Conceptualising and quantifying eco-geomorphic processes, rates and feedbacks in coastal wetlands

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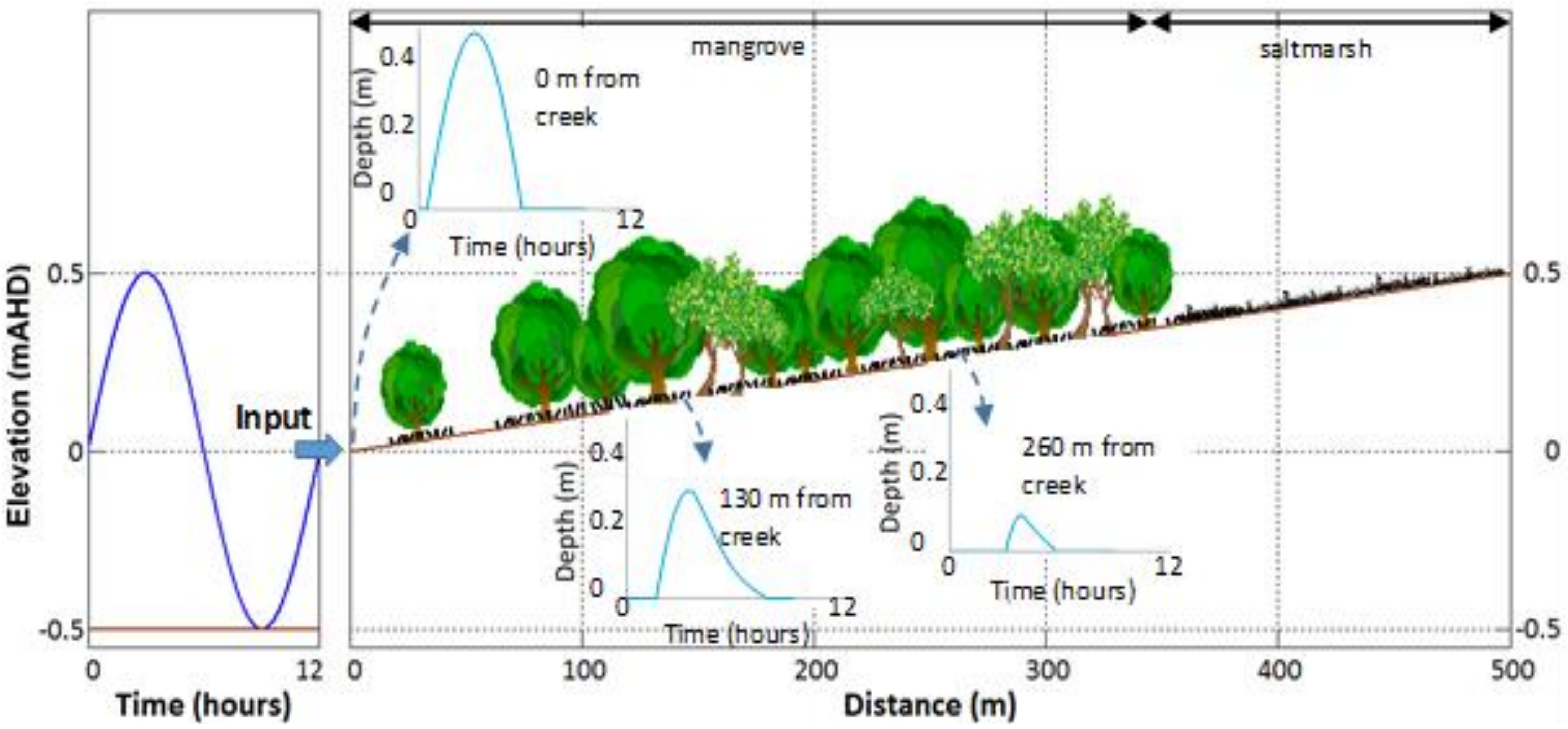
The future of costal wetlands

Up to 80% of worldwide coastal wetlands could be lost by 2100 due to sea-level rise (Titus 1988, Nicholls et al. 2007, Craft et al. 2009, Spencer et al. 2016).

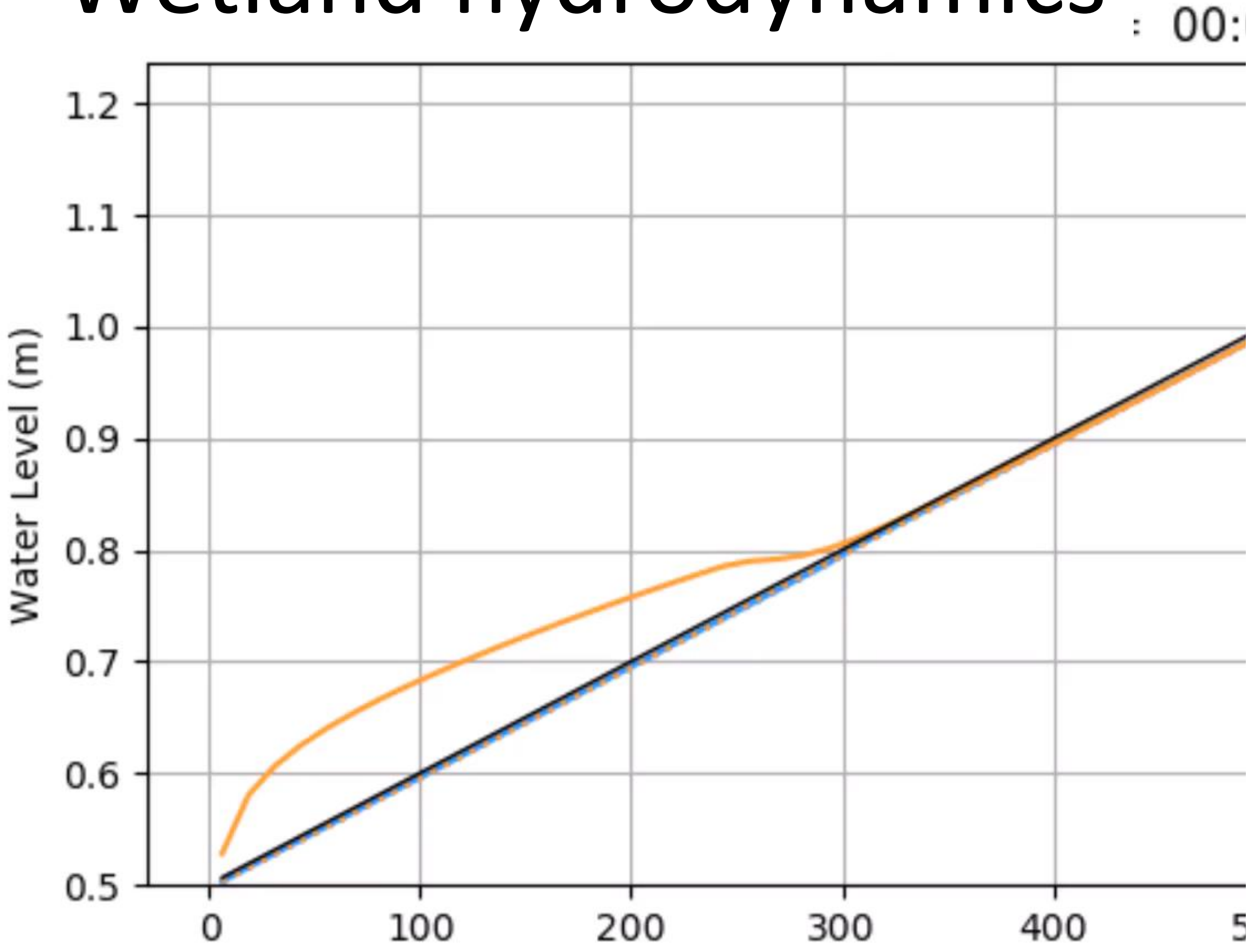
Ecogeomorphological feedbacks (i.e., wetland self-accretion mechanisms) can decrease wetland loss (Kirwan et al. 2013, 2016)

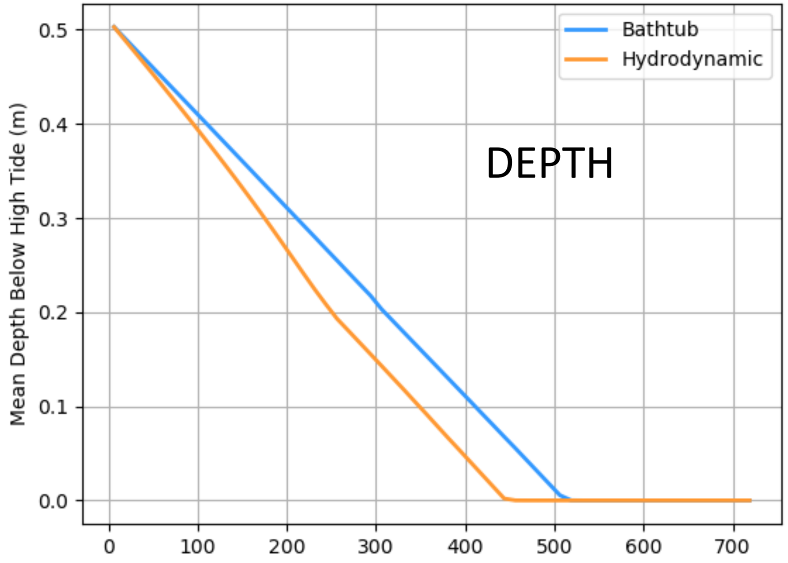
Hydrodynamic attenuation due to infrastructure and vegetation resistance modifies inundation of coastal areas (Passeri et al. 2015, Lentz et al. 2016), which may have an effect on coastal wetlands

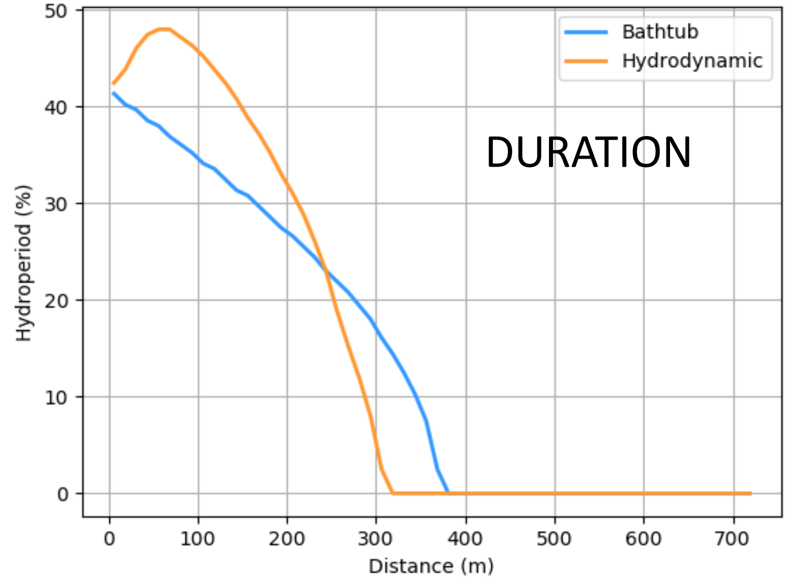
Mangrove-saltmarsh wetlands



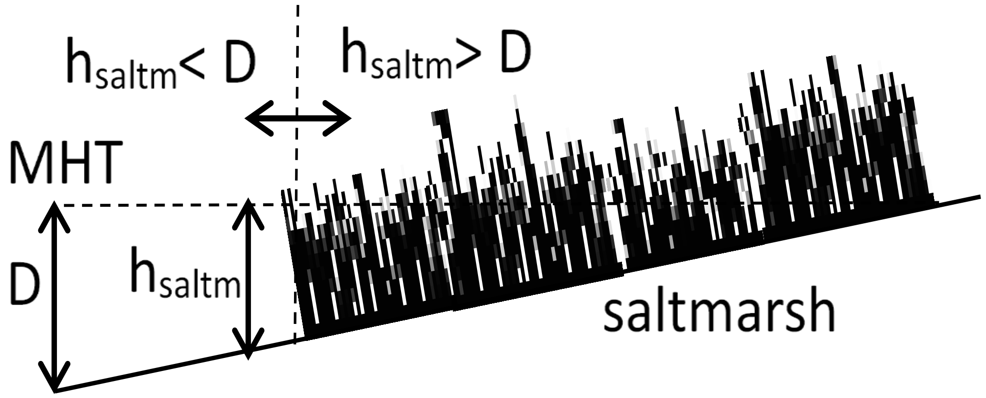
Wetland hydrodynamics

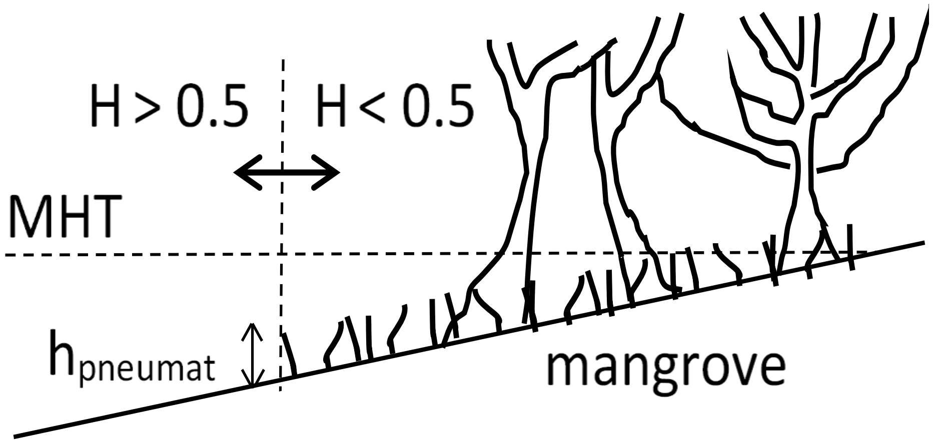






Vegetation response to hydrodynamics





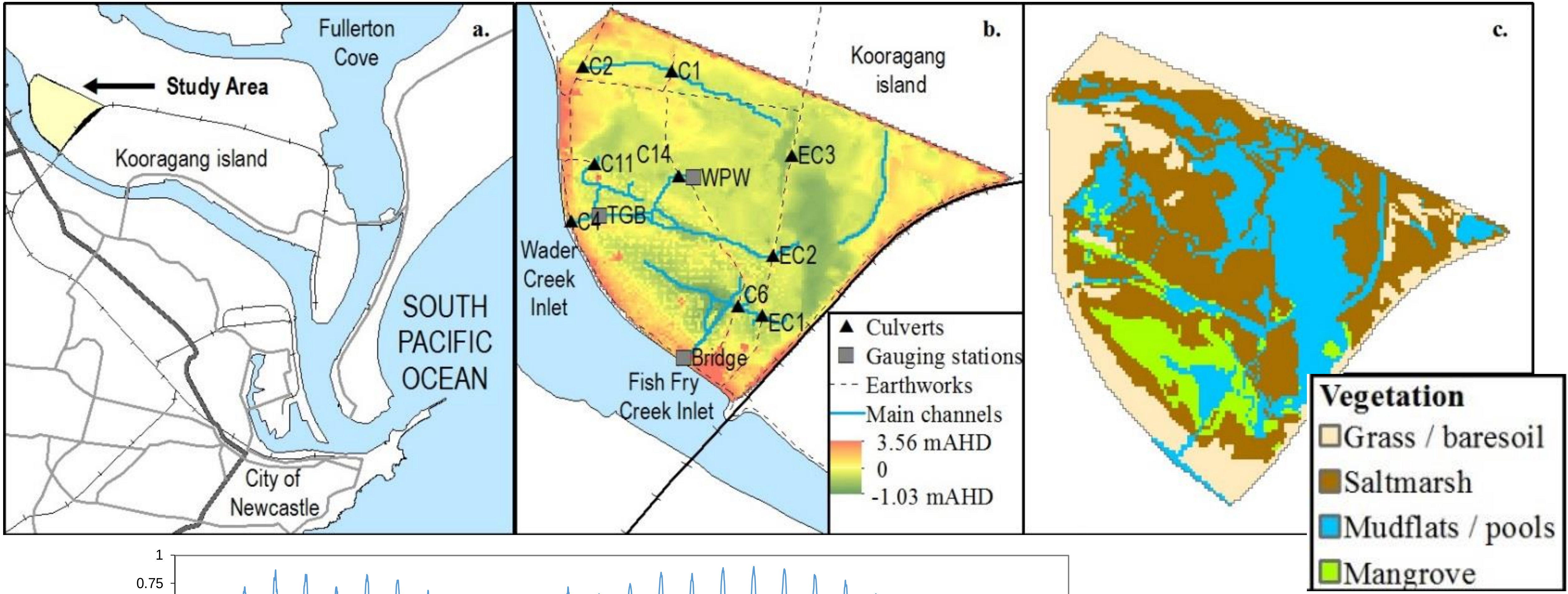
Saltmarsh controlled by inundation **depth**
(Morris et al. 2002, Mudd et al. 2004,
Kirwan & Murray 2007, D'Alpaos et al. 2007)

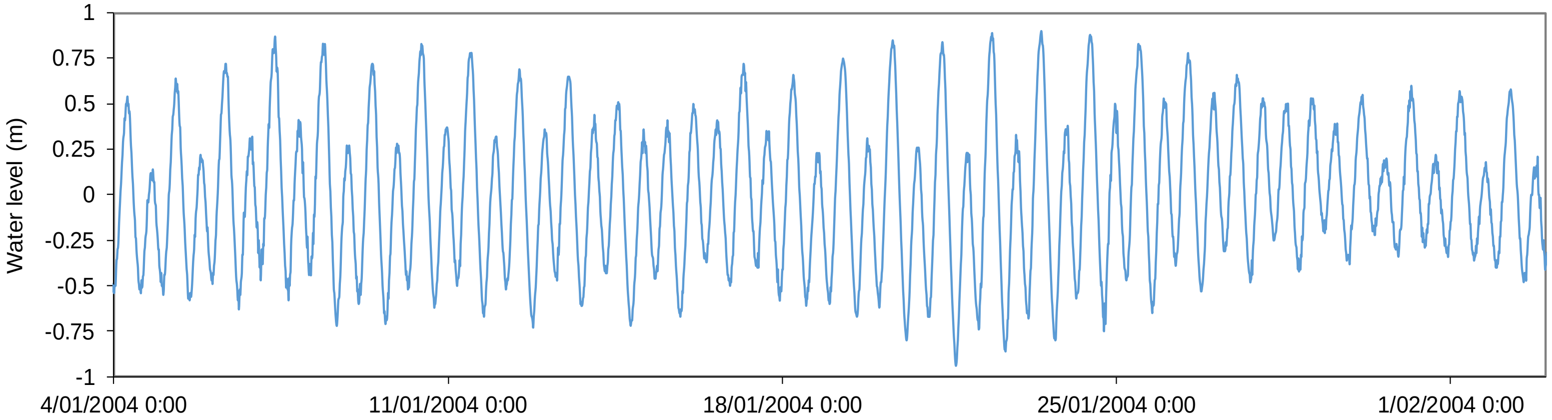
Mangrove controlled by inundation **duration**
(Krauss et al. 2013, Crase et al. 2013)

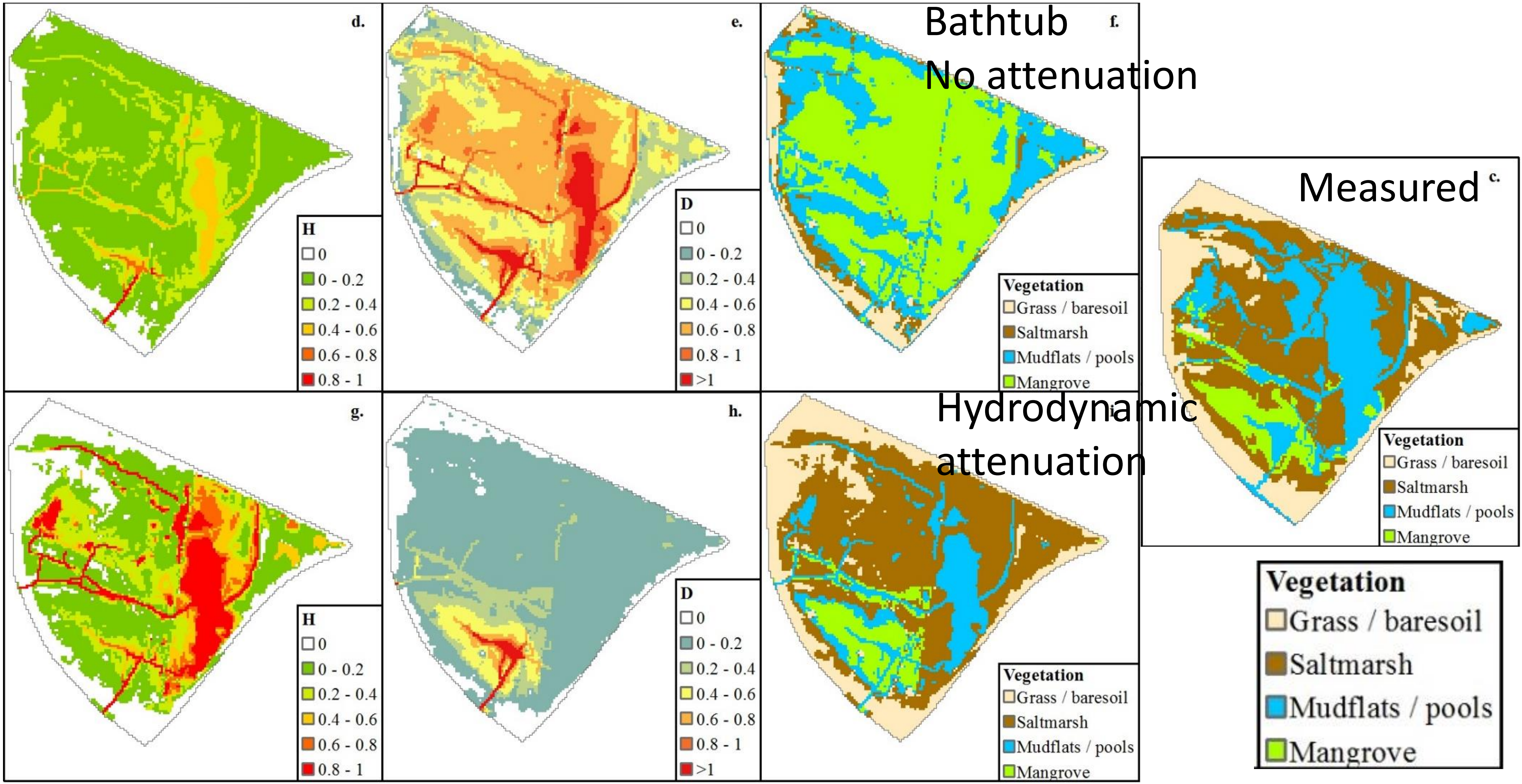
D= Depth below Mean High Tide (MHT)

H= Hydroperiod (proportion of time inundated)

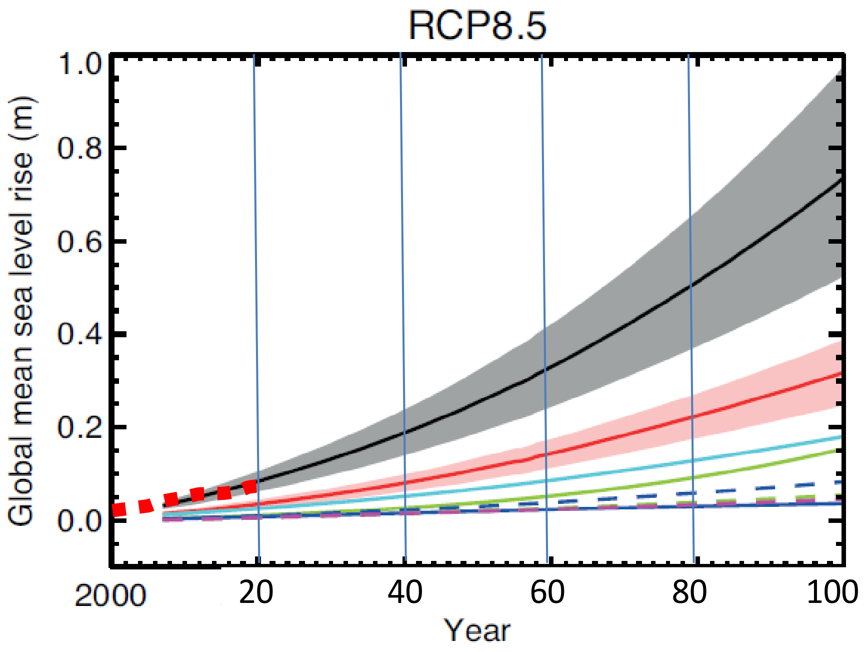
Attenuation due to vegetation and infrastructure






d.
H
0
0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
e.
D
0
0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
>1
Bathtub
No attenuation
f.
Vegetation
Grass / baresoil
Saltmarsh
Mudflats / pools
Mangrove
Measured
c.
Vegetation
Grass / baresoil
Saltmarsh
Mudflats / pools
Mangrove
g.
H
0
0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
h.
D
0
0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
>1
Hydrodynamic
attenuation
Vegetation
Grass / baresoil
Saltmarsh
Mudflats / pools
Mangrove
Vegetation
Grass / baresoil
Saltmarsh
Mudflats / pools
Mangrove

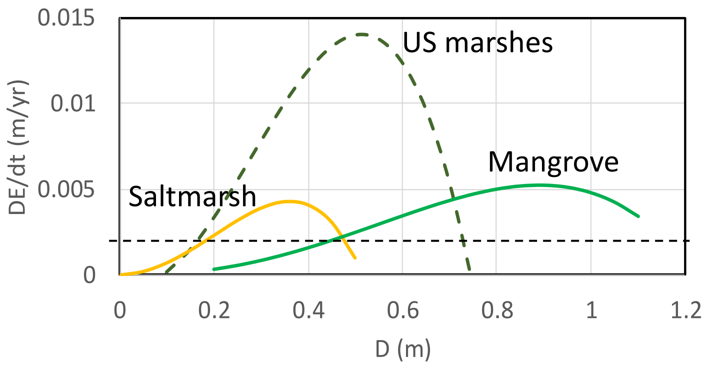
Wetland Evolution

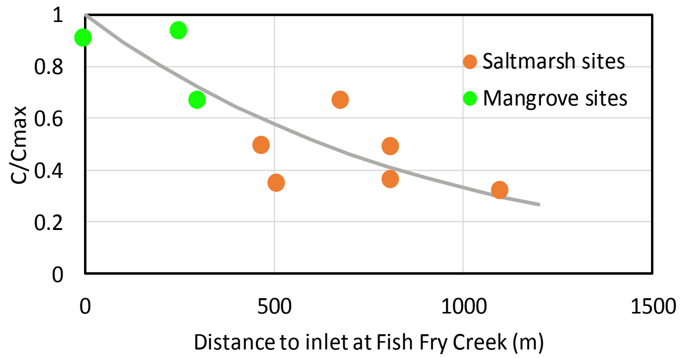


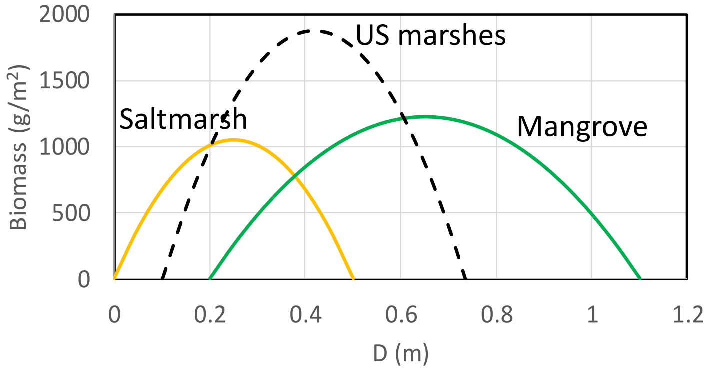
Sea-level rise
IPCC AR5 RCP8.5

Bio-geomorphic accretion
(Kirwan et al., 2010, Morris et al., 2002, D’alpaos et al., 2007)

$$\frac{dE}{dt} = f\,(C, B, D)$$

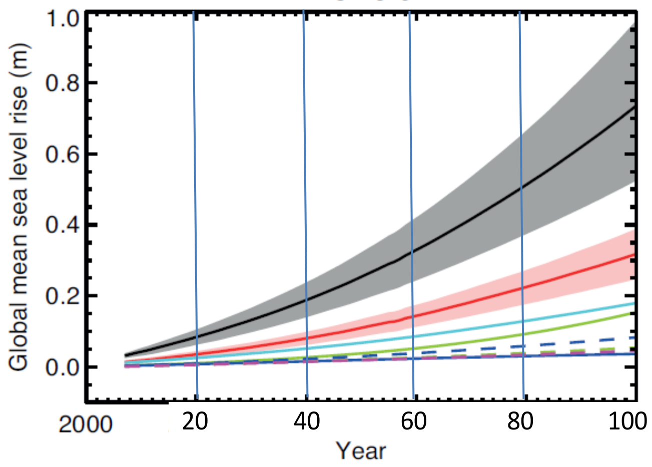


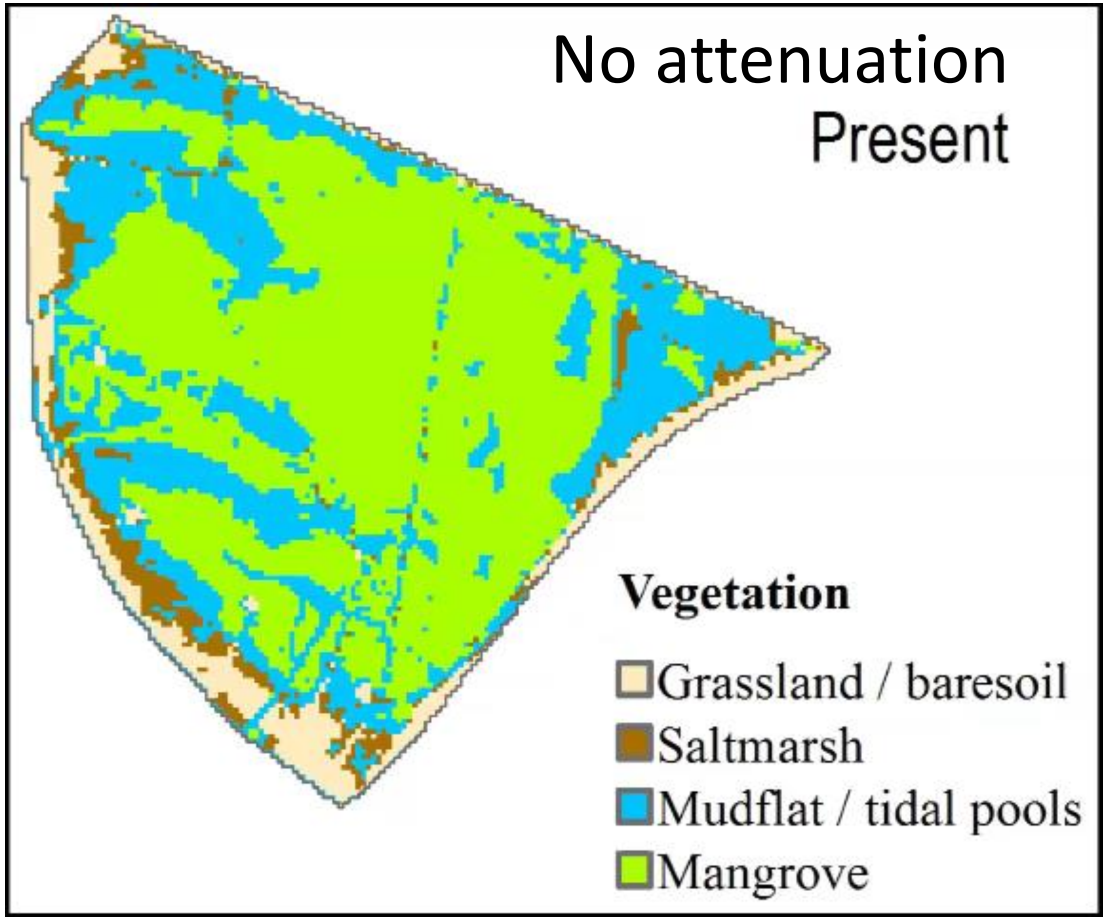


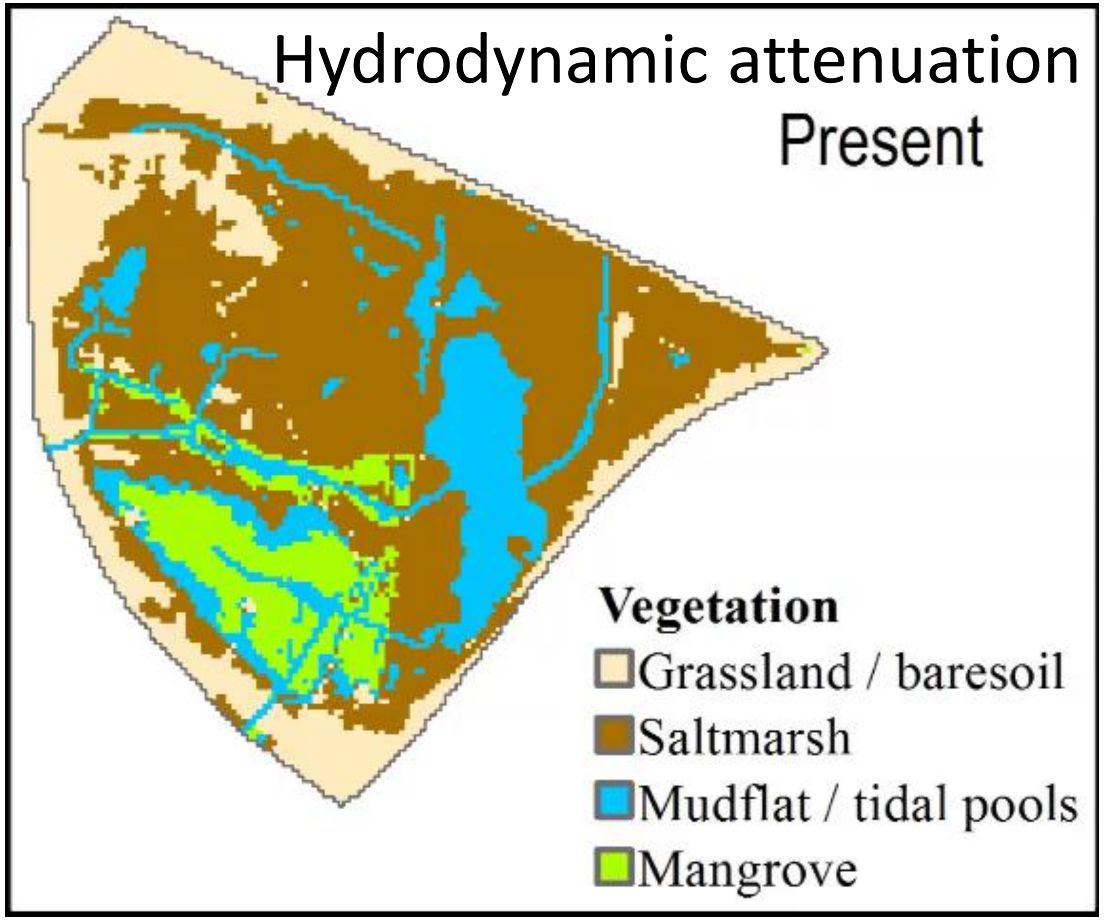


Long term wetland evolution

Rodriguez *et al*. 2017 Nature Comm

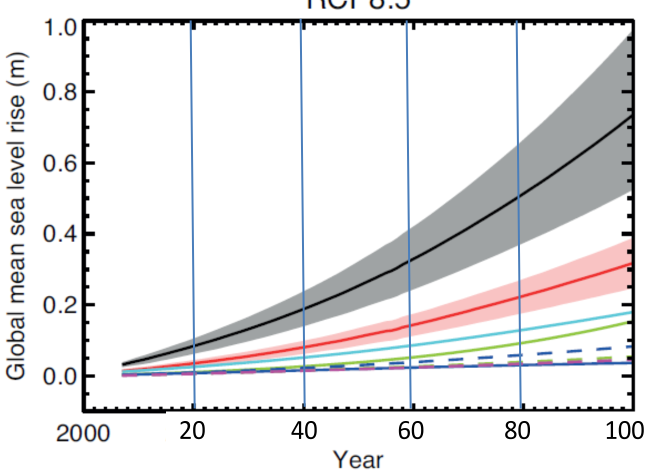


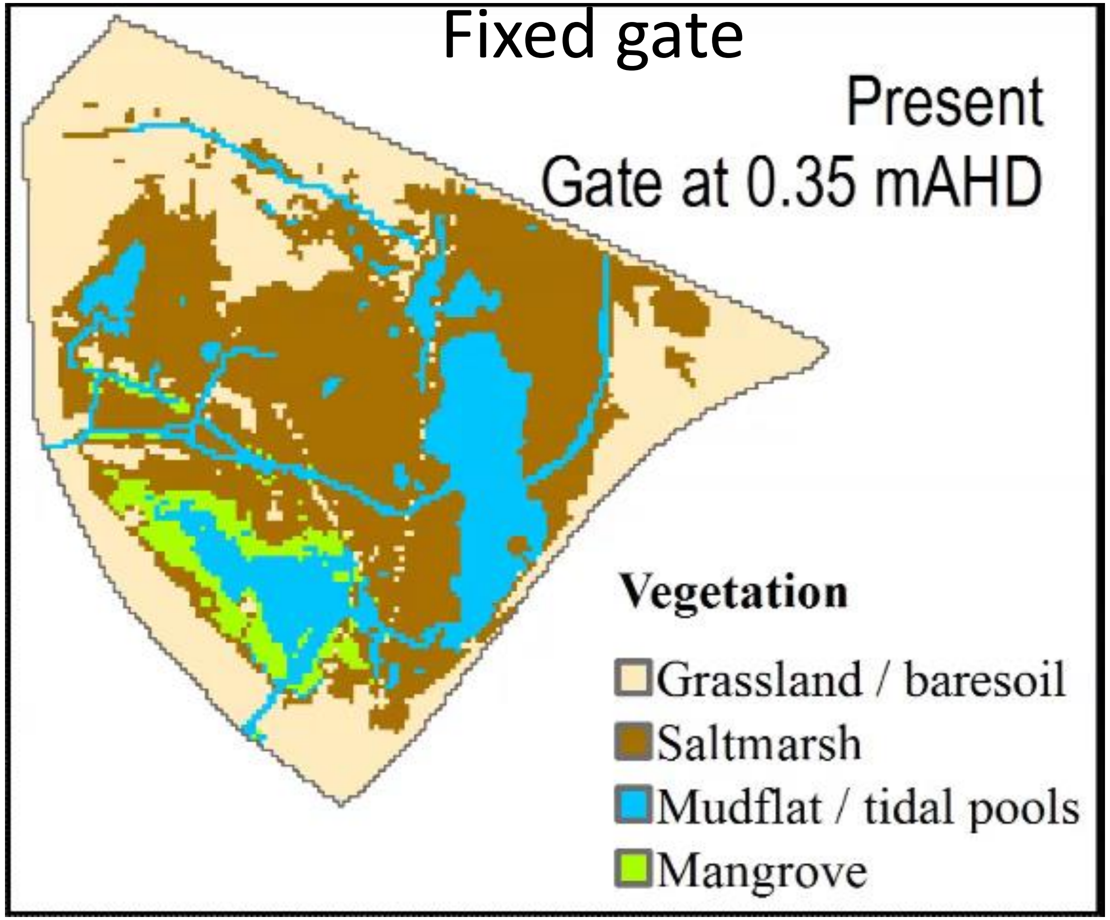


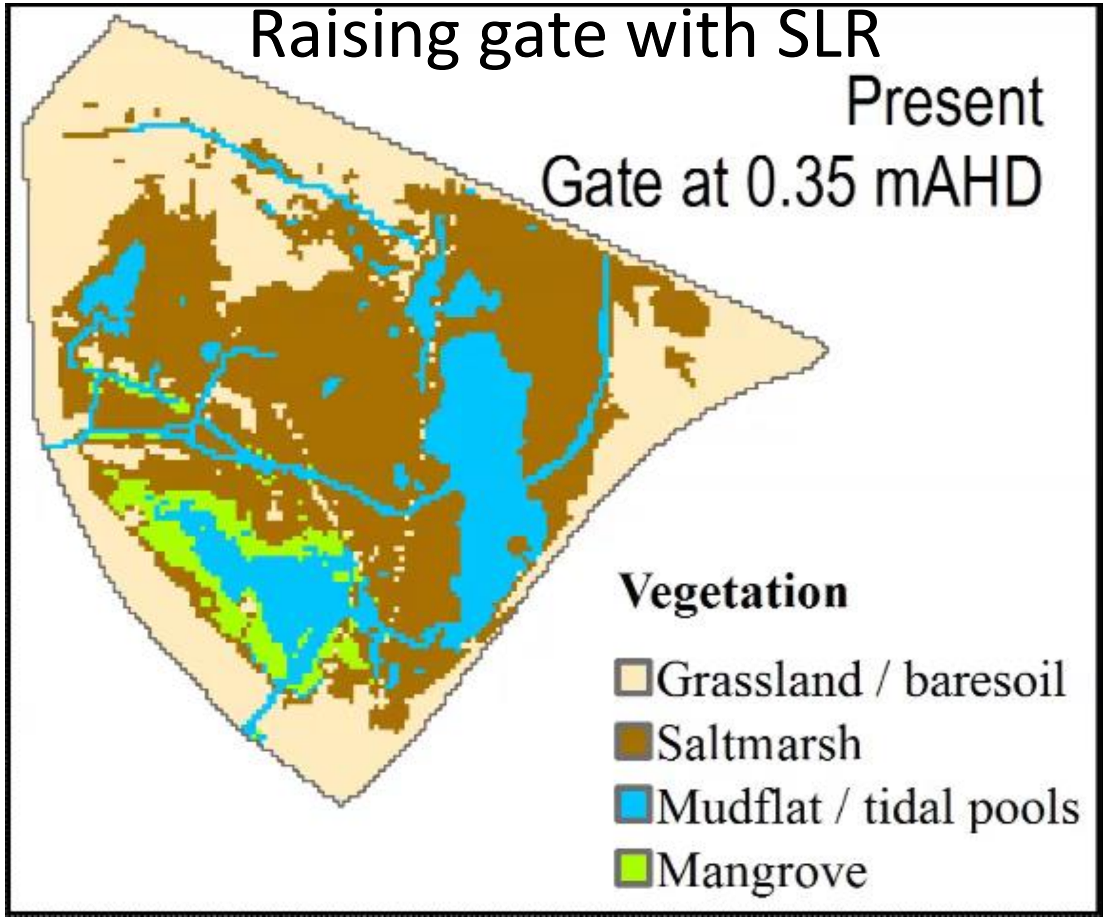


Long term wetland evolution with inlet control

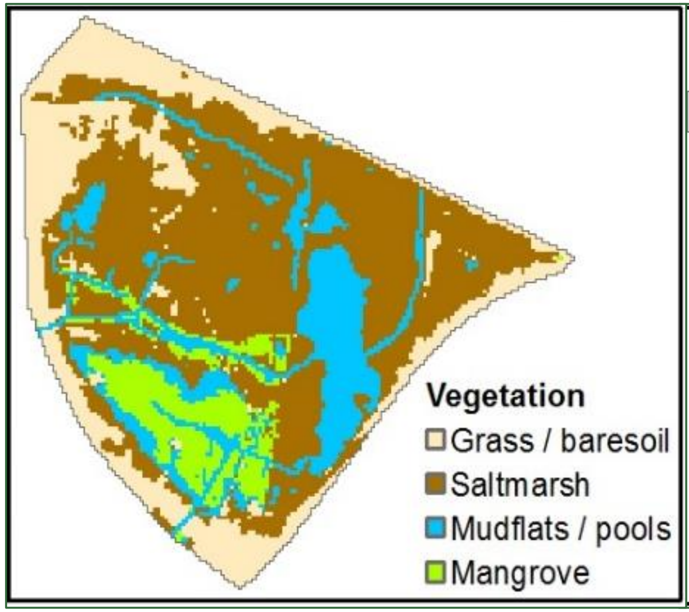
Sandi *et al.*(2018) *Advances in Water Resources*

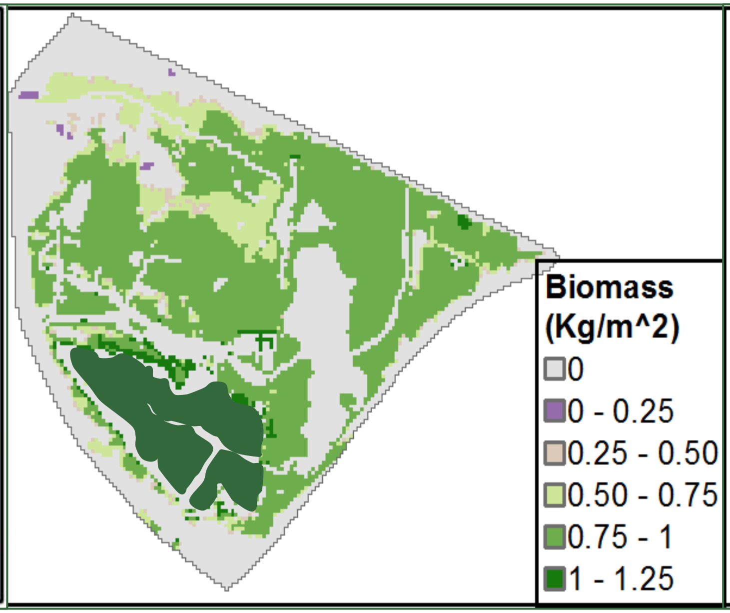


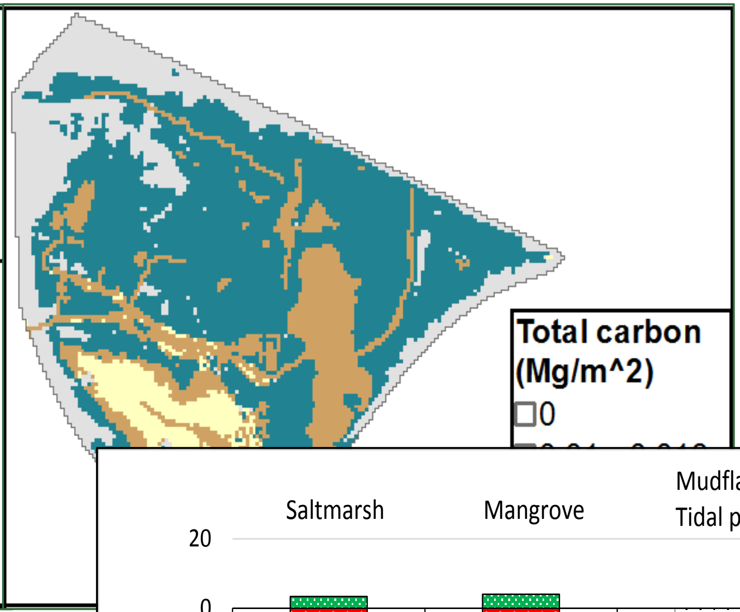


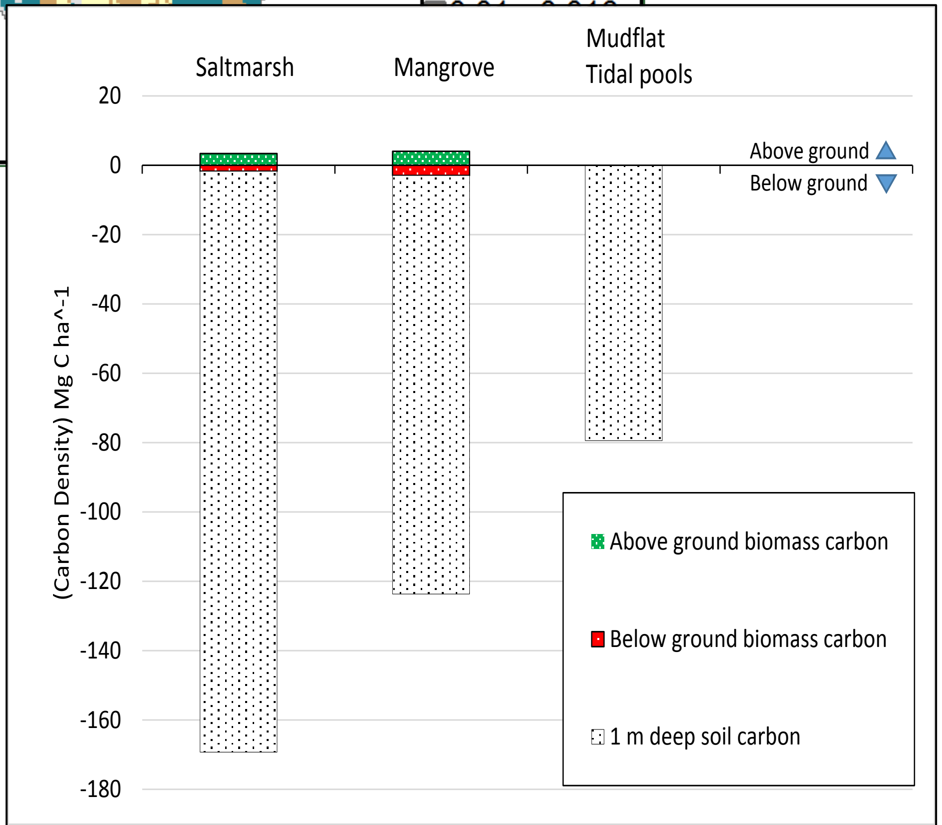


Carbon storage (initial)





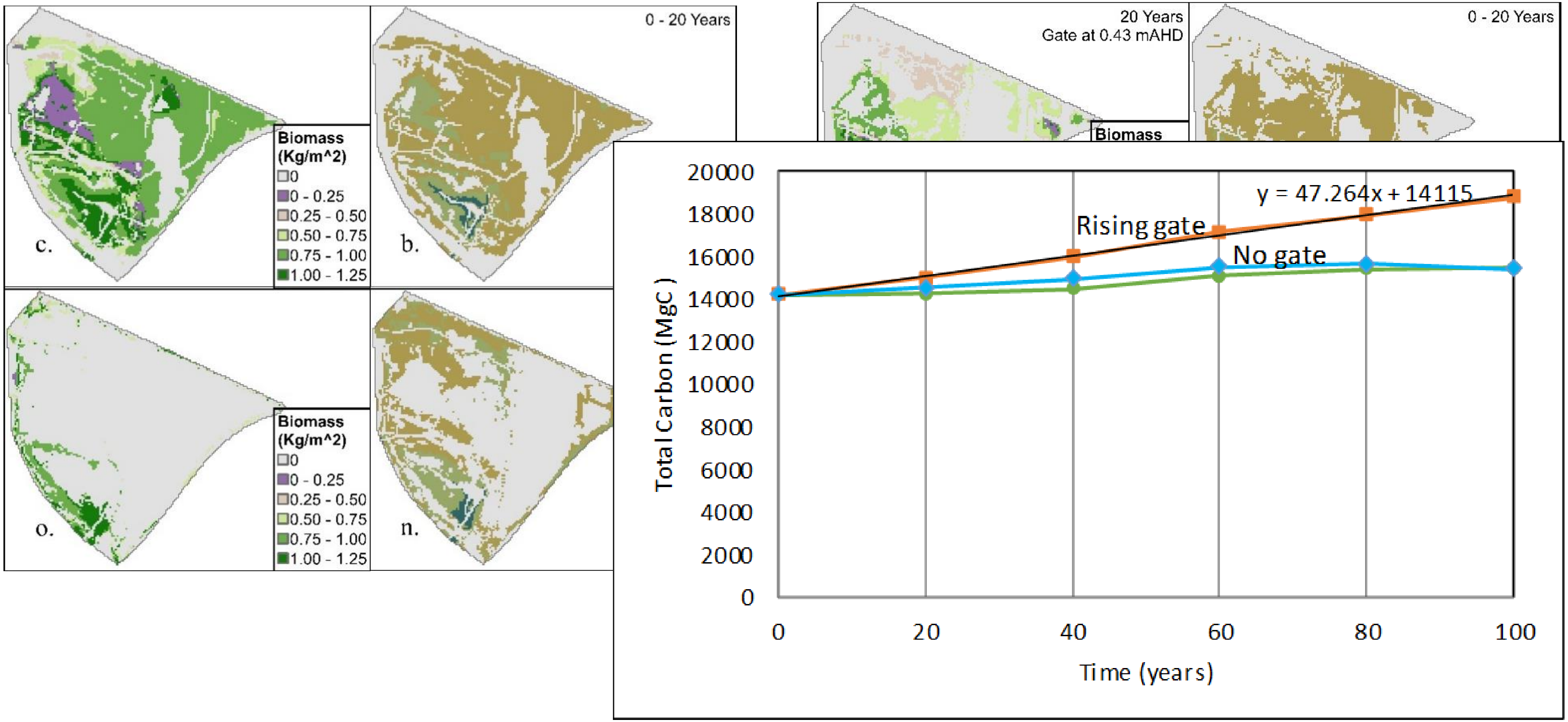




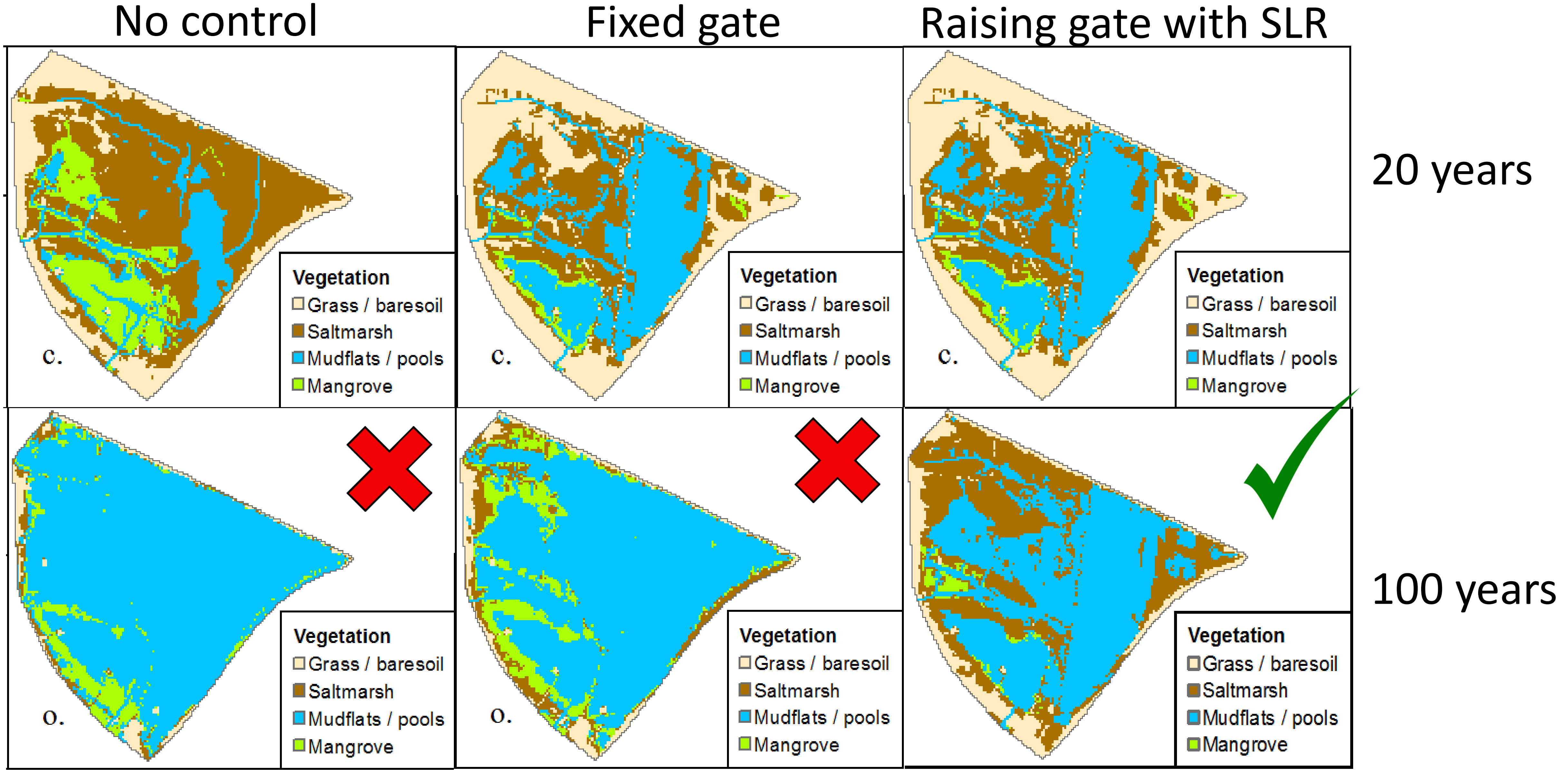
Carbon storage (evolution)

Fixed gate

Raising gate with SLR



Inlet control effects



Conclusions

A hydrodynamic -vegetation-soil evolution model is needed to accurately assess vegetation changes under sea-level rise including attenuation effects

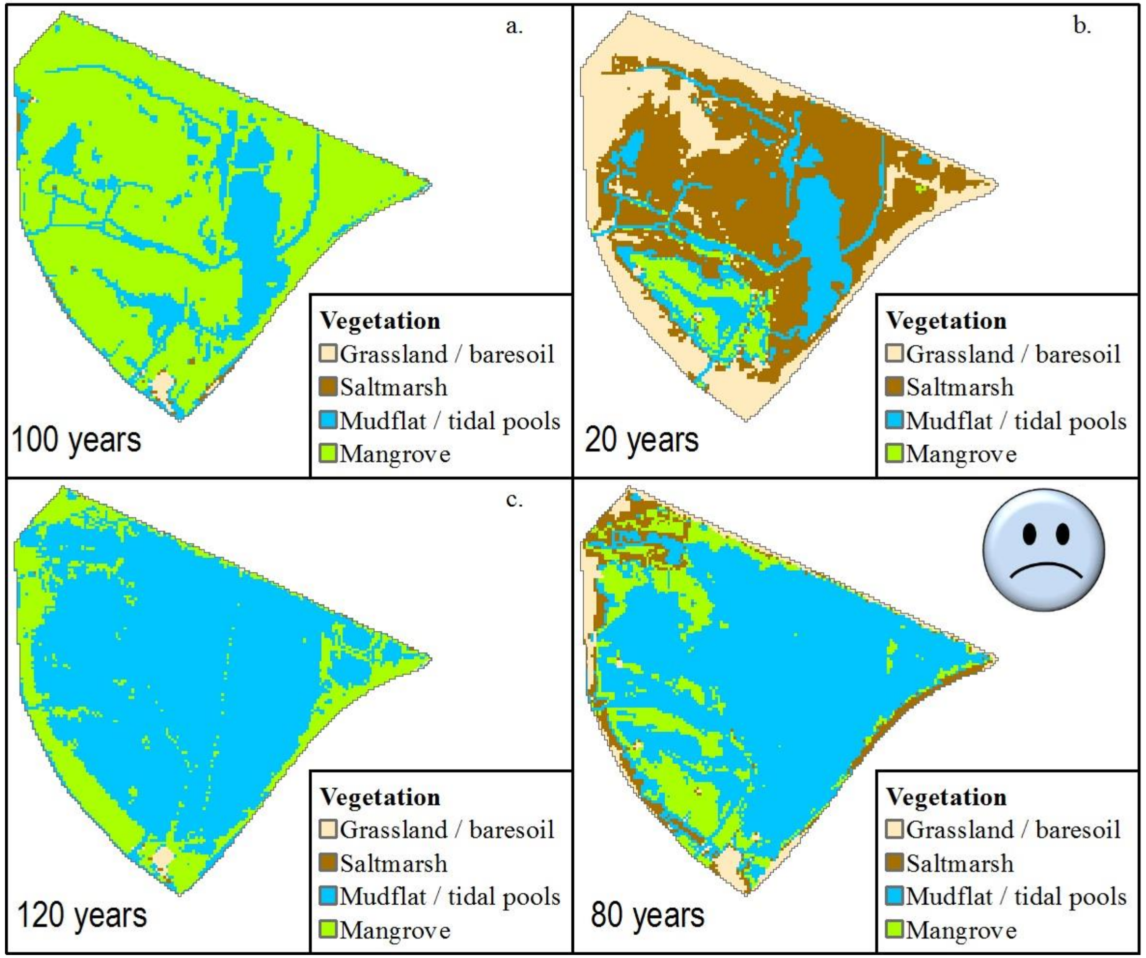
Compared with predictions without attenuation, effects due man-made infrastructure and vegetation resistance accelerates wetland loss by about 30-40%.

Inlet control has the potential to reduce wetland loss and can be used as an alternative when wetland retreat is not possible

Thanks

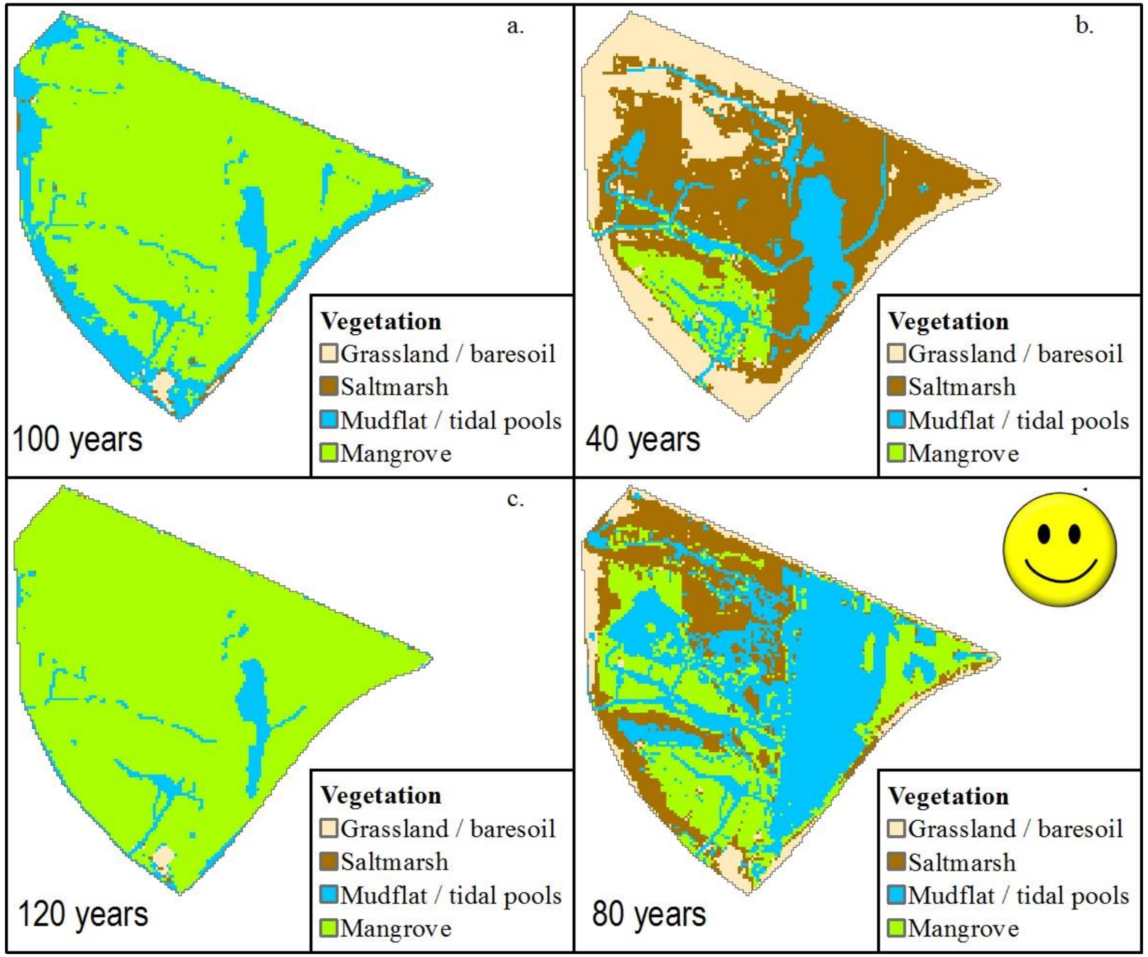
What if we increase sediment supply

No attenuation | Hydrodynamic attenuation

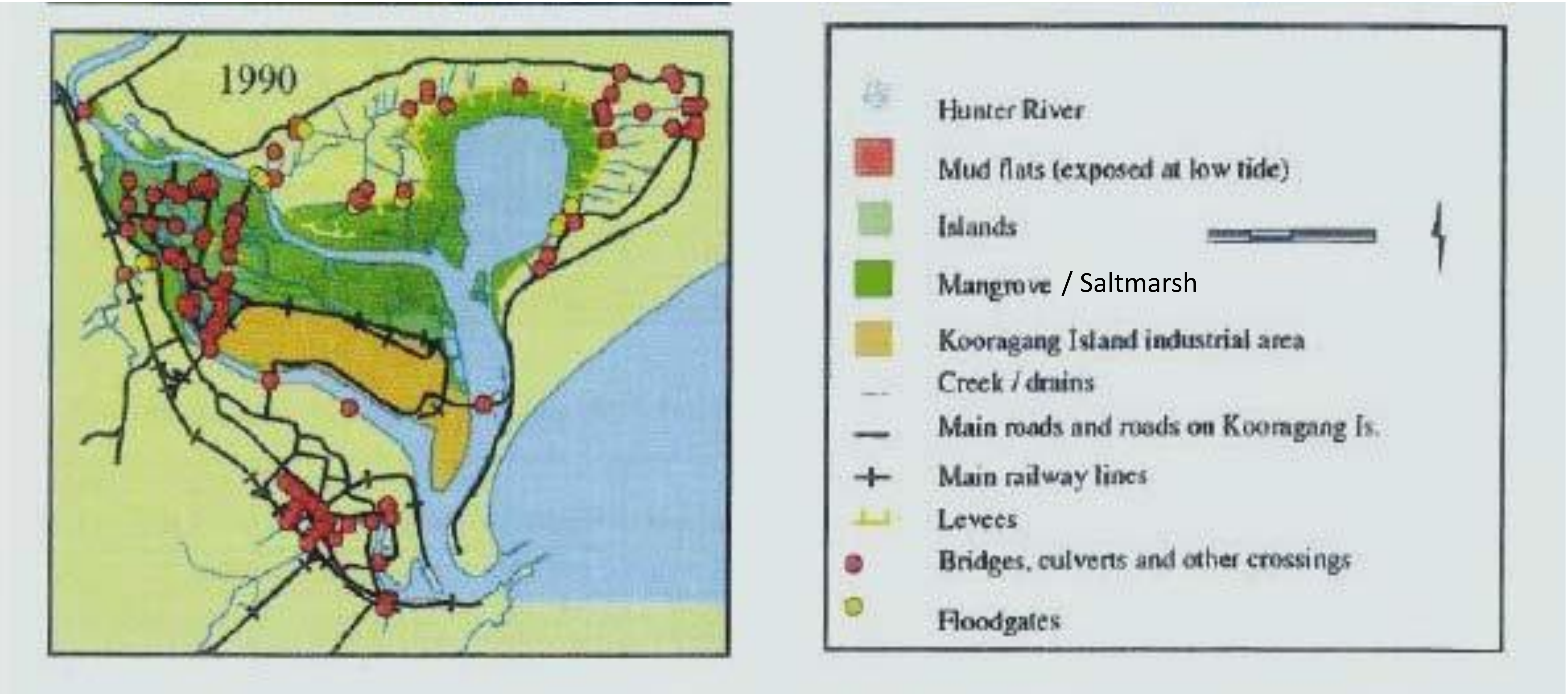


Low sediment (Cmax = 37 g/m^3)

No attenuation | Hydrodynamic attenuation

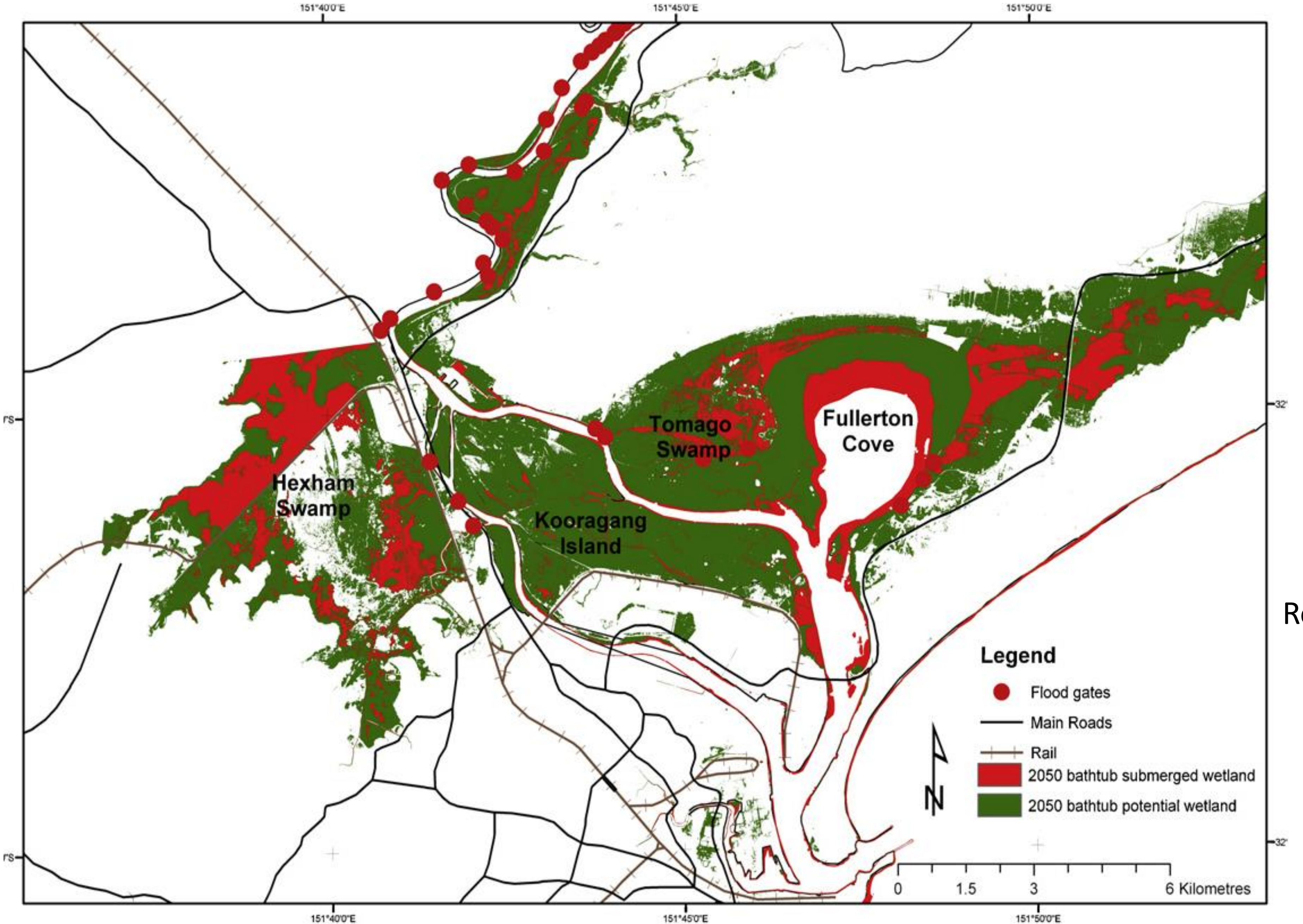


High sediment (Cmax = 111 g/m^3)

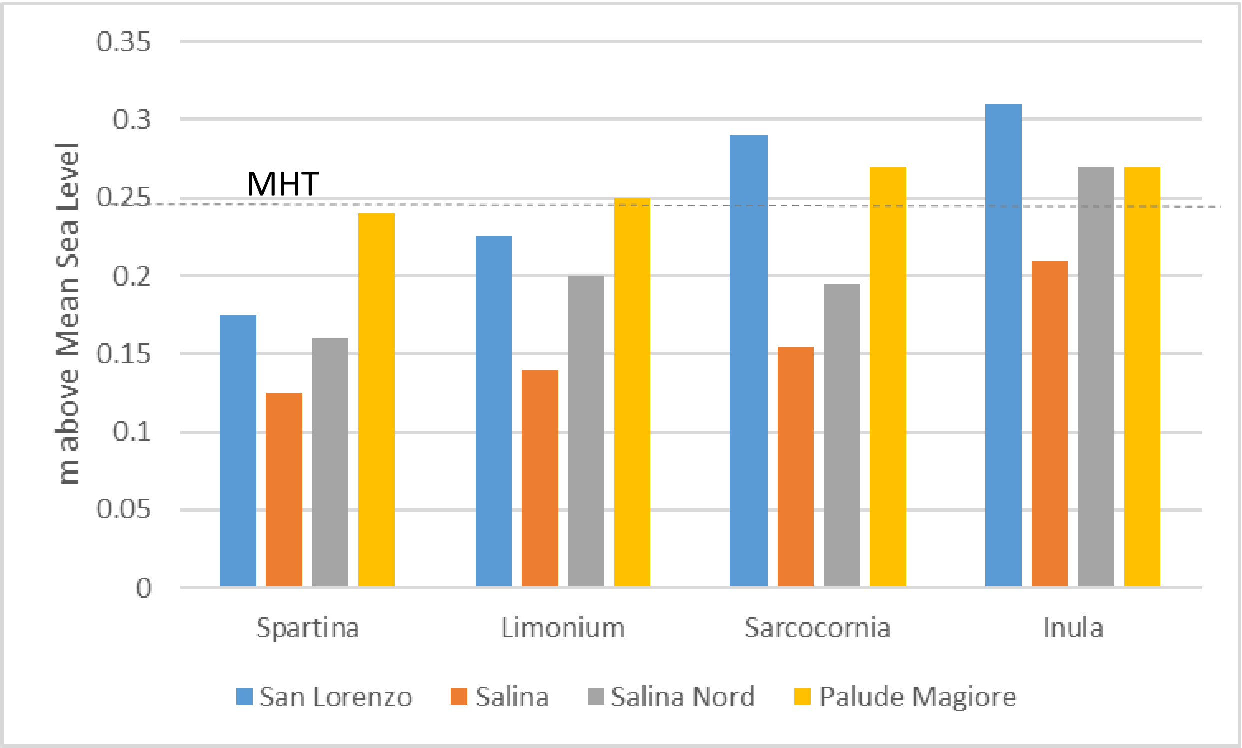


Williams *et al*. 2000

Resist or retreat?

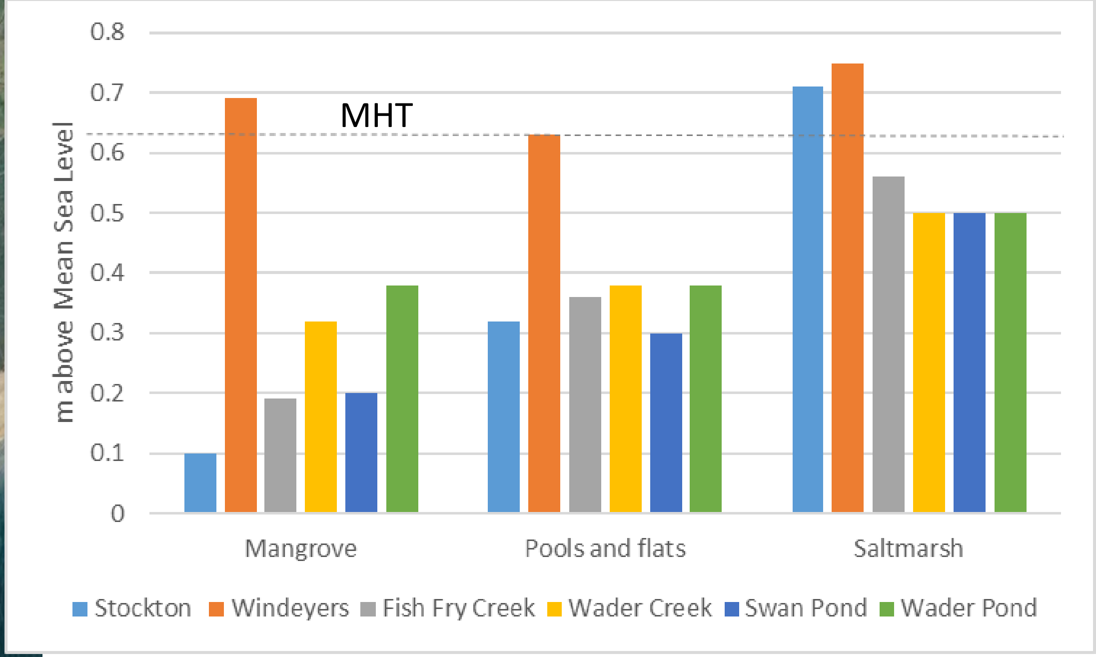


Rogers et al, 2012



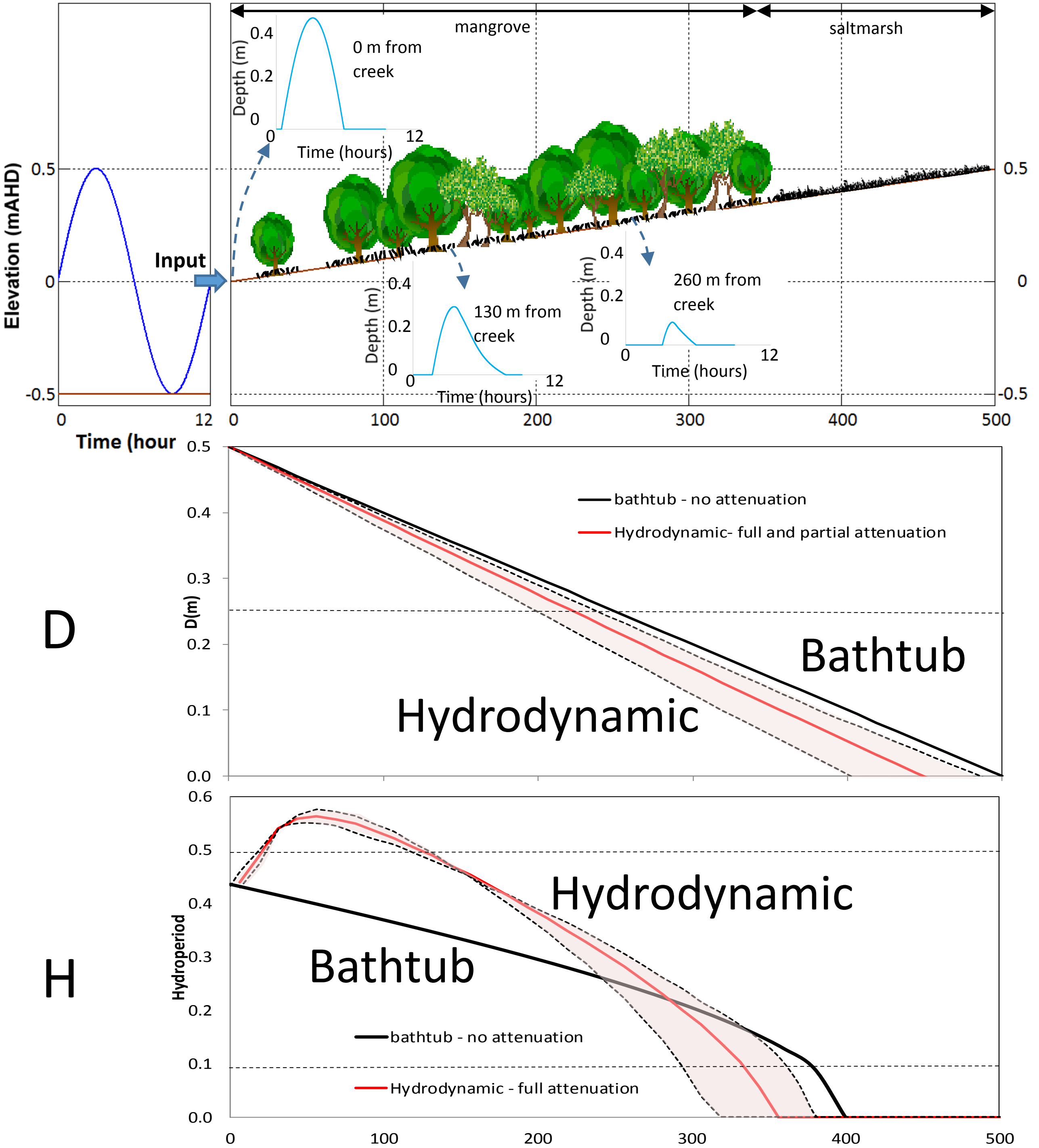
Silvestri and Marani, 2004


Hunter River North Arm
Hunter River South Arm
Windeyers Reach
Ash Island
Stockton Sandspit
City of Newcastle
Aerial Photo: AAM Hatch 2

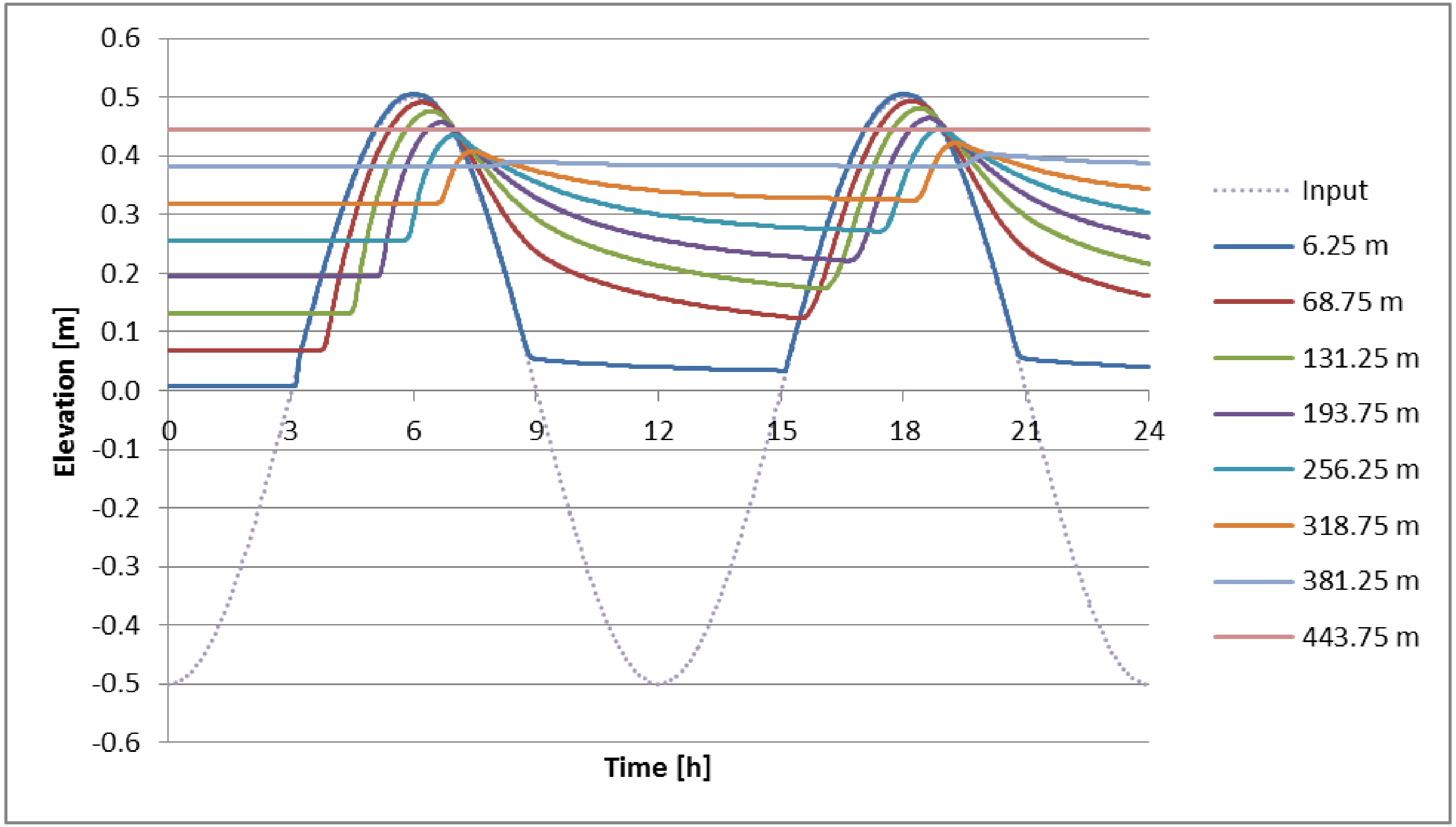

m above Mean Sea Level
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MHT
Mangrove
Pools and flats
Saltmarsh
Stockton
Windeyers
Fish Fry Creek
Wader Creek
Swan Pond
Wader Pond

Howe, 2008

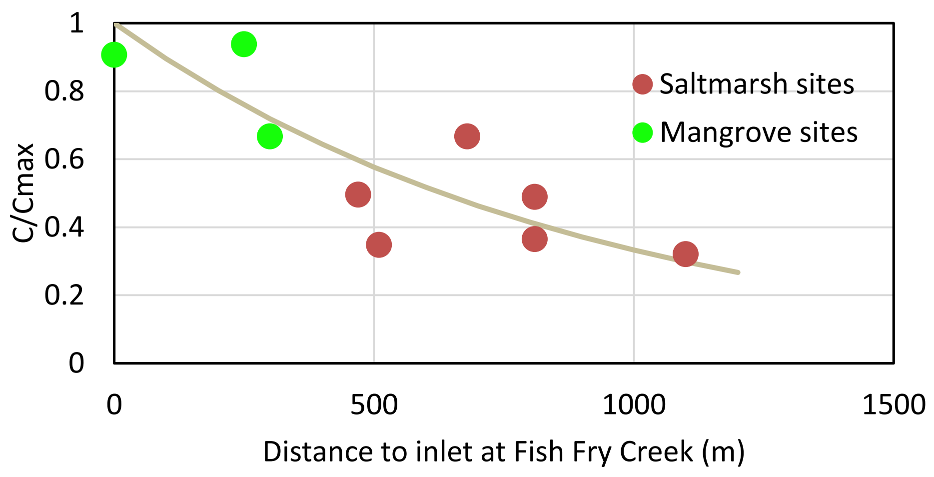
Attenuation due to vegetation

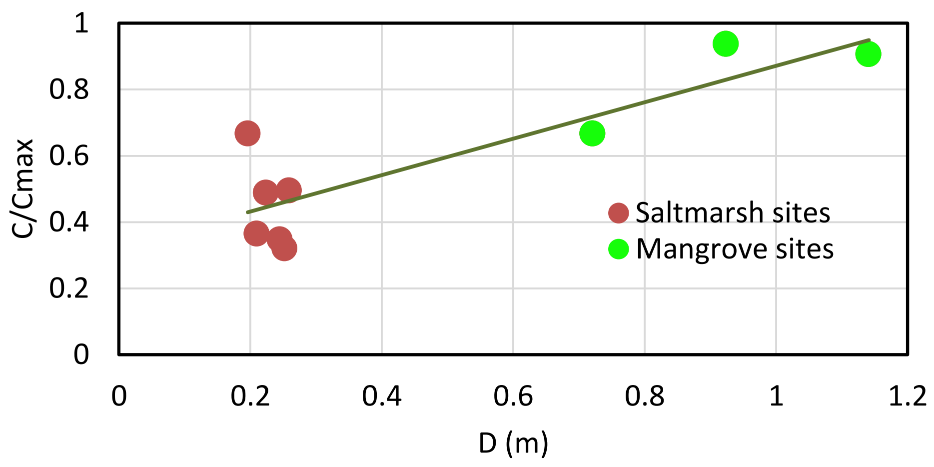


Hydrographs

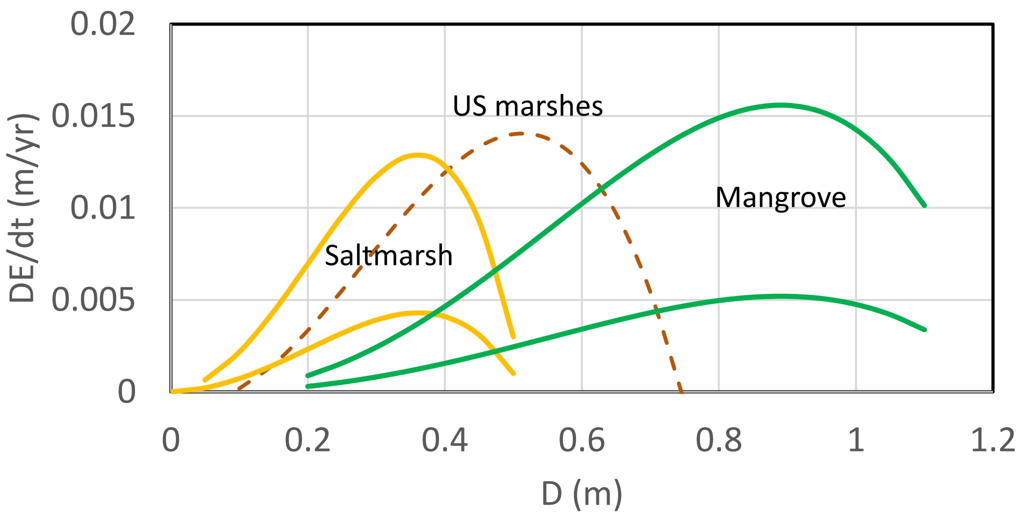


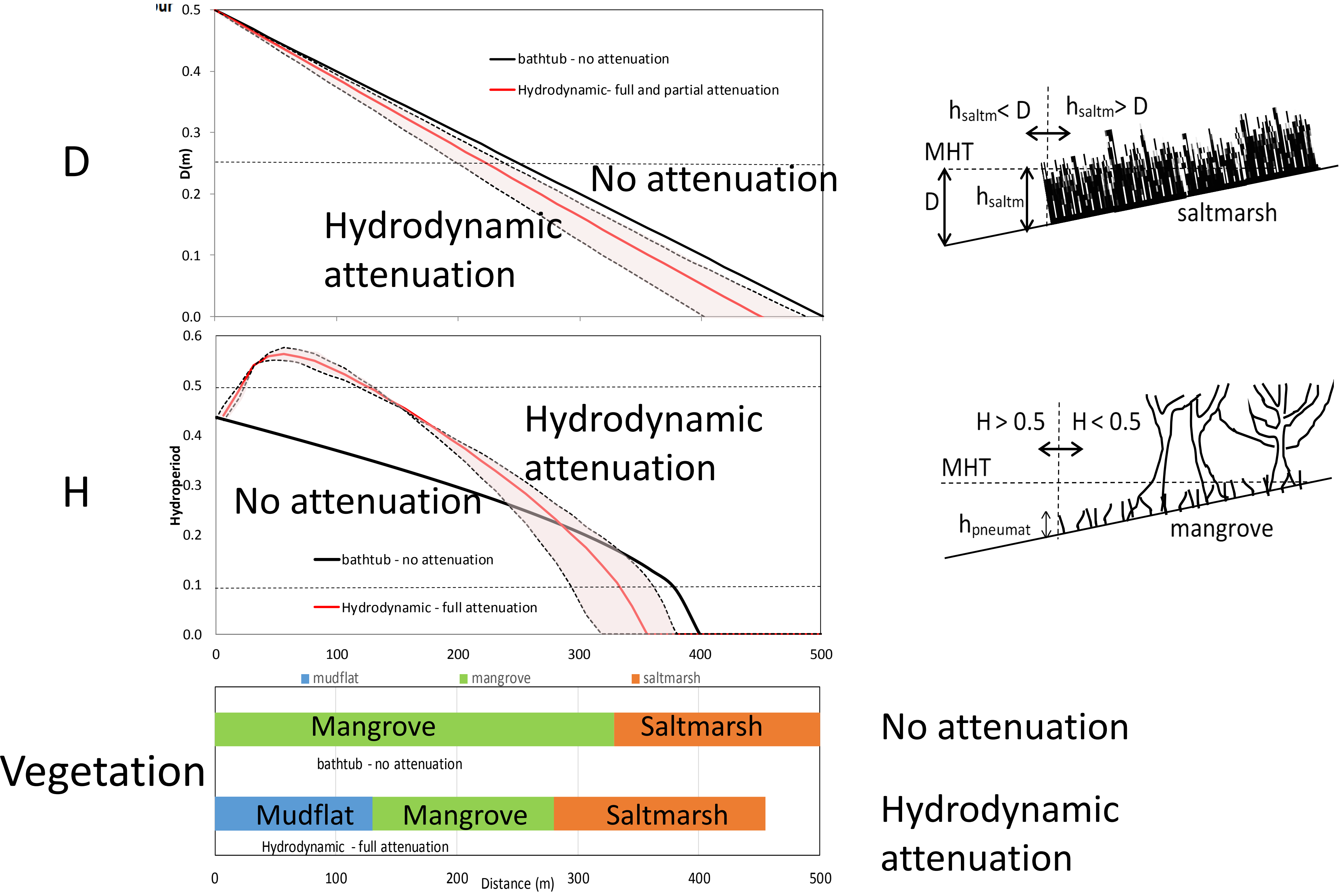
Suspended sediment concentration





Increasing sediment concentration





D
D(m)
0.5
0.4
0.3
0.2
0.1
0.0
bathtub - no attenuation
Hydrodynamic- full and partial attenuation
No attenuation
Hydrodynamic
attenuation
H
Hydroperiod
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Hydrodynamic
attenuation
No attenuation
bathtub - no attenuation
Hydrodynamic - full attenuation
0
100
200
300
400
500
Vegetation
mudflat
mangrove
saltmarsh
Mangrove
Saltmarsh
bathtub - no attenuation
Mudflat
Mangrove
Saltmarsh
Hydrodynamic - full attenuation
0
100
200
Distance (m)
300
400
500
h_{saltm} < D
h_{saltm} > D
MHT
D
h_{saltm}
saltmarsh
H > 0.5
H < 0.5
MHT
$h_{pneumat}$
mangrove
No attenuation
Hydrodynamic
attenuation