Unintended Long Term Environmental Disturbances from Estuary Entrance Breakwaters

Kathryn Duchatel, MWH Australia, kathryn.duchatel@mwhglobal.com
Lex Nielsen, Worley Parsons, Australia, lex.nielsen@WorleyParsons.com
Rob Williams, NSW Department of Primary Industries araluenrob@hotmail.com
Angus Gordon, Coastal Zone Management & Planning, Australia
sandgus@optusnet.com.au

Paper: A by-product of a 1970 study was the discovery that the entrance channel of Wallis Lake was in an "unstable scour mode". Scour had compromised piles supporting the road bridge connecting Foster to Tuncurry and major rectification works were required. Scouring had commenced shortly after the northern breakwater was completed in 1969 after which the tidal range in the lake began to increase markedly. It was theorised that these effects resulted from the entrance breakwaters improving the hydraulic efficiency of the entrance by reducing the hydraulic energy loss over the entrance bar. Calculations at the time indicated these effects could continue for centuries (Nielsen & Gordon, 1980). Over the ensuing 30 years the early predictions have proven correct. Subsequent studies where entrance breakwaters and training walls have been constructed (Figure 1) identified tidal ranges increasing progressively (Nielsen & Gordon, 2008).

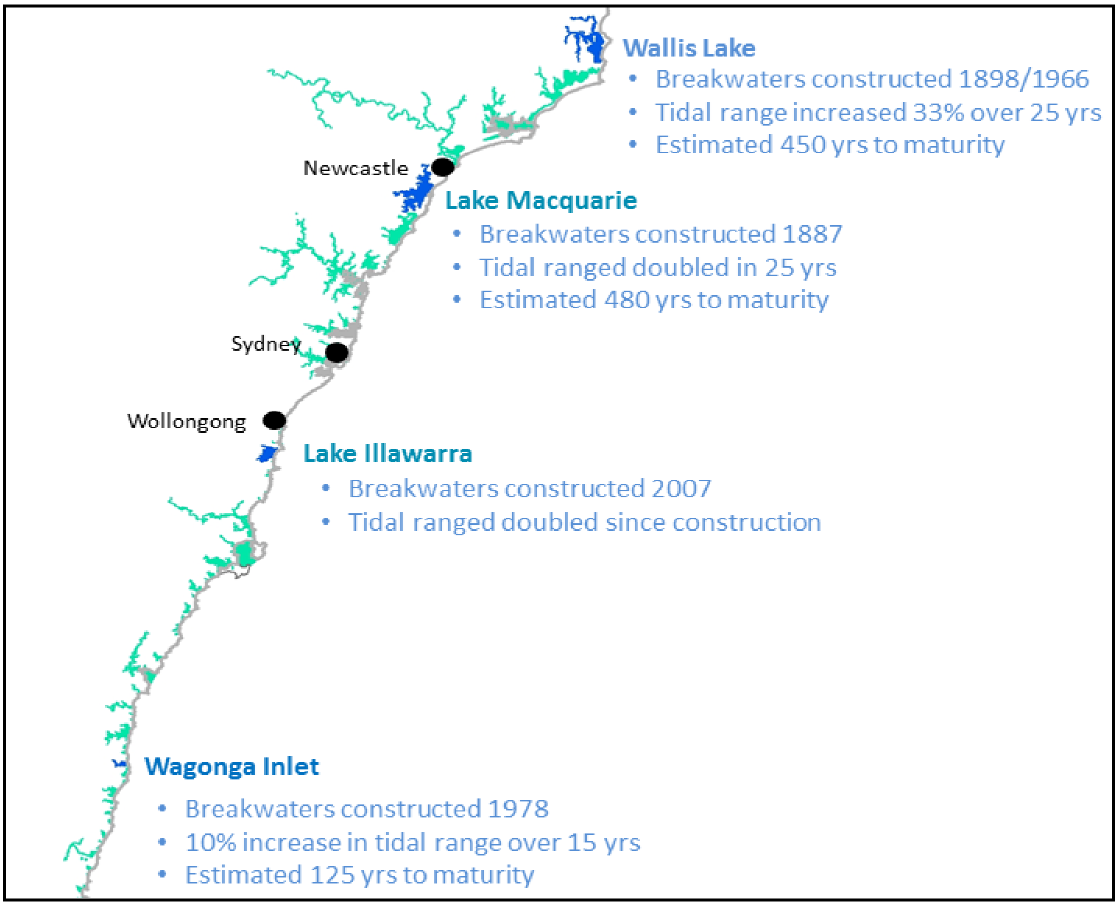


Figure 1 Location of studies on the NSW coast

It is posited that breakwater-induced hydraulic change will mimic future climate change effects, in particular, sea level rise impacts on the distribution and abundance of estuarine macrophytes.

Estuarine macrophytes (saltmarsh, mangrove, seagrass) grow within the subtidal and intertidal zones, where their presence is affected by physical, chemical and hydrodynamic conditions. Figure 2 provides a generalised schematic of tidal distribution of macrophytes.

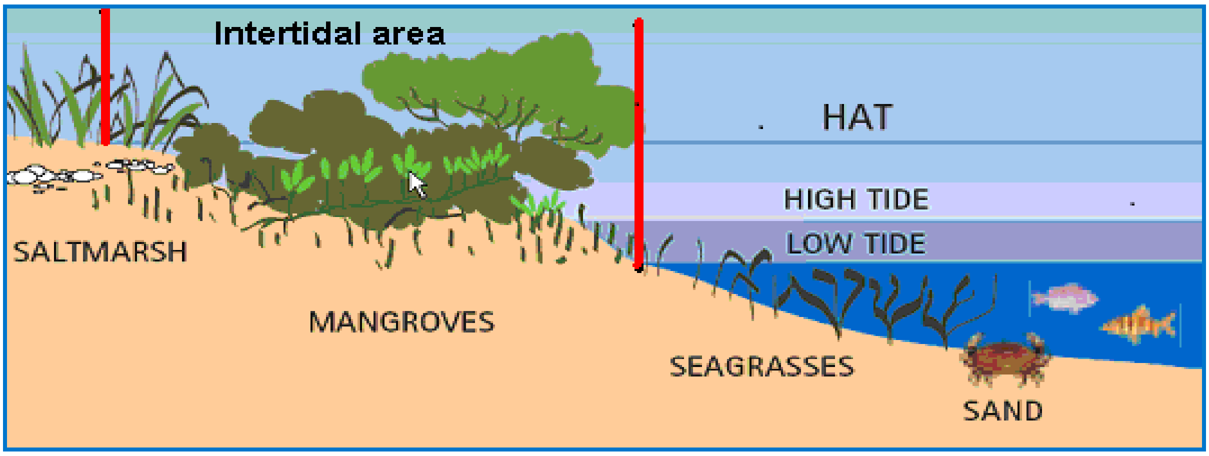


Figure 2 Common habitat zones in an estuary, where HAT = highest astronomical tide (adapted from Kailola et al 1993)

Estuarine macrophytes are fundamental building blocks of estuarine ecology as they: create new tissue from sunlight and, hence, initiate estuarine food chains; stabilise sediment; provide habitat for fish, crustaceans and molluscs in which to shelter from predators as well as forage for food. Most of NSW's commercially and recreationally important fish species are dependent at some stage of their life cycle on estuarine habitats.

As a result of anthropogenic activities, estuarine communities are among the most threatened ecological systems in the world (Burrell 2012). This is reflected in their conservation status in NSW under the *Fisheries Management Act 1994* (FM Act), *Threatened Species Conservation Act 199* (TSC Act) and, nationally, under the *Environment Protection and Biodiversity Conservation Act 1999*(EPBC Act) as summarised in **Table 1**.

Table 1 – Conservation status of estuarine macrophytes in NSW

Community or Species	Legislation	Status
Seagrass, mangrove and saltmarsh	FM Act	Protected Marine Vegetation
Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	TSC Act	Endangered Ecological Community
Subtropical and Temperate Coastal Saltmarsh	EPBC Act	Vulnerable Ecological Community
Posidonia australis, the largest of eight species of seagrass that occur in NSW	FM Act	Endangered population in Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie
Posidonia Seagrass Meadows	EPBC Act	Item currently under finalised priority assessment

Hydraulic Impacts of Breakwaters

The threats arising from the placement of breakwaters are summarised in Table 2, but it is recognised that there may be opportunities for some species to expand their range. For example, the seagrass *Posidonia australis* is confined to the entrances of permanently open estuaries where it is thought the salinity and temperature envelopes are suitable. Enhanced penetration of marine waters of estuaries either through breakwater placement or rise of sea level will favour the upstream colonisation of this seagrass.

Another consequence of breakwater placements is the raising of high tide and lowering of low tide. This expansion of tide range on wetland communities is as yet unstudied but it might be expected to allow saltmarsh and mangrove to migrate upslope as well as upstream as topography and/or infrastructure might allow.

Table 2 - Threats to and opportunities for estuarine macrophytes arising from breakwater emplacement

Hydraulic disturbance	Macrophyte threats	Macrophyte opportunities
Increased tidal velocity - bank and bed scour progress upstream	• Erosion, undermining and loss of macrophytes	• Colonisation of sediment deposition
Sedimentation-changes in channel patterns growth of deltas	• Smothering of seagrass beds • Changed composition of seagrass	• Establishment of new or altered habitat for macrophytes
Increase in tidal exchange impacts on the salinity of the estuary and therefore water chemistry	• Enhanced penetration of saline waters (marinisation) that create conditions unsuitable for brackish species	• Expansion upstream for some species (e.g., *Posidonia* seagrass, *Avicennia* mangrove) due to more appropriate salinity envelope
Increasing tidal range higher high water levels and therefore inundation of estuary margins	• Reduced light reaching seagrass beds, thus reducing productivity • Mangrove invasion of saltmarsh • Loss of mangrove and saltmarsh where upslope and upstream migration is limited	• Upslope migration of macrophytes • Upstream migration of macrophytes

Case Study: Wagonga Inlet

The distribution and extent of estuarine macrophyte communities in NSW have been mapped and studied over various time scales (West et.al in 1985, Williams et al. 2006, Burrell 2012) providing a basis to investigate correlations between hydrologic change and ecological disturbance.

Wagonga Inlet showed a significant decrease in the distribution of macrophytes over the 25 year period between mapping campaigns. Figure 3 shows seagrass mapping at the entrance of the estuary, where changes to seagrass distribution and abundance is expected as a result of increased tidal velocity, bank and bed scour, and a changing sediment regime.

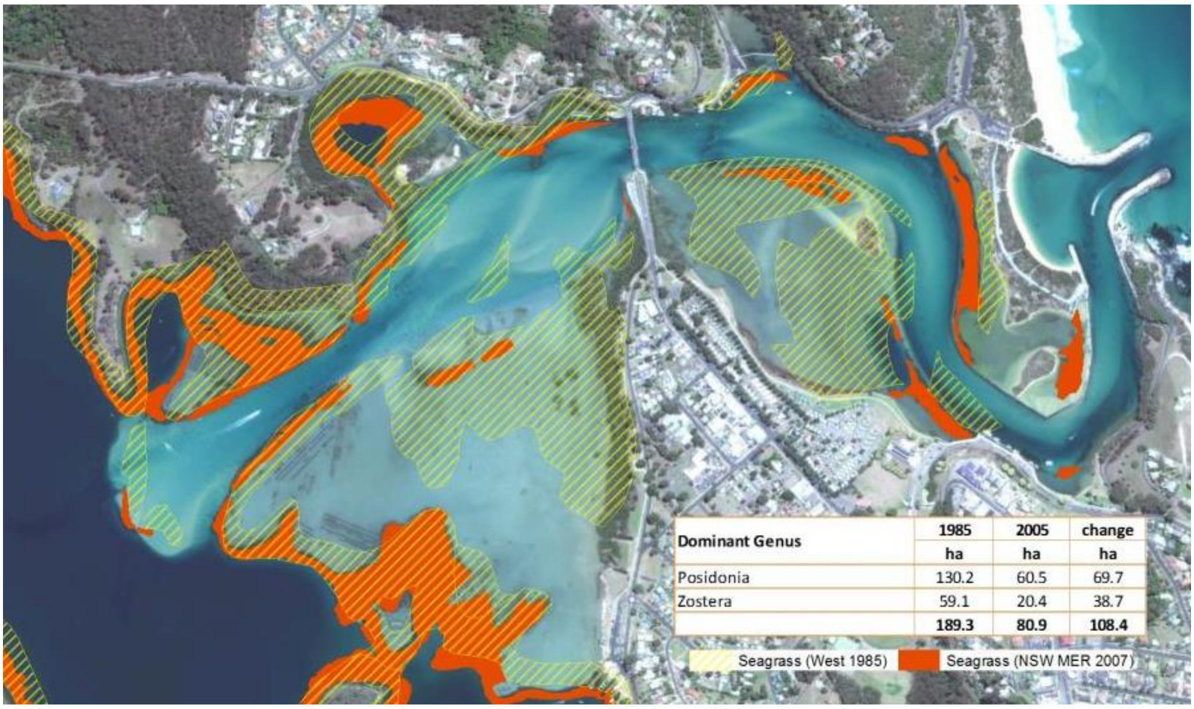


Figure 3 Change in the extent of seagrass at the entrance to Wagonga Inlet: 1979-2005

The data indicates that the total abundance of all seagrass throughout the estuary decreased by 57% (from 189.3 to 80.9ha). Approximately 64% of this loss was *Posidonia* and the remaining 36% predominantly *Zostera*. Over 33% of the total estuary loss occurred within the inlet channel, and within the inlet channel, approximately 72% of seagrass lost was *Zostera* (see Table 3).

Table 3 - Change in the extent of seagrass at the entrance to Wagonga Inlet: 1979-2005

Total Estuary	**1985**	**2005**	**Change**	**%**
Posidonia	130.2	60.5	69.7	64.3% of all seagrass in estuary lost
Zostera	59.1	20.4	38.7	
Total	**189.3**	**80.9**	**108.4**	
Estuary Inlet	**1985**	**2005**	**Change**	
Posidonia	24.5	14.4	10.0	
Zostera	32.3	6.7	25.7	72% of seagrass lost in estuary inlet
Total	**56.8**	**21.1**	**35.7**	33% of all seagrass lost in estuary

These data suggest a correlation between the construction of the breakwater in 1978 and the change in distribution and abundance of estuarine macrophytes.

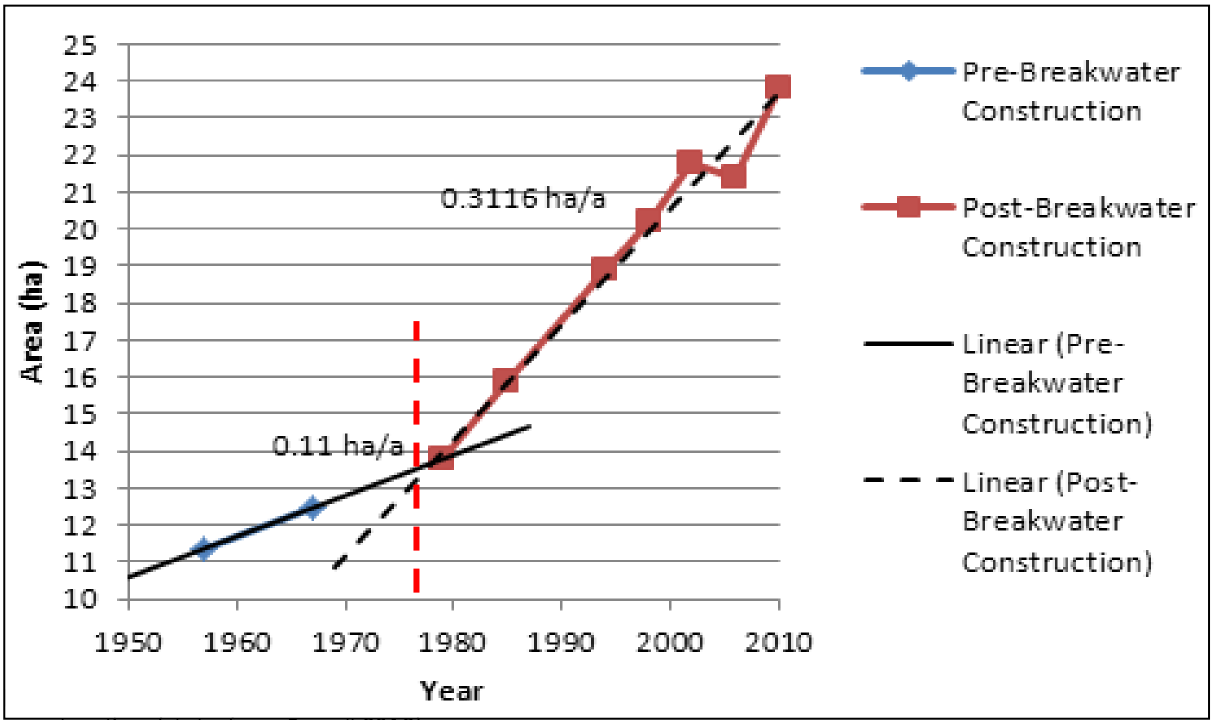
However, there are of course other factors that can influence the distribution and abundance of estuarine habitat, which make it difficult to differentiate change due to entrance breakwaters from other factors. Factors relevant to changes observed in the entrance channel of Wagonga Inlet include but may not be limited to dredging and reclamation, management of oyster leases and urban development.

To assess more accurately the potential for breakwater-induced impacts to estuarine macrophytes in this estuary, time series mapping undertaken by Burrell (2012) was used to compare before and after breakwater construction distribution and extent of mangroves and saltmarsh.

Using GIS aerial photographic interpretation and field investigations, Burrell (2012) mapped changes in the extent of mangrove and saltmarsh between 1957 and 2010. Burrell's analysis found a significant increase in both the distribution and extent of mangroves around the inlet from 1957 to 2010. The change in cover included:

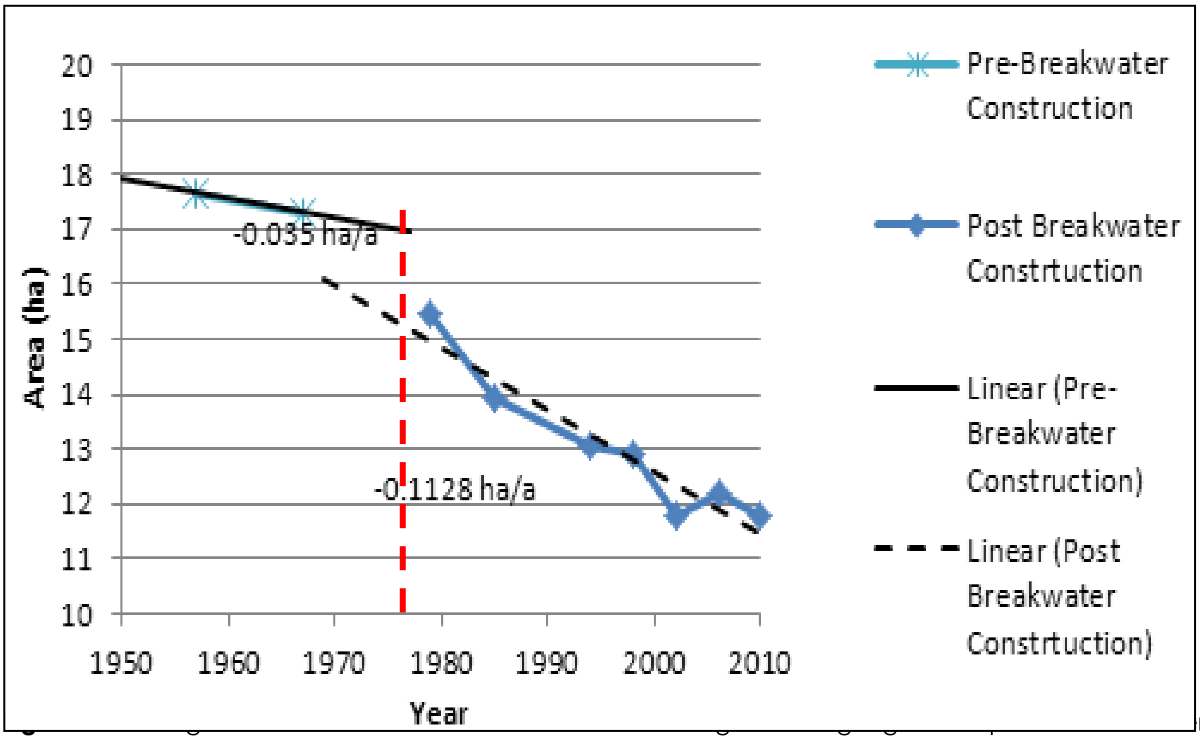
- Incursion up-slope into saltmarsh,
- Laterally along the foreshore, and
- Down-slope onto pro-grading deltas and sandbars.

The rate at which mangroves were found to be expanding substantially increased since the construction of breakwaters (see Figure 4).



construction (data from Burrell 2012).

Burrell (2012) also found that saltmarsh had decreased throughout the estuary. The most significant losses were due to infilling of wetlands and other landuse changes. Removing these factors, the rate of loss is shown to have increased significantly since breakwater construction (see Figure 5).



entrance breakwater construction – adjusted for shore-based landuse changes (data from Burrell 2012)

Conclusion

Stabilising entrances with breakwaters can cause estuarine instability that may take centuries to stabilize! Further complicating these processes is the amplification of high tides and lake levels as a result of sea level rise. There is an urgent need to understand the follow-on ecological disturbances, particularly the impacts to already vulnerable ecosystems.

Our next step is to examine a suite of time series data similar to that undertaken by Burrell (2012) in both subject lakes and reference lakes with no breakwaters.

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