7. Conclusion

Comparing Tidal Wetlands of the three Regional Study Areas

Tidal wetlands of Moreton Bay, Port Curtis and Fitzroy River regions are characterised and influenced by different environmental and climatic conditions. The chief characteristics of the three study regions are listed in Table 25. Each have quite different sized catchments varying from the vaste Fitzroy River Basin catchment in central Queensland, to the moderately large area of the Moreton Bay region catchment (consisting chiefly of 4 distinct river catchments – Brisbane, Logan, Pine, Caboolture), to the much smaller catchment of the Port Curtis region (consisting chiefly of 2 distinct river catchments – Calliope, Boyne). Despite these differences, there are notable patterns which reflect both natural and human influences on tidal wetland vegetation. It is important to distinguish between these types of change and their relative importance so adaptive management strategies might be applied effectively both ecologically, socially and economically.

Table 25. Current extent of tidal wetlands of Moreton Bay, Port Curtis and Fitzroy River regions around 2000. Area estimates based on DPI data for specific regional areas defined in the study area assessments (Chapters 4, 5 & 6).

	Fitzroy River Estuary	**Port Curtis**	**Moreton Bay SE Queensland**
Major Catchment Area (km^2)	+145,205	+4,374	+21,220
Latitude South for general area	23.4° S	23.8° S	27.5° S
Average Max. Temperature (°C)	28.2	27.6	25.4
Average Min. Temperature (°C)	16.5	18.5	15.7
Mean Annual Rainfall (mm)	820	928	1185
Mangrove Taxa	16	14	8
Mangrove (ha)	20,800	2,369	14,386
Saltmarsh/Saltpan (ha)	30,158	2,510	2,522
Total Tidal Wetlands (ha)	50,959	4,879	16,908
WCI	40.8*	48.6*	85.1*

Genetic diversity, measured in terms of species numbers, is notably highest in the warmer latitude regions. Lower temperatures generally limit genotypic diversity, notable with the fewer species the Moreton region (Duke et al., 1998; also see Table 25) compared with the other two regional areas. There has been no evidence of genetic decline, or loss of diversity of vegetated cover in any of the three study regions. However, is it of notable interest in the Moreton Bay Region of two indications of potential effects on diversity from both natural factor and a human related factors. In the first case, severe storm effects may have influenced species composition of mangrove forests. This is evident where *Avicennia marina* was favoured over many other mangrove species since it can respond and recover more readily from serious physical damage. This species dominates the region, and other species which dominate elsewhere, like *Rhizophora stylosa*, are both poorly represented and have more diminutive growth forms. Secondly, *Avicennia marina* and other species there, have a lethal genetic mutation correlated with the presence of hydrocarbons in the sediments.

Table 26. Diversity of mangrove species in tidal wetlands of Moreton Bay, Port Curtis and Fitzroy River regions (see Duke et al., 1998). Dominant taxa in each region are indicated with bold underline.

	Fitzroy River Estuary	Port Curtis	Moreton Bay SE Queensland
Acanthus ilicifolius	X		
Acrostichum speciosum	X	X	X
Aegialitis annulata	X	X	
Aegiceras corniculatum	X	X	X
Avicennia marina	X	X	**X**
Bruguiera exaristata	X		
Bruguiera gymnorrhiza	X	X	X
Ceriops australis	**X**	**X**	X
Excoecaria agallocha	X	X	X
Lumnitzera racemosa	X	X	X
Rhizophora stylosa	**X**	**X**	X
Osbornia octodonta	X	X	
Pemphis acidula	X	X	
Scyphiphora hydrophyllacea	X	X	
Xylocarpus granatum	X	X	
Xylocarpus mekongensis	X	X	

The tidal wetlands of Moreton Bay, Port Curtis and Fitzroy River regions have different complements of mangrove species. This is shown in Table 26 comparing lists of mangrove species in each region. Generally, species numbers follow a decline from northern to southern locations, generally acknowledged to be influenced by corresponding declines in air temperature. Dominant taxa also vary from *R. stylosa*-*C. australis* in northern regions to *A. marina* in the south.

Rainfall amounts and longer-term patterns varied between regions (Fig. 126). Reported mean annual rainfall was least in the Fitzroy region and greatest in the Moreton Bay region. A longer term decline was evident in the Fitzroy region and was supported by the linear trendline with slope of -2.55 overall, and closely corresponding with the 20 year running average. The decline was therefore progressive over the last century. Other regions showed only slight if any overall declines in rainfall. Rainfall was more or less constant in the Port Curtis region, however in the Moreton Bay region , the 20 year running average rainfall showed relatively broad fluctuations. These data identify a long dry period from 1910 to 1945 to a period of relatively high rainfall from 1970 to 1995. The variation from high to low levels of rainfall in the 20 year running average amount to around 500 mm, being ~38% of the total rainfall for the region.

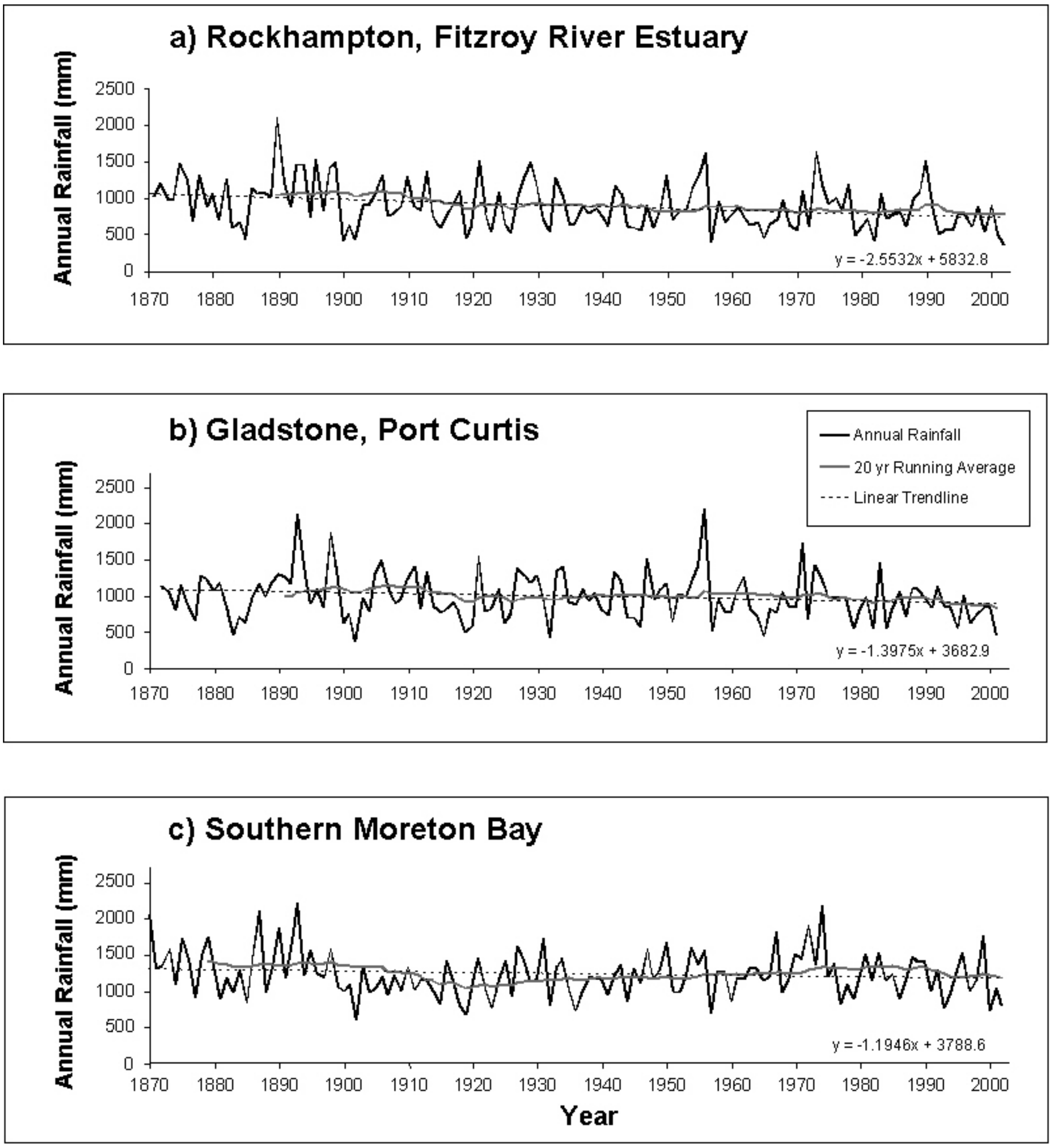

Figure 126. Plots of annual rainfall (1870-2002) for the study regions of (a) Fitzroy River Estuary (Rockhampton Aero, Rockhampton PO & Port Alma), (b) Port Curtis (Gladstone Aero) and (c) Southern Moreton Bay (Russell Island, Rocky Point & Brisbane) assessed in this report. Data was supplied by the Bureau of Meteorology, Brisbane Office.

The extent of tidal wetlands is largely dependant on the respective catchment size, but the biomass of vegetation depends more on annual rainfall. The amount of biomass was chiefly correlated with the extent of mangrove vegetation since trees have greater mass than the more diminutive saltmarsh, consisting of shrubby monocots and grasses. In the classification used in this assessment, saltmarsh has been grouped with saltpan areas. Saltpans have been nominally classified as vegetation-free zones in the past (ala. Fosberg, 1961), but this does not account for the prolific benthic microalgae which inhabit the surface layers. These algae flourish seasonally during periods of higher rainfall when they form extensive green mats up to 1 cm thick.

The larger catchment of the Fitzroy may also have some influence on the higher number of species, but the catchment size factor was considered of secondary importance regards the amount of vegetative cover. Vegetative cover appears to depend more on rainfall. As part of this assessment, the relationship between mean annual rainfall and the Wetland Cover Index (WCI) was proposed as a convenient quantitative measure of vegetative condition for tidal wetlands. Index estimates were positively correlated with rainfall, as discussed previously (see Chapter 1). However, overall regional estimates, shown in Table 1, were not considered accurate indicators of rainfall condition since other important types of change, like ‘reclamation loss’, and ‘depositional gains and losses’ would effect the proportions of vegetative cover. The combination of types of change in these wetlands provide insights into the different drivers acting in respective regional areas.

In this treatment, we introduce and propose a selection of indicators for evaluation of the types of change. These indicators include field observations in combination with remote sensing parameters. The key indicators most relevant to change in each region were identified. Some may apply more widely, but in most cases, the types of change may be ranked based on the area or percent coverage. For ecotone shift, we have quantified this effect using the Wetland Cover Index for areas of little or no human influence (direct or indirect). Wetland habitats were expected to integrate and combine a variety of influencing factors over longer-term periods in their composition, structure and distribution.

The indicators described in this study take advantage of the special characteristics of tidal wetlands in general. For instance, mangroves were expected to show their response to climate change in fluctuations in vegetative ecotones, or zonation patterns, across tidal profiles. Furthermore, tidal wetlands might also show their response to sea level change with corresponding and unidirectional shifts in sea and land margins. For instance, an appropriate research and monitoring strategy might use mangrove forest transect plots to quantify human impacts and changes in climate and sea level. Quantification will be supported further by using remote sensing

– comparing historical aerial photographs retrospectively to assess change over the last half century, and to link these findings with current imagery confirming prior condition as the baseline for future ongoing monitoring and assessment.

The relative extent and importance of the major types of change are shown in Table 3 comparing each of the three regional study areas. There were both human and natural disturbances affecting tidal wetland habitats of each region. Each may have notable longer term consequences. Changes were observed as both overall gains and losses in wetland habitat. The benefits of distinguishing between the different impacts and types of changes aids quantification of the dominant and moderate drivers of change which characterize each region.

Dominant influences

The dominant driver of change in tidal wetlands in Moreton Bay and Port Curtis regions has been Reclamation Loss, directly affecting more than 2,200 ha and 1,600 ha respectively. This shows that ~13% and ~33% of tidal wetlands in these regions have been converted to other use over the last 60 years. These other uses is partially location dependant where losses were largely due to port and industrial development in the Port Curtis region, while in the Moreton Bay region losses included airport construction and canal estates. By contrast, the dominant driver in the Fitzroy River estuary region had been Depositional Losses and Gains which increased the net area of tidal wetlands by 860 ha, or ~2% of the total. These changes were likely due to land use changes in the catchment, in conjunction with changes to the hydrology of the river. Considerable efforts were made to improve the navigation of the river from the late 1800s up until the 1960s (Webster and Mullins, 2002). These efforts involved the construction of river training walls, channel dredging, bank excavation and landfill. The combination of these alterations to the river channel are expected to have changed the hydrology, affecting both depositional and erosion sites along the lower estuary. It was notable that several large mangrove islands formed in the estuary mouth between 1950 and 1970 (see Chapter 5).

Moderate influences

Moderate, or secondary, drivers of change were notable also in each region. In Fitzroy River Estuary, ~830 ha (~2%) were lost to reclamation of tidal wetlands chiefly for conversion to port facilities and salt works near Port Alma. The impact of these changes were not expected to extend beyond the immediate areas affected.

Table 27. Effect levels for types of change influencing tidal wetlands of Moreton Bay, Port Curtis and Fitzroy River regions over the last two centuries until 2000. The 12 types of change are grouped into 4 categories (A-D) for human and natural influences. Refer also to Table X ($1^{\text{st Chap 1}}$).

Type of Change	Fitzroy River Estuary	Port Curtis	Moreton Bay SE Queensland
A. Direct – Intended & obviously human related			
1. Reclamation loss	**Effect:** Moderate **Driver:** >830 ha lost to ponded pasture, salt production & development around Port Alma.	**Effect:** Dominant **Driver:** >1,600 ha lost to industrial and port development in Auckland Creek and toward Calliope River mouth.	**Effect:** Dominant **Driver:** >2,200 ha of wetlands lost to industry, airport & seaport development plus urban, canal estates & agriculture.
2. Direct damage	**Effect:** Minor **Driver:** Occasional tree cutting, access paths & tracks.	**Effect:** Minor **Driver:** Occasional access paths, tree cutting, access paths, tracks, trampled roots.	**Effect:** Moderate **Driver:** Numerous access paths, trampled roots, although areas generally protected under law & with walkways.
B. Direct – Unintended & obviously human related			
3. Restricted tidal exchange	**Effect:** Minor **Driver:** Impoundment, built-up roads.	**Effect:** Minor **Driver:** Impoundment, built-up roads.	**Effect:** Moderate **Driver:** Impoundment, built-up roads - proportionate to population size.
4. Spill damage	**Effect:** None	**Effect:** Minor **Driver:** Occasional small oil spills proportionate to shipping volume.	**Effect:** Minor **Driver:** Oil spill incidents proportionate to shipping volume - accumulation may exceed toxicant degradation rates.
C. Indirect – Unintended & less obviously human related			
5. Depositional gains and losses	**Effect:** Dominant **Driver:** Net gain of ~860 ha around river mouth due to increased sediment in run-off, plus construction of training walls. River channel dredging ceased in 1965.	**Effect:** Minor **Driver:** Clearing of catchment vegetation & increased crop agriculture increased sediment run-off, resulting in shallower waters around the river mouth.	**Effect:** Minor **Driver:** Site hardening with city-urban roads and built-up areas and reduction in catchment croplands, altered & decreased sediment run-off. Dredging maintained the navigation channel.
6. Nutrient excess	**Effect:** None	**Effect:** None	**Effect:** Minor **Driver:** Possible dieback of mangroves resulting from impoundment caused by blooms of algae attached to roots.
7. Species-specific effect	**Effect:** None	**Effect:** Moderate **Driver:** *Avicennia* dieback in early 1970s affecting ~500 ha of mangroves. Apparent toxicant in run-off, or industrial emission.	**Effect:** Minor **Driver:** Minor dieback associated with toxicants in apparent run-off, & with application of herbicides along drains.
D. Not obviously human related, if at all			
8. Wrack accumulation	**Effect:** None	**Effect:** Minor **Driver:** Litter debris, debris from blooms, storm waves.	**Effect:** Minor **Driver:** Litter debris, debris from blooms, storm waves. Recent *Lyngbya*.
9. Herbivore/insect attack	**Effect:** Minor **Driver:** Insect plagues - occasional in upper estuary.	**Effect:** Moderate **Driver:** Insect plague depleted canopy foliage by 40% leaf area.	**Effect:** Minor **Driver:** Insect plagues - occasional.
10. Storm damage	**Effect:** Minor **Driver:** Severe storm, hail, lightning, storm waves - occasional.	**Effect:** Moderate **Driver:** >210 ha affected by hail damage along Calliope River. Severe storms, lightning, storm waves - occasional	**Effect:** Moderate **Driver:** >190 ha affected by hail damage around Cobby Cobby Island, southern Moreton Bay. Severe storms, lightning, storm waves - occasional
11. Ecotone shift	**Effect:** Minor **Driver:** Climate change - longer-term	**Effect:** Minor **Driver:** Overall rainfall decline notable, longer-term change, causing some dieback.	**Effect:** Moderate **Driver:** Rainfall fluctuations notable over period, climate corresponds with mangrove increase & recent dieback.
12. Zonal shift	**Effect:** None	**Effect:** None	**Effect:** Moderate **Driver:** Sea level increase - notable local effect in southern Moreton Bay.

Relative effect levels: None; Minor; Moderate; Dominant, based on relative extent and presence of changes observed.

In Port Curtis region, ~500 ha were apparently affected by an unidentified toxicant, causing dieback of only *Avicennia marina* in the early 1970s (cp. Duke et al., Mackay report, 2002) while other species appeared unaffected. Much of this damage has since recovered apparently, although the proportion of *A. marina* in the region may have remained relatively low. Further losses in Port Curtis region include damage caused by insect herbivores removing 30-40% of canopy foliage of *Rhizophora* stands across an area of >200 ha. No dieback or tree death was observed in this case. Additionally, in Port Curtis region, there was a significant damage and dieback of trees caused by a severe hail storm in 1994 (Houston, 2000). Tree damage was selective chiefly killing *Rhizophora* and *Ceriops* species while *Avicennia* trees were able to recover.

In Moreton Bay region, many areas have been affected by Direct Damage caused by people walking through mangrove areas trampling above ground roots, disturbing below ground roots and crab burrows, causing erosion, breaking branches, and preventing establishment and growth of new seedling recruits. Such sites were eroded as sediment binding the roots broke down. With erosion, any recruitment was undermined, as well as the undermining of mature trees. The site generally deteriorates from this point, and such changes are expected to be irreversible. Damage caused by a hail storm was also observed in Southern Moreton Bay. In one storm, ~190 ha were killed and severely damaged. As observed in Port Curtis region, *Avicennia* was able to recover from this severe physical damage, while other species like *Rhizophora*, *Ceriops* and *Bruguiera* were slower to recover, if at all.

Additional apparent natural factors have also affected tidal wetlands of the Moreton Bay Region indicating notable trends in climate-related factors. Ecotone shift had occurred in southern Moreton Bay, corresponding to fluctuations in annual rainfall. Zonal shift was also described in the case study of Cobby Cobby Island, indicating apparent sea level rise in southern Moreton Bay. It is yet to be determined whether this effect was a regional or localised, although it appears to be the latter. Both these shifts in vegetation components of tidal wetlands where influenced and partially obscured by significant erosion over the last 20-30 years of the mangrove fringe (depositional losses and gains) apparently caused by dredging and wave action of vessels navigating Canaipa Passage along the eastern side of Cobby Cobby Island (Andrews, 1997; Morton *et al.*, 1999).

Benefits in identifying drivers of change

By identifying the types of changes affecting tidal wetlands, it has been possible to quantify and compare their combined influences on tidal wetlands for each study region. Knowing the relative importance of such factors affecting coastal areas provides distinct advantages for those deciding on management options which would be most effective. For example, this information would be useful in an evaluation of management options and actions in response to clear indications of environmental degradation, like mangrove dieback. An assessment of the chief drivers of change, provides information for cost effective management actions. These actions might also be socially acceptable provided people are advised of the assessment outcomes in popular media and education. In the instances where changes might be related to human activities, mitigation efforts may be directed effectively to respective levels of government to implement appropriate remedial actions. For example, local government might direct effects might respond to direct effects from land use, while national government might deal with indirect factors like national emission controls. For changes related to fluctuations in climate, including sea level change, it may also be necessary to implement ‘accommodation’ measures where predicted changes might be anticipated while planning for future development in coastal areas.

The strategies proposed in this report offer a means to systematically assess and evaluate the types of change in tidal wetlands, and to identify the relative importance of the dominant drivers of change. The advantage in having this knowledge is that effective management options can be applied to preserve environmental health of protected tidal wetland habitat, and to sustain the acknowledged benefits of these valuable natural ecosystems.