The influence of estuarine geomorphology and intertidal wetlands on hydrodynamic changes associated with sea-level rise

Fig.1: Minnamurra River estuary (©Australias, 2021).

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Science Background

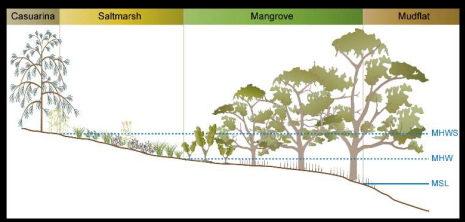
Fig.1: Minnamurra River estuary (©Australias, 2021).

Hydrodynamics (e.g. tidal range, velocity, asymmetry)

- variable along an estuary
- have been show to be affected by tidal wetlands (asymmetry)
- alter in response to SLR

Mangrove and saltmarsh wetlands

- driven by tidal dynamics
- may adjust to SLR by lateral migration & vertical accretion



But, in SLR impact assessments (science + coastal management) estuarine hydrodynamics & tidal wetlands are mostly separated (+ little is known about feedbacks)

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Management Context

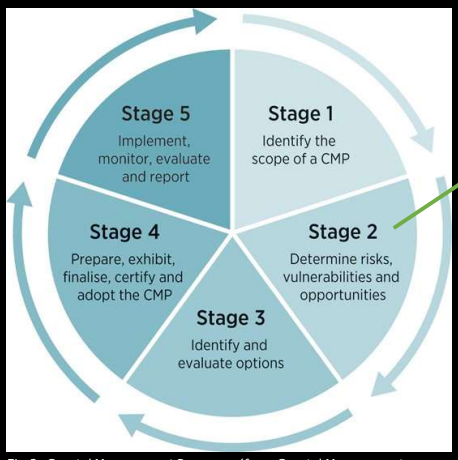

Fig.2: Coastal Management Programs (from Coastal Management Manual - DPE, 2022).

CMP - Stage 2 (Determining risk & vulnerabilities)

What we do …

- Tidal inundation modelling (assuming static intertidal areas)
- Determining risks to mangrove and saltmarsh areas (using outputs of tide modelling)

What we may miss …

- Vertical adjustment of wetlands to rising sea level
- Potential feedbacks between estuarine hydrodynamics and tidal wetlands

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Study 1: Hydrodynamic modelling in two barrier estuaries (immature / mature)

Fig.3: Location of study sites along the southern NSW coastline (micro-tidal semi-diurnal regime).

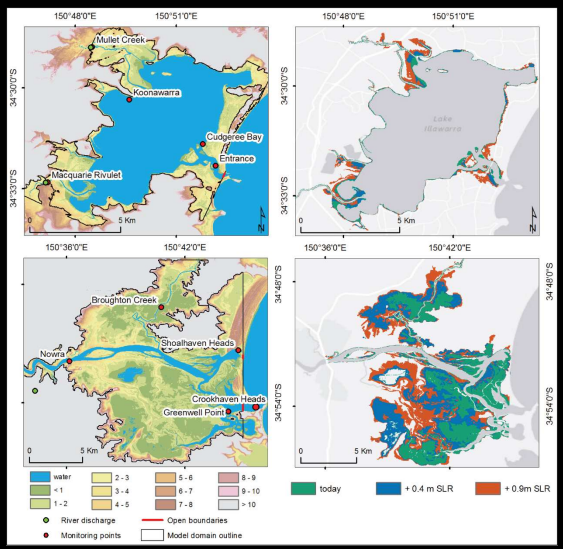

Fig.4: Model setup and spring tide inundation extents for SLR scenarios at Lake Illawarra (top) and Shoalhaven River estuary (bottom). Kumbier et al. (2018).

- Hydrodynamic responses vary between types of estuaries
- Large increase in inundation extent for mature estuary; only minor changes in tidal range
- Moderate increase in inundation extent for immature estuary; doubling of tidal range
- Geomorphological classifications may guide SLR assessments
- Wetlands may play an important role!


Modelling Hydrodynamic Impacts of Sea-Level Rise on Wave-Dominated Australian Estuaries with Differing Geomorphology

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Study 2: Relationships between main channel hydrodynamics & tidal wetlands

Fig.5: Location of study sites along the southern NSW coastline (micro-tidal semi-diurnal regime).

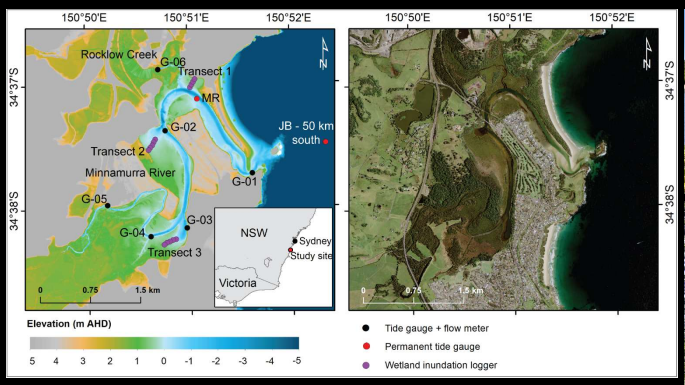
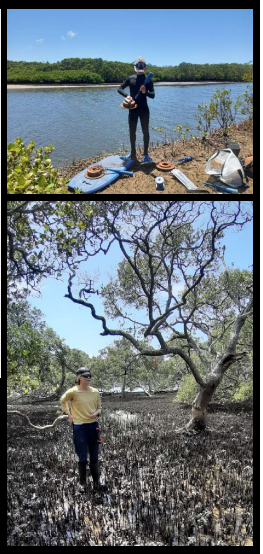


Fig.6: Topography (left) and data collection (right) at Minnamurra River estuary (Kumbier et al., 2022).



- Tidal monitoring of water levels & velocity for 3 month
- Wetland inundation measurements along 3 transects

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Study 2: Relationships between main channel hydrodynamics & tidal wetlands

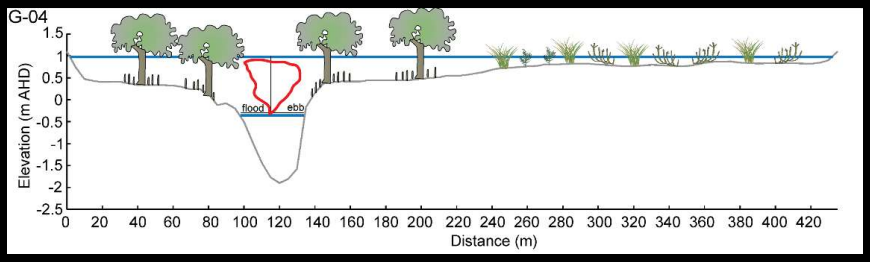
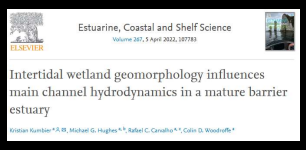


Fig.7: Schematic stage-velocity plots and in a cross-section located 4km upstream (Kumbier et al., 2022).



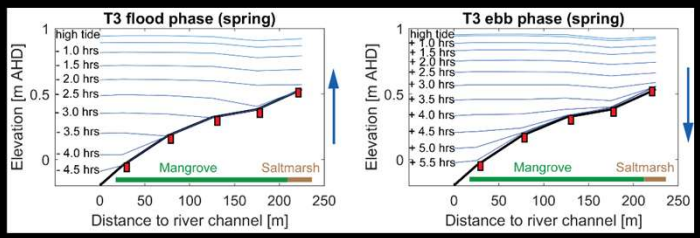


Fig.8: Water levels across the floodplain during spring tides at a location 4km upstream (Kumbier et al., 2022).

- Tidal velocity influenced by wetland geomorphology / flood and ebb tide flows
- Should modelling of SLR in mature barrier estuaries account for changing wetland geomorphology?

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Study 3: Understanding inundation characteristics of mangrove & saltmarsh

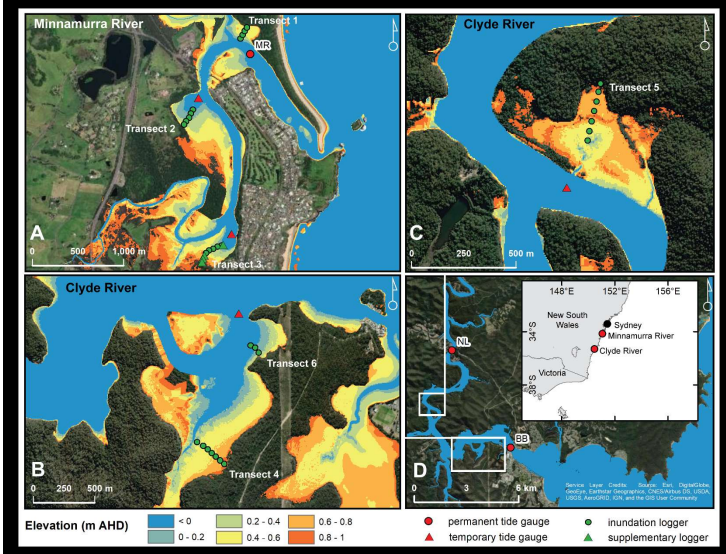

Fig.9: Intertidal topography of wetlands studied at Minnamurra and Clyde River estuaries. Green symbols represent wetland inundation loggers in mangrove and saltmarsh substrate (Kumbier et al., 2021).

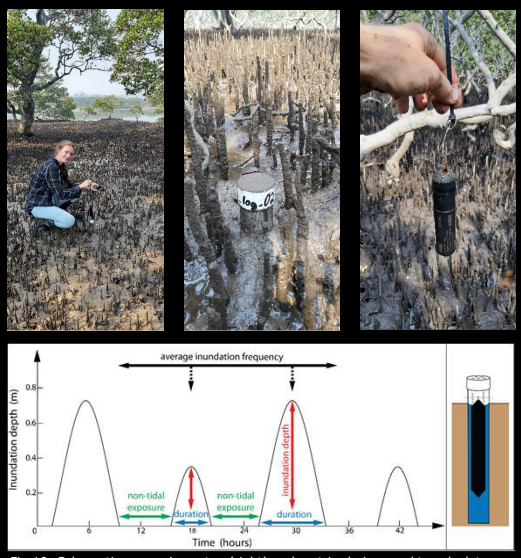

Fig.10: Schematic measuring setup (right) and metrics being used to calculate wetland inundation characteristics (Kumbier et al., 2021).

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Study 3: Understanding inundation characteristics of mangrove & saltmarsh

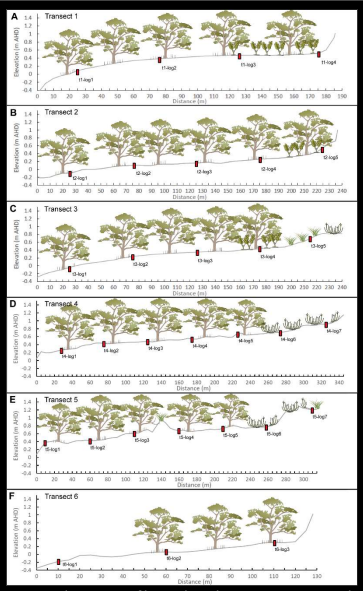

Fig.11: Elevation profiles and predominant vegetation along measuring transects 1 – 6 (Kumbier et al., 2021).

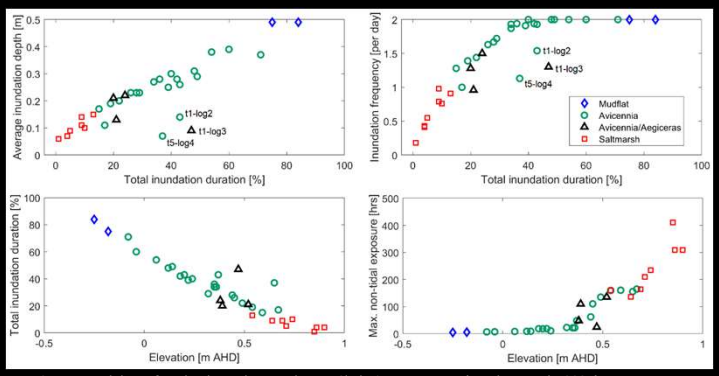

Fig.12: Empirical data of wetland inundation taken at Clyde & Minnamurra (Kumbier et al., 2021).

- Mangroves = total duration 15-75%, average duration 2-5 hrs
- Saltmarsh = total duration < 15%, average duration 0.85-2 hrs
- Inundation tolerances to be used in an eco-hydrodynamic model

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Study 4: Eco-morphodynamic modelling of sea-level rise

Fig.13: Hydrodynamic model for Minnamurra River estuary (floodplain mesh size 10m).

Wetland mapping vs Telemac2D prediction

Fig.14: Processing of model output for average inundation durations from a 28 day tide simulation (right).

Fig.15: Surface elevation table (SET) measurements from mangrove and saltmarsh over 20 years.

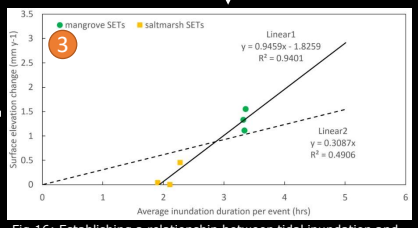

Fig.16: Establishing a relationship between tidal inundation and wetland surface elevation change.

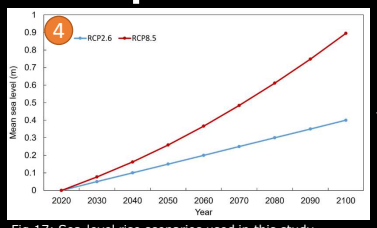

Fig.17: Sea-level rise scenarios used in this study.

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Study 4: Eco-morphodynamic modelling of sea-level rise

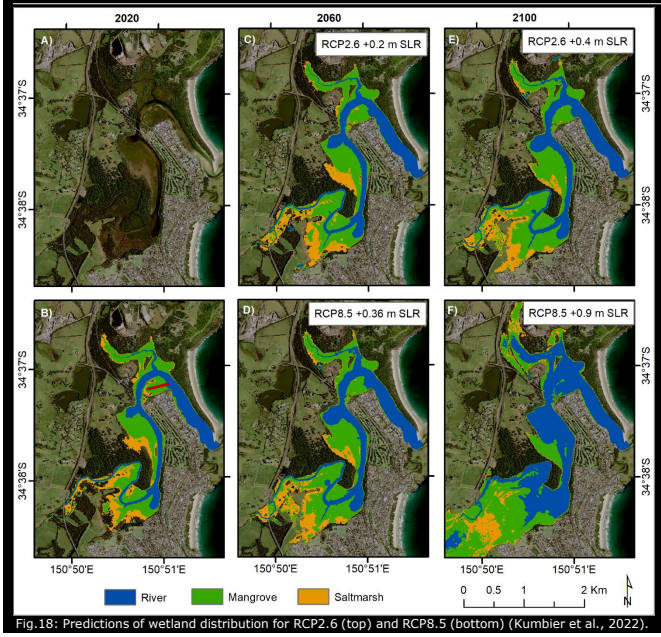

Fig.18: Predictions of wetland distribution for RCP2.6 (top) and RCP8.5 (bottom) (Kumbier et al., 2022).

- Wetlands can withstand modest SLR rates (+ 5mm yr^{-1}) through sedimentation
- Wetlands submerge and convert to subtidal areas under fast SLR rates (> 10mm yr^{-1})
- Geomorphological adjustment of wetlands
- What about hydrodynamics?

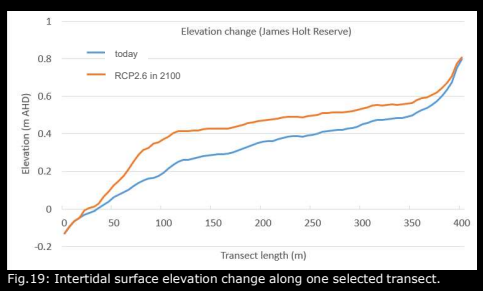

Fig.19: Intertidal surface elevation change along one selected transect.

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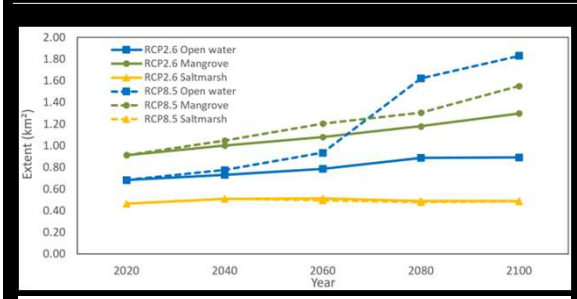
Study 4: Eco-morphodynamic modelling of sea-level rise



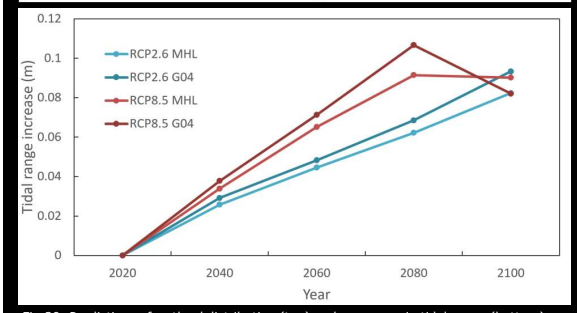
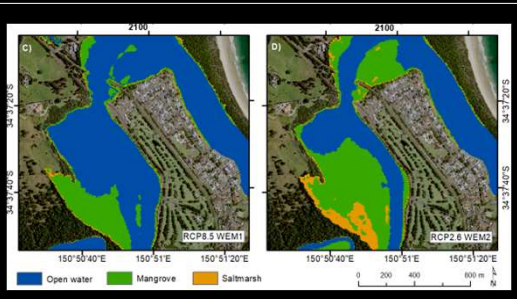


Fig.20: Predictions of wetland distribution (top) and responses in tidal range (bottom) (Kumbier et al., 2022).



- Under low SLR (RCP2.6) tidal range increased linearly (+0.1m by 2100)
- Under high SLR (RCP8.5) tidal range increased initially (+0.08m until 2060), but decreased once mangroves largely covert to open water
- Hydrodynamic-only modelling underestimated increases in tidal range by up to 50%

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Management Implications

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- Move towards more holistic modelling and management strategies (CMP)


An Eco-Morphodynamic Modelling Approach to Estuarine Hydrodynamics & Wetlands in Response to Sea-Level Rise

- Avoid misleading predictions of hydrodynamics & wetland vegetation distribution
- Anticipate shifts in intertidal wetland vegetation distribution – facilitate migration corridors
- More research into interrelationships of estuarine-wetland systems

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