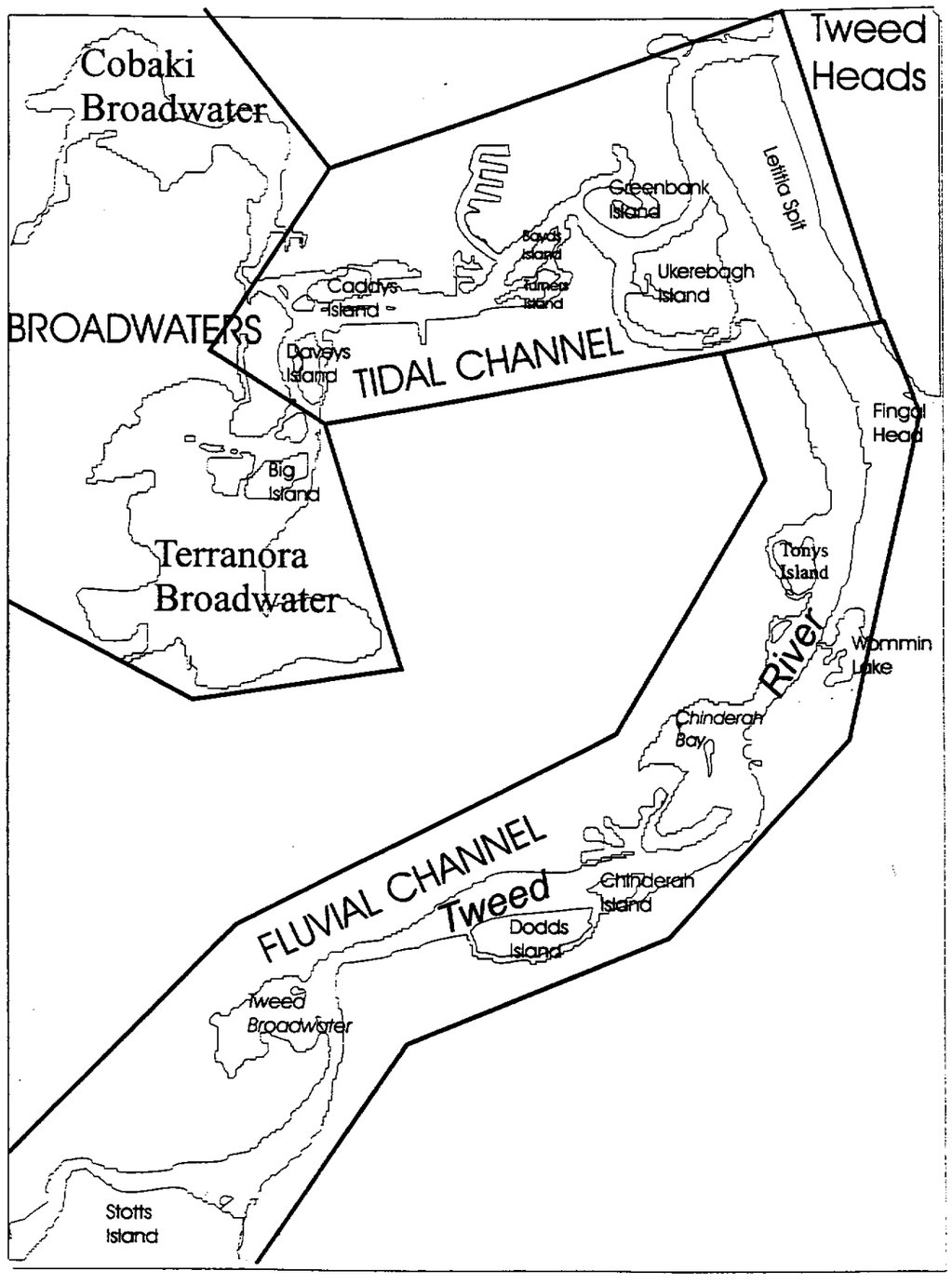

Figure 1: Geomorphic settings of wetland environments on the Tweed River Estuary

likely to promote a locally distinct wetland assemblage structurally and floristically.

The Tidal Channel

The Tidal Channel extends from the entrances of the Terranora and Cobaki Broadwaters to the mouth of the estuary. Sedimentation in this segment of the estuary is dominated by the flood tide, and consists mostly of reworked marine sands forming subaqueous shoals and intertidal deltas, some of which contain wind-blown dunes. Dredging has occurred extensively through this channel (Dreury and Curedale 1979).

The Broadwaters

As a geomorphological unit, the Broadwaters refers to the Terranora and Cobaki Broadwaters, which are linked to the estuary mouth by the Terranora Channel. The Broadwaters represent low-lying coastal land inundated as sea-level reached its present position 6000 yrs BP. The Broadwaters are shallow water bodies being infilled by flood-tidal sedimentation at their seaward end and fluvial sedimentation from small tributaries at their landward edge. Dredging of Cobaki Broadwater 1884-1897 left a series of linear mangrove-covered islands of dredgespoil still present (Druery and Curedale 1979).

Description of methods

Photogrammetry

Photogrammetric analysis in this survey was undertaken using the Wild Aviolyt ACI stereo plotter. This instrument produces high resolution digital spatial data from stereo pairs of aerial photograph diapositives (Hanslow *et al.* 1997). The stereo plotter has the advantage of rectifying distortion in photo scale and differences in scale between photographs, as well as allowing high resolution magnification of images, assisting in interpretation. Ground control was based on Integrated Survey Grid (ISG) control points provided by the NSW Lands Department. The 1962 air photographs were used as a model upon which the 1946 and 1930 distributions were plotted, due to the difficulty in rectifying earlier photographs. Data output was downloaded to a CADD system for analysis and presentation.

Photo record

Photographs were made available by the Department of Land and Water Conservation for the years 1930 (15.8.1930 Springbook – Tweed Heads Qld & NSW zone 8), 1946-47 (2.4.1946 SVY 599, 27.5.1947 SVY 122), 1962 (1962 Tweed Shire), 1971 (Tweed Heads), 1985-86 (Tweed Heads ISG, Coastal Wetlands) and 1994 (Tweed/Clarence Rivers). This analysis treated only those areas common to all photo records which consisted of the estuary downstream of Stotts Island. For this reason the headward extent of mangroves was not measured in any survey and an analysis of changes in the headward extent could not be made.

Interpretation

Interpretation of wetland units followed the precedents set by the reports of West *et al.* (1985) and AWACS (1996). These interpretations then formed the basis of the establishment of discrete wetland units from which analysis of historical changes in wetland extent proceeded.

Analysis

Areas of individual wetland units were calculated in the CADD system. The total areas were then calculated for each wetland type (mangrove, saltmarsh) for each geomorphic setting and for each year. Raw data and digitised maps are held within the photogrammetric division of DLWC. *Casuarina* forest was classified as saltmarsh for the purpose of the analysis.

RESULTS

Substantial increases in the area of mangrove have occurred in all settings over all time periods (Table 1, Figure 2), with the exception of 1962-1971, in which a net decline of mangroves is observed in all geomorphic settings. The decline in the period 1962-1971 is attributed to reclamation and development of intertidal environments. The protection of mangroves has allowed the continuation of the

Table 1: Areal extent (ha) of mangroves and saltmarsh in each geomorphic setting in each year of analysis

Setting	wetland	1930	1948	1962	1971	1985	1994
Tidal channel	mangrove	44.33	69.48	82.17	81.41	79.80	77.65
	saltmarsh	18.79	23.33	22.62	28.36	17.41	18.13
Broad-waters	mangrove	48.61	91.78	97.32	96.09	107.10	112.18
	saltmarsh	2.67	2.75	4.07	9.88	17.32	13.54
Fluvial channel	mangrove	51.19	62.93	68.86	67.41	87.71	92.03
	saltmarsh	5.97	8.02	5.82	14.22	11.52	14.77
Total	mangrove	144.13	224.19	248.35	244.91	274.61	281.87
	saltmarsh	27.43	33.11	36.52	52.47	46.25	46.45

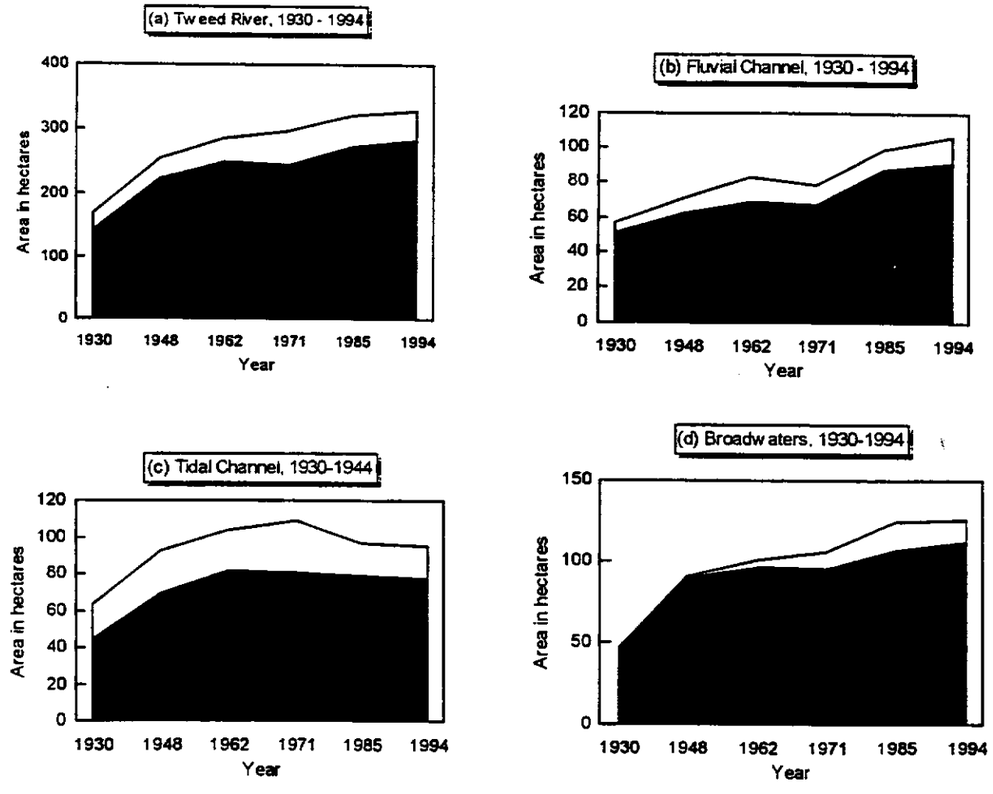

Figure 2: Changes in the extent of mangrove (■) and saltmarsh (□, above mangrove) on the Tweed River in the period 1930-1994 for (a) the Wider Estuary, (b) the Fluvial Channel, (c) the Tidal Channel and (d) the Broadwaters.

expansion of mangrove area in the Tweed Estuary.

Changes in the distribution of mangroves

Extension of the seaward edge

Most of the increase in mangrove area has been due to the extension of the seaward edge of previously existing forests (Figure 3). There are a number of circumstances in which this has occurred.

- Forests fringing the channel have expanded over the study period, particularly in the Boyds Channel south of Dodds Island.
- Sedimentation in the Tidal Channel has led to the extension of Ukerebagh, Boyds, Caddys and Daveys Islands. The 1971 photographs show a considerable increase in the number of mangrove juveniles in the channel and frontal fringes of the islands of Terranora Creek. By 1985 these juveniles had grown to maturity.
- Sedimentation has occurred at the mouths of tributary channels. Following the construction of drainage channels in 1948 and 1971 from a sugar cane plantation to the Tweed Broadwater, significant sedimentation occurred as a delta at the mouth of the channels and the mangrove habitat has prograded seaward. By 1962 extensive seagrass beds had been lost from the broadwater and by 1994, more than 5 hectares of new mangrove habitat had been created.

  The Broadwaters have been subject to lateral accretion at both the flood-tide deltaic entrances and the tributary deltas, extending the area of mangroves in both broadwaters.

Landward incursions of mangroves

While most of the extension in mangrove area has been due to expansion at the seaward edge, landward incursions are also evident at some locations, though the mangrove-saltmarsh boundary has been generally stable. Landward incursions of mangroves has been identified at four locations.

- An unvegetated segment in the centre of Chinderah Island in the 1930 photographs is well vegetated in the 1962 and later photographs.
- A substantial area of saltmarsh in the Tweed Broadwater in the 1971 photographs has by 1994 been lost to mangroves, and a new landward area of saltmarsh has appeared.
- A large saltmarsh area on Caddys Island evident in the 1962 photograph shrunk considerably to 1994.
- Landward transgression of mangroves is likely to have occurred on Ukerebagh Island into saltmarsh on the southern segment of the saltmarsh. Juveniles of *Avicennia marina* appear to be colonising in a northern saltmarsh plain.

Losses of mangrove and saltmarsh

The most significant losses of intertidal wetland in the Tweed Estuary have occurred with the development of Greenbank Island. Historical surveys of the Tweed mouth reveal a number of large islands extending from Ukerebagh to the mouth of the estuary incorporating the Greenbank Island group. These islands from the earliest surveys are highly dynamic, responding in shape and elevation to flood discharge, tidal entrance conditions, wind and waves. By the turn of the century they had been consolidated behind the northern training wall to become an important mangrove and saltmarsh habitat. The 1930s photographs show extensive saltmarsh and small mangrove areas in the more stable, southern areas of the islands. The main body of Greenbank Island was by 1930 dominated by dune instability and was bare sand. The mangrove and saltmarsh area on the island increased in the period 1930-1962 with the stabilisation of conditions. This habitat was lost between 1962 and 1968 when 486 000 m^3 of dredgespoil was dumped on the island to allow development (Druery and Curedale 1979), restricting wetland habitat to the southern 'Keith Curran Park'. Most of this wetland was lost by 1985 with the construction of a canal estate.

Other, smaller developments within the estuary have also resulted in the loss of wetlands, including the reclamation of the intertidal flat on the western side of the Pacific Highway adjacent to Boyds Island in the early 1970s. Developments since

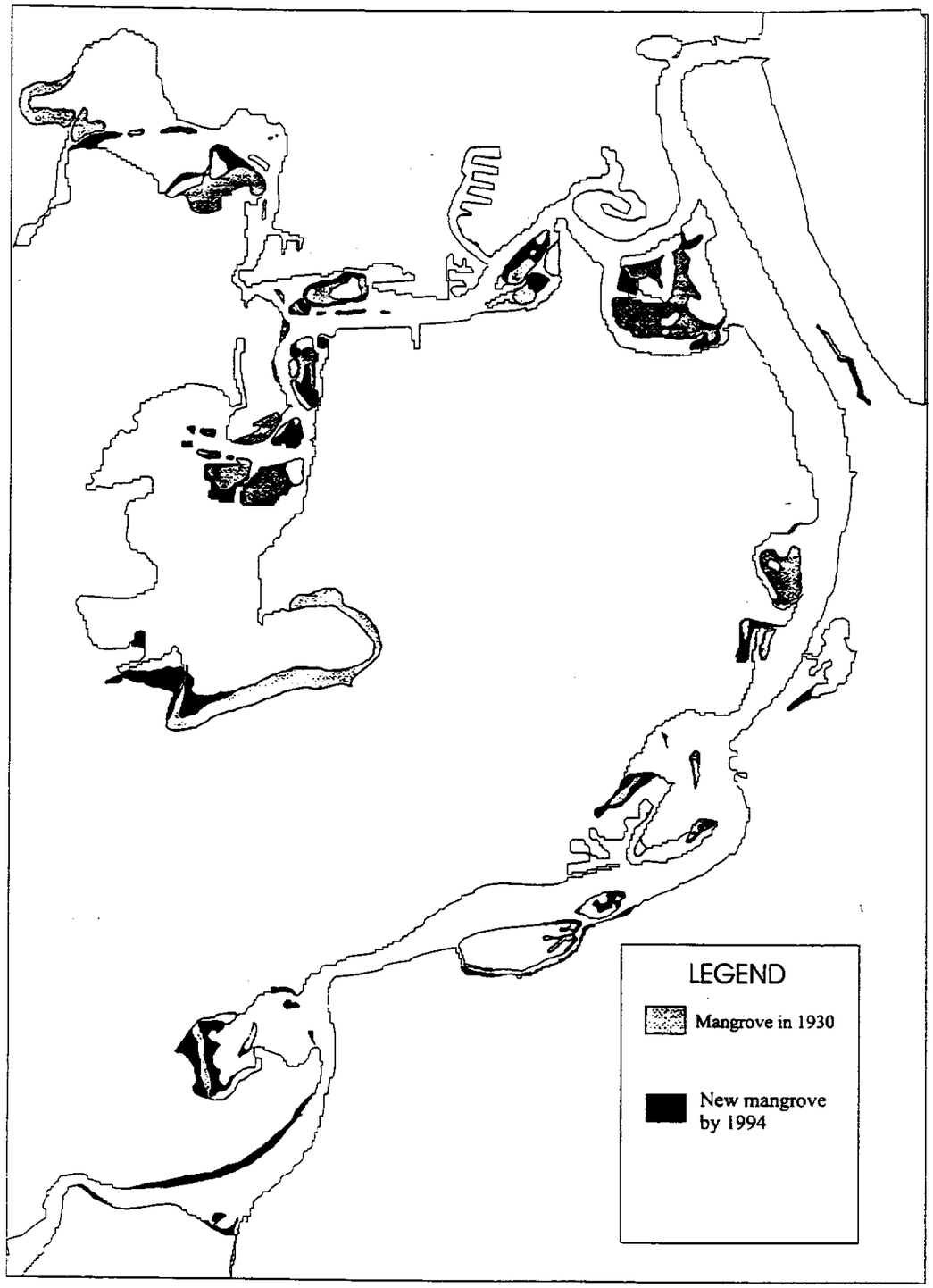

Figure 3: Distribution of mangrove and saltmarsh on the Tweed River estuary in 1930 and 1994.

1980, such as the canal estate on the north bank at Chinderah Bay, have generally avoided the mangrove areas.

DISSCUSSION

The extent of mangroves on the Tweed River Estuary has nearly doubled in the period 1930-1994, from 152 hectares to 283 hectares. It should be remembered in this context that the survey did not include upstream areas of mangroves which may have been lost to floodplain development and the installation of floodgates on small creeks. The increase in mangrove area in the lower estuarine section has a seaward and landward component and the possible causes of each are discussed in turn.

Expansion of mangroves at the seaward edge

Evidence can be found of a number of distinct factors contributing to the seaward extension of mangroves, as listed below;

- *flood-tide sedimentation*
  Druery and Curedale (1979) document the effects of the amplification of tidal hydraulics created by the 1966-1968 dredging, including the noticeable siltation of the tidal delta distributaries due to flood-tide oriented sediment transport (Druery and Curedale 1979 p.44). Extending air photo surveys back to the 1930s has demonstrated that this pattern of sedimentation has a longer history, and has occurred continuously over the study period. The 1971 photographs show a considerable increase in the number of mangrove juveniles in the channel and frontal fringes of the islands of Terranora Creek, perhaps resulting from a redistribution of sediment following dredging in the late 1960s. Expansion of mangrove areas continued in the period 1985-1994.

- *fluvial sedimentation*
  Deposition of terrestrial sediment has occurred at the mouths of tributary creeks, accelerated by changes in landuse. Creeks draining into the Terranora and Cobaki Broadwaters have extended their deltas and both broadwaters have shallowed considerably. Siltation here has been attributed to the changes in catchment landuse from sugar cane to banana plantations (Druery and Curedale 1979).

  Similarly, channels created to drain sugar-cane fields adjacent to the Tweed Broadwater have deposited deltas which have been rapidly colonised by mangroves. The texture of the newly mangroved area indicates high biomass, and is similar in canopy density to mangrove communities on freshly accreted, nutrient laden substrates on the Hawkesbury River (Saintilan 1997b). The mangrove area in Chinderah Bay expanded following a canal estate development on the bay foreshores, possibly claiming freshly deposited sediments washed from the development site.

- *altered tidal parameters*
  Expansion of mangroves at the seaward edge might also be a response to a periodic lowering of water levels within the estuary, which can occur following dredging of the channel mouth. Such a lowering of water level occurred following the 1968 dredging (Druery and Curedale 1979), and the colonisation of juveniles in the tidal channel observable in the 1971 photographs might have been precipitated by this event. Dredging will also increase tidal amplitude, which could further extend the seaward limit of mangrove colonisation.

Expansion of mangroves at the landward edge

While most of the increase has been an advance of the seaward edge, landward incursions of mangroves into saltmarsh have been observed in a number of locations on the Tweed River, in both the Tidal and the Fluvial Channels. A variety of factors might be responsible for these occurrences on the Tweed, including;

- *subsidence* - within the Tweed Broadwater, landward mangrove incursion has occurred following the construction of drainage channels. It is possible that these channels have promoted subsidence of the adjacent saltmarsh environments.
- *recolonisation* - there is evidence of prior agricultural use of Chinderah Island, and here mangroves may be recolonising previously occupied areas.
- *altered tidal parameters* - as previously mentioned, the opening of the channel mouth following dredging increases the tidal amplitude of the estuary. This may promote the landward expansion of mangroves.

A similar landward incursion of mangroves has been observed in a number of east-coast Australian estuaries including Oyster Bay Point (McTainsh *et al.* 1986), Moreton Bay (Morton 1992), the Hunter River (Williams and Watford 1996), Lake Macquarie (Williams and Watford 1996), the Hawkesbury River (Wilton 1997, Saintilan 1997a, Williams and Watford 1997), Botany Bay (Mitchell and Adam 1989), the Hacking River (Mitchell and Adam 1989), and Corner Inlet (Vanderzee 1988). These advances may be linked to higher rainfall and sea-level in the period 1945-1994, as not all the above-mentioned locations have been subject to altered entrance conditions, clearance or subsidence.

Loss of saltmarsh

The extent of saltmarsh increased on the Tweed River in the period 1930-1971, as a function of the increase in total intertidal area throughout the estuary. Since 1971, however, total saltmarsh area has declined, primarily through the following processes:

- reclamation for urban development, principally with the loss of Greenbank Island
- dune instability leading to the smothering of saltmarsh, noticeable in the northern and southern sections of Ukerebagh Island. Dune instability appears to have also prevented the establishment of intertidal wetland communities in Kerosene Inlet, and precluded the spread of saltmarsh on Greenbank Island until conditions stabilised following 1948.
- mangrove transgression into saltmarsh, though not as extensive as in southern estuaries, small areas of saltmarsh have been lost to mangrove on the Tweed Estuary as previously detailed.

Though saltmarsh area has declined since 1971, the total area of saltmarsh is still greater than was evident in the 1930 photographs.

CONCLUSION

Mangroves on the Tweed River Estuary have expanded their range considerably since 1930, in spite of urban developments at the channel mouth. A number of factors are likely to be working concurrently to promote mangrove colonisation, including an increase in fluvial sedimentation and altered tidal amplitude. The increase of saltmarsh area has been checked by the reclamation of key saltmarsh habitats, and may be vulnerable to future mangrove incursions.

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