Coastal Processes, Tourism and Climate Change in the East Coast Cluster: Impacts & Opportunities

Briefing Note #4: A resource document for exploring adaptation options within the tourism industry, related communities and coastal managers

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Key messages

- Natural coastlines and marine habitats are major attractions for domestic and international visitors to the East Coast Cluster, including the southern Great Barrier Reef, Fraser Island World Heritage Area, Moreton Bay Marine Park, Cape Byron Marine Park, Myall Lakes, Hunter Estuary Wetlands and Sydney Harbour. The **coastal and nature-based tourism industry is dependent on these natural assets** which are vulnerable to climate change.

- State-level tourism bodies and some regional networks **recognise the potential impacts of climate change on iconic coastal environments**. Industry bodies are also looking to improve the resilience of coastal tourism operators to climate-related natural disasters through advice on risk management and disaster preparedness.

- **Sea level rise**, increasing sea surface temperatures, changing distribution and intensity of major storm events, and **impacts on coastal infrastructure** across the region will influence the types of tourism values that can be maintained in current locations and the viability of operators.

- In northern parts of the region, **high vulnerability to fluvial erosion** may increase water quality impacts on downstream coastal environments. In southern parts of the region, large and **internationally significant areas of coastal wetlands may be lost** in areas like the Hunter River Estuary under high-emissions sea level rise scenarios.

- There is significant opportunity for regional tourism networks along the east coast to **align their industry plans with regional NRM planning** to identify shared assets to protect, explore opportunities for the co-management of coastal resources and environments, and to coordinate disaster planning and recovery efforts.

- The **strong environmental stewardship ethic** of coastal tourism operators provides a platform to explore future opportunities as managers of the coastal environment, including the potential for monitoring and managing carbon sequestration in coastal wetlands as an income diversification strategy.

Background

The focus of this briefing note is to assist regional Natural Resource Management (NRM) and Local Land Services (LLS) groups within the East Coast Cluster to plan future engagement with the coastal tourism industry and other coastal managers on issues related to climate change. Much of the coastal and marine tourism industry in the region is heavily dependent on natural assets that are vulnerable to climate change impacts. An increased frequency of extreme weather events, warming sea surface and land temperatures, and sea level rise are expected to significantly alter already dynamic coastal systems (Wong et al., 2014). Changes in coastal landforms and coastal ecosystems may create new opportunities as well as challenges for regional communities and tourism businesses. Given the dependence of the industry on continued access to, and amenity of, the local coastal and in-shore marine environment, understanding these changes will help identify options to help the industry adapt.

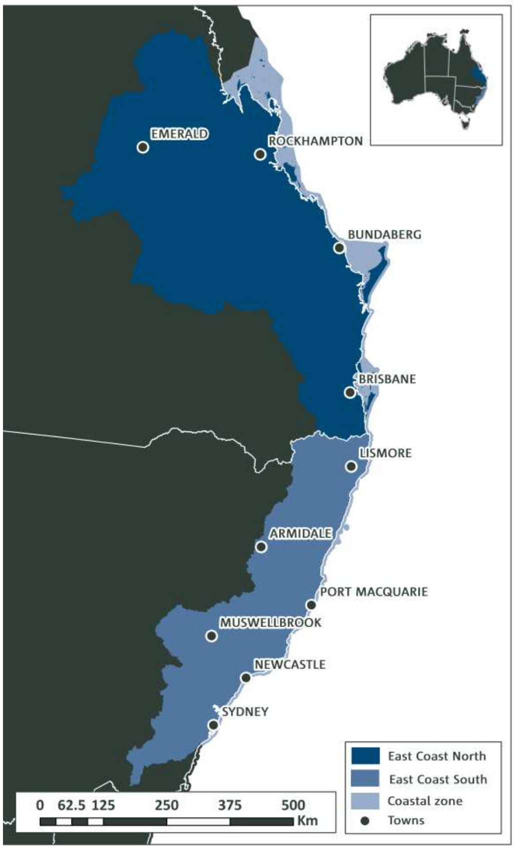

Figure 1. Map of the East Coast Cluster (Dowdy et al., 2015)

This briefing note reports on climate change vulnerability and adaptation opportunities for the coastal tourism industry within the six NRM/LLS regions of the East Coast Cluster (Figure 1). These regions include from north to south, the Queensland NRM regions of Fitzroy Basin, Burnett-Mary, South East Queensland (SEQ) (also referred to as East Coast North), and the New South Wales LLS regions of North Coast, Hunter and Greater Sydney (East Coast South). The briefing note is structured using a series of headings and sub-headings that reflect the main parts of an *integrated vulnerability assessment framework*, e.g. exposure, ecological/biophysical impacts, socio-economic impacts, and adaptive capacity. This framework has been developed specifically to help think about sector-based adaptation to climate change in resource dependant industries, and has been adapted to suit the writing of this briefing note (Marshall et al., 2013).

The briefing note also summarises tourism industry policy perspectives and outlines a suite of adaptation responses where opportunities for cooperation between industry and NRM groups on shared priorities exist for reducing vulnerability to climate change. Detailed scientific data used in this analysis were commissioned by the Australian Government's Department of Environment and can be accessed through the references listed in the final section.

A brief overview of the industry in the face of climate change

Tourism is a vitally important industry for the East Coast Cluster region, making significant contributions to job creation, export earnings and regional development. In 2012-13, total annual tourism expenditure for destinations spanning the cluster region was estimated at more than $35B (TRA, 2014) (see Table 1 below). Whilst Sydney and Brisbane accounted for nearly $20B of this expenditure, a significant part of the overall expenditure was also spent on regional/coastal nature-based tourism activities. Indeed, an extensive and diverse range of natural coastlines and marine habitats are key attractions for domestic and international visitors. Important natural features in the East Coast Cluster region include the southern end of the Great Barrier Reef, Fraser Island World Heritage Area, Moreton Bay Marine Park, Cape Byron Marine Park, Myall Lakes, Hunter Estuary Wetlands and Sydney Harbour. The tourism industry is dependent on these natural assets, and climate change threatens these assets (Cox et al., 2013). Protecting these natural assets will be paramount for the region and for the industry.

Table 1. Key Statistics for Tourism Regions within the East Coast Cluster

Tourism region	**Holiday visitors** (2012/13) '000	**Tourism businesses** (2011/12)	**Tourism expenditure**[1] ($m) (2012/13)	**Nature based experiences** (2012/13) '000	**Going to the beach**[2] '000
Central QLD	501	2,021	1,064	266	212
Bundaberg	283	907	459	130	136
Fraser Coast	457	1,260	484	266	231
Sunshine Coast	1,882	5,330	2,789	875	1,425
Brisbane	1,888	22,753	6,198	1,296	238
Gold Coast	2,805	9,106	4,676	1,116	1,624
Northern Rivers	1,061	3,860	1,439	515	1,371
Mid North Coast	1,960	4,006	2,318	949	1,617
Hunter	778	5,300	1,412	394	892
Central Coast	712	2,888	861	246	-
Sydney	3,767	60,632	13,509	2,809	-
Total	**16,094**	**118,063**	**35,209**	**8,862**	**7,746**

Source: Destination NSW 2015; TEQ 2013, TRA 2014

Beaches, in particular, are a major natural asset for many coastal communities in the East Coast Cluster, attracting a considerable number of tourists and thereby contributing significantly to the local economy. Indeed, more than 7.7 million visitors to coastal areas within the East Coast Cluster indicated that 'going to the beach' was one of their top 5 activities undertaken while visiting the region (TRA, 2014). Beaches, however, are highly vulnerable to climate change-induced changes to sea levels and their extremes, as well as associated erosion (Hinkel et al., 2013).

[1] Tourism expenditure includes international and domestic visitor expenditure. It captures all expenditure relating to the trip, including airfares, accommodation, food and beverages, etc. It also includes different types of purposes for visiting, including holidays, business travel, visiting relatives and friends, etc.

[2] Data was sourced from national annual surveys of travellers (Tourism Research Australia's National Visitor Survey and International Visitor Survey. For the NRM regions in Queensland, data was averaged over a four year period (Dec 2009 – Dec 2012). For the NSW LLS regions, data was also averaged over a four year period (Sept 2011 – Sept 2014). In NSW, data is only based on responses from domestic visitors and does not include responses from international travellers. Data for Sydney and the Central Coast was not available.

In 2012-13, more than 8 million visitors to the East Coast Cluster participated in 'nature based experiences', including visits to national parks, botanical gardens or wildlife parks/zoos/aquariums, whale/dolphin watching, bushwalking, snorkelling and scuba diving (Destination NSW, 2015; TEQ, 2013; TRA, 2014). Areas with the highest density of nature-based coastal and marine tourism activity in the cluster include greater Sydney, Brisbane, the Gold Coast, the Mid North Coast of NSW and Queensland's Sunshine Coast region (TRA, 2014; see Figure 2 below).

The marine and coastal tourism industries of some regions within the East Coast Cluster show a degree of specialisation and dependence on particular resources (see Appendix 1). For example, marine tourism in the Gladstone region is dominated by charter fishing with some scuba diving operations that provide access to reefs and islands of the southern Great Barrier Reef. Marine tourism in Hervey Bay has a strong seasonal dependence on migratory humpback whales (Corkeron, 2004). The major coastal cities show a higher diversity of marine and coastal tourism types (e.g. Brisbane, Gold Coast, Sydney areas) and will be able to draw on their larger population bases to provide a buffer against market shocks and fluctuations at a regional scale. However, some operator types will be highly dependent on the preserved health/state of their natural resources and hence are vulnerable to the impacts of climate change at local and enterprise scales.

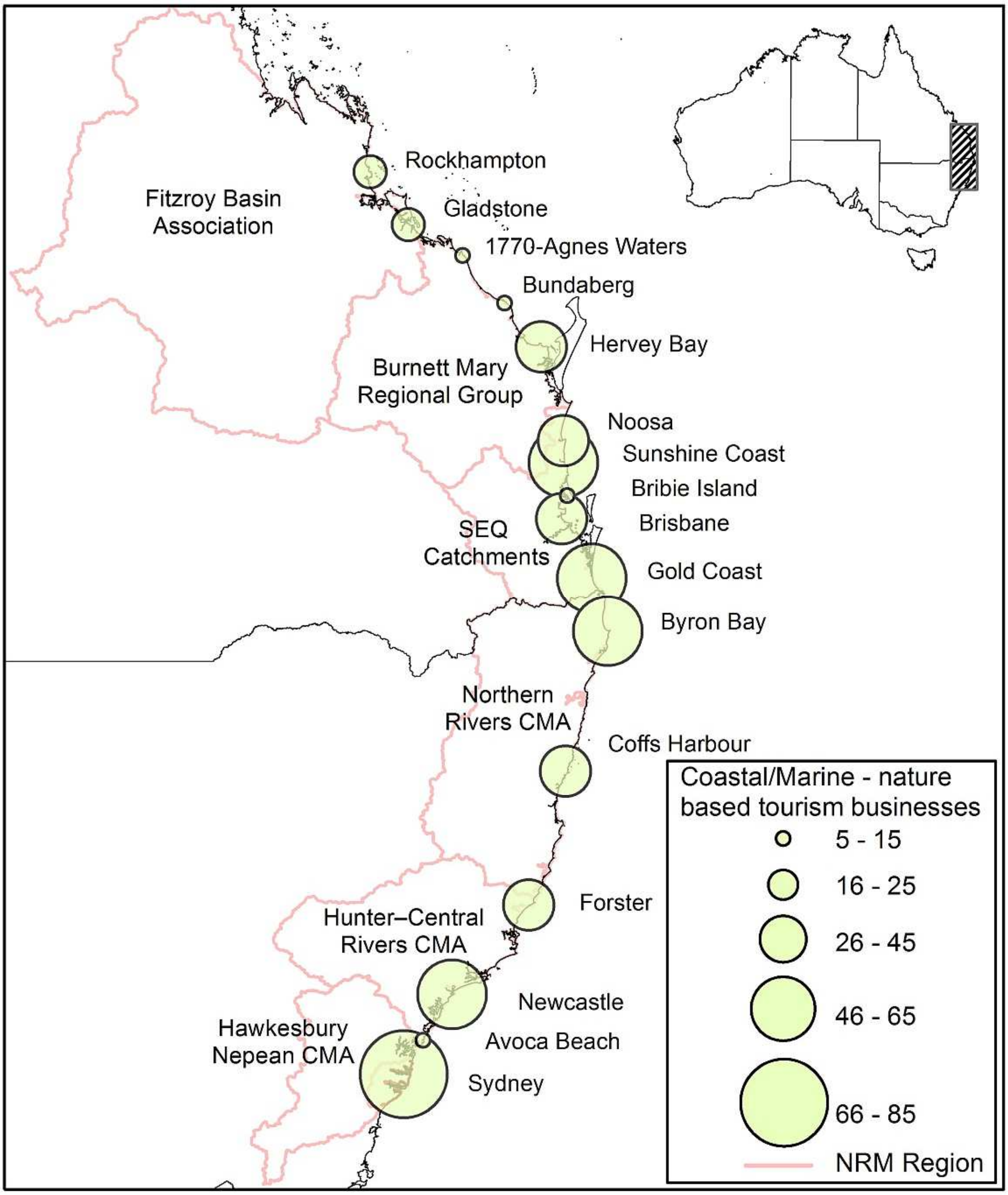

Figure 2 Indicative density of nature and wildlife based coastal and marine tourism activity, based on the number of such businesses identified via a spatially explicit, systematic web search method (at March 2015). NB. Six major categories of tourism businesses offering the most common coastal/marine activities were chosen: diving and snorkelling, waters sport rentals and/or lessons, charter fishing, whale-watching, boat cruises and/or rentals, and other wildlife/nature observation tours. Key words relating to each category were combined with the name of each coastal city/town (160 in total for the cluster). The first five pages of each Google™ web search results were examined and all relevant links to a tourism operator were recorded.

Industry perspectives on the challenge ahead

A review of tourism industry policies, documents, plans and information in both Queensland and New South Wales gives some indication of how the tourism industry currently understands potential climate change related impacts, and the types of actions being taken or proposed to address related risks.

At a general level, the industry recognises the potential impacts of climate change on iconic coastal environments, including the natural, physical and ecological assets and locations that currently serve as major attractions in the East Coast Cluster region. Industry organisations are also aware of the potential impacts of extreme heat events, the spread of some diseases, and changed rainfall patterns on business operation and on visitor experiences. For example, the '*Better Business Guide*' (TQ, 2011b) highlights the impacts of natural disasters on the tourism industry in Queensland. This document also outlines the environmental and economic impacts of climate change on tourism businesses, and explains carbon offsetting. Lastly, and perhaps most concretely, State-level industry organisations like Tourism Industry Council (TIC) NSW and Tourism Queensland have started promoting crisis management and disaster preparedness planning at the individual business level to reduce the impacts of extreme weather events on business resilience and recovery. Within the East Coast Cluster region, the strategic plan of the North Coast Destination Network (NCDN) – the regional tourism organisation for Mid North Coast and Northern Rivers – also recognises natural disasters, such as flooding and bushfires, as a risk to tourism operators on the north coast (NCDN, 2013).

State-level industry organisations have developed and are undertaking promotion of several activities relating to helping individual operators manage climate related risks to their businesses. In 2010-2011, Tourism Queensland ran '*Weatherproof Your Business*' workshops, which provided information about preparing for and responding to natural disasters. This program has now been made available as an online training module. Tourism Queensland has also developed a number of factsheets that deal with sustainability, carbon-offsetting, climate change, and risk and disaster management. TIC (NSW) also provides a number of online resources for risk management. The overall objective is to foster knowledge exchange by assisting tourism operators to prevent, prepare, respond to and recover from natural disasters and extreme weather events. A major component of the risk management work developed to date focuses on bushfires.

Exposure

This section provides a summary of future climate projections relevant to coastal and marine areas of the East Coast Cluster region based on CMIP5 models, which also underpin the Fifth Assessment Report of the IPCC. A set of four scenarios, also referred to as Representative Concentration Pathways (RCPs), has been produced which represent the full range of plausible future emission scenarios. This briefing note focuses on the high scenario (in terms of future carbon emissions – RCP8.5) and the moderate scenario (intermediate scenario resulting from moderate emissions reduction - RCP4.5) (Dowdy et al., 2015).

Current climate for the East Coast Cluster

The East Coast Cluster region spans a large range of latitude and altitude, resulting in a diverse range of climatic conditions. Its climate is predominantly subtropical, with regional variations such as tropical influences in the north and temperate influences in the south. Since the close proximity to the ocean has a moderating influence on temperatures, the East Coast Cluster generally experiences fewer hot days than locations elsewhere in Australia at similar latitudes (Dowdy et al., 2015).

The seasonal rainfall characteristics in the East Coast Cluster are determined by a complex series of rain-bearing weather systems that occur in this region (i.e. trade winds, easterly trough, tropical cyclones, fronts and low-pressure systems, changes in sea surface temperatures). Overall, February is the wettest month, followed by a dry period during the cooler months (June to September). Northern parts of the East Coast Cluster tend to experience more pronounced differences between the wet and the dry months of the year, relating to stronger tropical influences. Across the region, there is a spatial gradient in rainfall, where locations near the coast generally experience more rainfall than locations further inland (Dowdy et al., 2015).

Changes in mean sea levels and their extremes, as well as sea surface temperatures and ocean acidity have the potential to affect both the terrestrial and marine environments in coastal regions of the East Coast Cluster. In line with global mean sea levels, Australian sea levels have risen during the 20th century. Global mean sea level rise (GMSL) over the 20th century was around 1.7mm per year, with an increase to around 3mm per year over the last 20 years (Church and White, 2011; White et al., 2014). Around Australia, sea levels have risen at an average rate of 1.4mm per year from 1966 to 2009 (Dowdy et al., 2015), with fastest rates currently in northern Australia (Poloczanska et al., 2012).

Sea surface temperatures have also increased significantly in the waters surrounding Australia since the early 20th century, with enhanced warming associated with the East Australian Current (Wu et al., 2012; Dowdy et al., 2015). Comparing the time period from 1910-29 with 1992-2011, sea surface temperatures have risen by 0.68°C (Lough et al., 2012). The rate of temperature rise in Australian waters has accelerated since the mid-20th century to 0.11°C per decade from 1950 to 2011. Warming is generally largest in the southern part of the East Coast Cluster region and smallest in the north (Dowdy et al., 2015). Sea surface temperatures are a primary controlling factor for marine life in waters surrounding Australia, and the warming of ocean waters is affecting the distribution and abundance of a wide range of marine species (Lough et al., 2012).

Low pressure systems, such as tropical cyclones and East Coast Lows, also directly impact coastal areas of the East Coast Cluster. Tropical cyclones can have severe impacts on the northern regions of the East Coast Cluster due to the occurrence of extreme wind and rainfall events during the warmer months of the year. Along the eastern Australian Seaboard region, the mean number of tropical cyclones is four per year, based on the time period from 1981-82 to 2012-13. Due to a lack of data, only limited conclusions can be drawn regarding the frequency and intensity of tropical cyclones in the Australian region prior to 1981 (Dowdy et al., 2015). East Coast Lows often develop in the southern regions of the East Coast Cluster (from Southeast Queensland to Greater Sydney) during the winter months. They are a major cause of storm surges in these locations (McInnes and Hubbert, 2001; Steffen et al., 2014).

East Coast Lows frequently occur in close sequence, creating long periods of high rainfall and strong winds, which generate high-energy waves that can lead to severe coastal erosion and flooding (DERM, 2011). Over the last 30 years a decreasing trend in East Coast Low occurrence has been observed (Dowdy et al, 2014).

Climate futures for the East Coast Cluster

There is very high confidence that sea levels will continue to rise during the 21st century (Dowdy et al., 2015). It is also very likely that sea levels are rising at a faster rate during the 21st century than over the 20th century (McInnes et al., 2015). Table 2 shows projections of future sea level changes for three coastal locations within the East Coast Cluster: Gladstone, Brisbane and Sydney. For the near future (2030) the projected range of sea level rise for the East Coast Cluster coastline is 0.08 to 0.19 m above the 1986-2005 level, with only minor differences between the model scenarios (RCPs). For the far future (2090) projections are more sensitive to concentration pathways. By 2090, the moderate emissions scenario (RCP4.5) is associated with a rise of 0.30 to 0.65 m and the high emissions scenario (RCP8.5) a rise of 0.44 to 0.88 m (Dowdy et al., 2015). These projections could be several tenths of a metre higher by late in the century if a collapse in the marine based sectors of the Antarctic ice sheet were initiated.

Table 2. Projected sea level change (metres) for three East Coast Cluster sites. Compared to 1986-2005. For 20-Year Periods (centred on 2030 and 2090) and three RCPs. The median projection across the models is shown. With the 10th to 90th percentile range of model results in brackets.

Sea level change	Gladstone (East Coast Cluster North) (meters)		Brisbane (East Coast Cluster North) (meters)		Sydney (East Coast Cluster South) (meters)	
	2030	2090	2030	2090	2030	2090
RCP2.6 Low emissions	0.13 (0.08 to 0.17)	0.38 (0.22 to 0.54)	0.13 (0.09 to 0.17)	0.39 (0.23 to 0.55)	0.13 (0.09 to 0.18)	0.38 (0.22 to 0.54)
RCP4.5 Mod. emissions	0.13 (0.09 to 0.17)	0.47 (0.30 to 0.64)	0.13 (0.09 to 0.18)	0.47 (0.31 to 0.65)	0.13 (0.09 to 0.18)	0.47 (0.30 to 0.65)
RCP8.5 High emissions	0.13 (0.09 to 0.18)	0.64 (0.44 to 0.86)	0.14 (0.09 to 0.18)	0.65 (0.45 to 0.87)	0.14 (0.10 to 0.19)	0.66 (0.45 to 0.88)

Source: Adapted from Dowdy et al., 2015

An allowance has been calculated for coastal infrastructure of the East Coast Cluster, taking into account uncertainty around mean sea level rise as well as the nature of extreme sea levels along the East Coast coastline (Table 3) (Dowdy et al., 2015). This 'allowance' is the amount by which the height of coastal infrastructure needs to be raised to cope with climate change (Hunter, 2012). When uncertainty is high (e.g. in 2090), this allowance approaches the upper end of the range of projected mean sea level rise. For the near future (2030) the vertical allowances along the cluster coastline are in the range of 0.13 to 0.15 m for all RCPs. By 2090, the allowances for the high emissions scenario range from 0.78 to 0.89 m (Dowdy et al., 2015).

Table 3. The allowance, or minimum height (in metres) for three East Coast Cluster sites. Structures would need to be raised for the future period so that the expected number of exceedences of that height would remain the same as for the 1986-2005 average sea level condition.

Sea level change	Gladstone (East Coast Cluster North) (meters)		Brisbane (East Coast Cluster North) (meters)		Sydney (East Coast Cluster South) (meters)	
	2030	2090	2030	2090	2030	2090
RCP2.6 Low emissions	0.13	0.45	0.14	0.52	0.14	0.48
RCP4.5 Mod. emissions	0.13	0.55	0.14	0.63	0.14	0.59
RCP8.5 High emissions	0.14	0.78	0.15	0.89	0.15	0.84

Source: Adapted from Dowdy et al., 2015

Heights of extreme sea level events will also increase with very high confidence (Dowdy et al., 2015). Extreme coastal sea levels arise from a combination of factors including astronomical tides, storm surges and wind waves. Storm surges are short-term rises in sea level driven by strong winds and/or intense low pressure systems (e.g. tropical cyclones and East Coast Lows) (Steffen et al., 2014). Quite frequently, the weather system that drives the storm surge event coincides with heavy rainfall to coastal catchments, resulting in severe coastal erosion and inundation from both the ocean and riverine run off. It is likely that these events will become more frequent in the future as sea levels rise and the probability of heavy rainfall events increases, which poses a threat to human activity in the coastal zone (McInnes and Hubbert, 2001; Steffen et al., 2014).

In general, storm surges tend to be higher in coastal regions with relatively wide and shallow continental shelves, including the wide and flat coastal plain of Central Queensland (DERM, 2011). On the other hand, higher wave energy can reach the coast in regions where the continental shelf is narrower, such as the coastline along the southern parts of the East Coast Cluster (McInnes et al., 2015). At present, the 1-in-50 year storm tide levels observed in Moreton Bay together with wave setup can reach 2.3m. Allowing for sea level rise, storm tide levels could reach up to about 2.7m and 3.0m for 1-in-100 year event in 2030 and 2070 (Wang et al., 2010).

Sea surface temperatures are also projected to continue to rise in East Coast Cluster coastal waters, with the magnitude of the warming dependent on the RCP. Under the high emissions scenario (RCP8.5) sea surface temperatures are projected to increase in the range of 2.1 to 5.7 °C by 2090. This warming poses a significant threat to the marine environment through biological changes in marine species and enhanced coral bleaching risk (Dowdy et al., 2015).

Importantly, many of the earliest and most significant impacts of a changing climate are likely to be experienced as changes in extreme weather events rather than changes to the mean climate. For instance, the intensity of heavy rainfall events is projected to increase, causing flooding impacts in the East Coast Cluster region. There are also projected increases in the proportion of the high intensity storms. In addition, a greater proportion of these intense storms may reach further into southern parts of the East Coast Cluster (south of 25 degrees south) (Dowdy et al., 2015).

Interestingly, regional modelling studies suggest a decline in the number of severe tropical cyclones making land-fall over the eastern Australian region, coinciding with a record high level of El Niño years (Callaghan and Power, 2010; Dowdy et al., 2015). Despite this overall decrease in the occurrence of tropical cyclones, there are some locations in the East Coast Cluster, such as Hervey Bay, where simulations indicate a possible increase in tropical cyclone occurrence by the mid-21st century (Abbs, 2010). Furthermore, projections suggest that increased greenhouse gas concentrations will also lead to a further decline in the number of East Coast Lows in the Cluster region. Climate models project an approximately 30% reduction in the formation of East Coast Lows in the late 21st century compared to the late 20th century (Dowdy et al., 2014; 2015).

Ecological and biophysical impacts

Climate change impacts, such as changes in mean sea levels and extremes, sea surface temperatures and ocean acidity (as outlined above) are predicted to lead to a number of ecological and biophysical impacts in coastal areas of the East Coast Cluster. The impacts of rising sea levels range from coastal inundation and flood damage to increased erosion, coastal recession and saline water intrusion. These impacts, in turn, are likely to affect coastal ecosystems through habitat loss in near-shore and intertidal environments such as beaches, mangroves, saltmarshes and seagrass beds (DERM, 2011). They will also lead to transitions in wetland community structure and dependent species, as well as reduced population sizes and shifts in species' ranges (Hadwen et al., 2011; Traill et al., 2011). Most at risk are coastal ecosystems in low-lying estuaries and tidal flats, as well as beaches where there is insufficient sand for replenishment (Poloczanska et al., 2012). For the adjacent marine environment, increases in ocean temperatures and decreases in pH have the potential to alter the distribution of marine vegetation, increase coral bleaching and mortality, and affect coastal fisheries (McInnes et al, 2015). The degradation of coastal ecosystems will have serious implications for the tourism industry in the East Coast Cluster.

Corals are vulnerable to thermal stress and have low adaptive capacity. Increasing sea surface temperatures have already been driving significant changes in the species composition and structure of coral reefs around Australia. For instance, since the late 1970s there have been multiple mass coral bleaching events on the Great Barrier Reef (Hughes, 2014). Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals (Nicholls et al., 2007). Ocean acidification will also impact on coral reef health. Great Barrier Reef corals and coralline algae are expected to experience reduced calcification rates. Lower calcification rates may generate a shift from net reef accretion to net erosion of reef structures (Poloczanska et al., 2012). Recent research has shown that stressors such as ocean acidification, coral bleaching and terrestrial runoff of sediment and nutrients do not act in isolation. Synergistic interactions between them are highly likely and may further exacerbate the decline of coral health (Brodie and Waterhouse, 2012; Schmidt et al., 2014).

Rising sea levels and an increased frequency of flood events and associated catchment erosion processes will also lead to a decline in seagrass abundance (Poloczanska et al., 2012). Historically, seagrass ecosystems have been threatened by diminished water quality. Rising sea levels and greater storminess have the potential to cause further decline in seagrass coverage as they contribute to extended periods of water turbidity in inshore areas (Fabricius et al., 2013). An increase in water depth will also reduce the availability of light to seagrass.

Coastal wetlands, such as mangroves and saltmarsh, provide important ecological services to the coastal zone, including habitat provision, fisheries production, sediment retention, flood protection and carbon sequestration (Adame et al, 2010; Lovelock et al., 2011; Rogers et al., 2014b). In addition, they provide important opportunities for recreational activities, such as fishing, to visitors and local residents. Sea level rise is likely to have significant impacts on coastal wetlands due to their location within the intertidal zone at approximately mean sea level (Lovelock et al, 2011; Shoo et al., 2014). Research indicates that coastal wetlands may have some capacity to adapt to lower rates of sea level rise through in situ processes that maintain their elevation relative to water levels (Lovelock et al., 2011; Rogers et al., 2014b; Saintilan and Rogers, 2013). However, higher rates of sea level rise will exceed the capacity of wetlands to proportionally build elevation and adjust (Rogers et al., 2014b; Traill et al., 2011). Flood control structures may also hinder sediment accretion and starve wetland ecosystems of sediment input.

Furthermore, rising sea levels will result in a landward migration of wetlands as tidal boundaries move upslope. Urban development (e.g. seawalls, roads and other infrastructure) acts as a barrier to this landward migration of wetlands and could thereby lead to a reduction of wetland area and loss of ecosystem services. Research also highlights the occurrence of habitat change in wetlands due to the expansion of mangroves into higher intertidal habitats (Burley et al, 2012; Lovelock et al., 2011). Indeed, saltmarsh environments in coastal areas of the East Coast Cluster are declining as they are undergoing a 'squeeze' between mangrove encroachment and urban development (Saintilan and Williams, 1999; Shoo et al., 2014).

In the SEQ NRM region, models project a general decline of wetland communities under sea level rise as the rate of inundation is more rapid than wetland community response. With a 0.64cm rise in sea level, 50% of the high intertidal and non-saline wetlands may be lost by 2100 (Traill et al, 2011). In western Moreton Bay, in particular, mangrove and saltmarsh habitat is in decline (Lovelock et al., 2011). SLR will also result in an overall decline of seagrass communities in Moreton Bay. The loss of seagrass habitat is greatest in western Moreton Bay where water clarity is lowest (Saunders et al., 2013).

In the North Coast LLS region, the extent of saltmarsh habitat is diminishing in the Tweed River due to mangrove encroachment as well as built obstructions, such as infrastructure and levees, resulting in a shrinking accommodation space (Rogers et al., 2014a). Similarly, in the Hunter LLS region, there is a projected 56% decrease in coastal wetland area by 2100 under a high SLR scenario around Kooragan Island in the Hunter River. Nearly all of the existing RAMSAR wetland extent is going to be lost by 2100 under a high SLR scenario (Rogers et al., 2014b).

Degradation of coastal and inshore habitats will lead to declines in the diversity and abundance of marine species that are the focus of tourism activities (e.g. charter fishing, scuba diving and snorkelling) (Wilson et al., 2010; Uyarra et al., 2009). However, in some cases the warming of sea surface temperatures, combined with the strengthening of the East Australian Current (Poloczanska et al. 2007) may lead to the altered/expanded geographic range of some species that are desirable to tourists. For example, grey nurse sharks are a popular attraction for scuba dive tourists along the NSW coast. These sharks are sensitive to sea temperature changes and may expand their range southwards in response to warming (Bradshaw et al., 2009). The southward range expansion of some tropical and subtropical fishes has also been observed, including desirable edible species such as coral trout (Ridgway and Hill, 2009). At least five tropical fish species from the Great Barrier Reef have been predicted to become capable of establishing as far south as Sydney (34^{o}S) and surviving winter temperatures by 2080 (Figueira and Booth 2010).

Some marine species that are undesirable for marine tourism are also likely to expand their range southward. For example, the box jellyfish (*Chironex fleckeri*) and several cubozoan species attributed to causing Irukandji syndrome currently inhabit North Queensland coastal waters during the summer months and are responsible for hundreds of hospitalisations and some deaths among unprotected swimmers who have been stung (Poloczanska et al. 2007; Gershwin et al. 2013). In March 2007, a specimen of the Irukandji jellyfish *Carukia barnesi* was recorded in Hervey Bay for the first time (Klein et al. 2014). It has been suggested that tolerable future conditions and shifting ecological boundaries (e.g. favourable coastal habitats) may lead to the future establishment of these species in subtropical waters (Gershwin et al. 2013; Klein et al. 2014). Similarly, with a continued recovery of Queensland's population of estuarine crocodiles (*Crocodylus porosus*), there is a reasonable probability of their expansion down the central and southern Queensland coast (Hamann et al., 2007).

Coasts are naturally dynamic and adjust to changing environmental conditions through processes of erosion and accretion. Physical response to sea level rise is far from uniform (Eliot, 2013). Regional differences between coastal landform types (e.g. beaches, estuaries, reefs) will mean different coastal responses to sea level rise. Researchers from the University of Wollongong applied an integrated framework to assess the future vulnerability of estuaries in the East Coast Cluster to climate change (excluding the Greater Sydney LLS region which was not modelled). This work involved the development of four indices: (i) marine erosion, (ii) marine inundation, (iii) fluvial erosion, and (iv) fluvial inundation (Table 4). These indices were combined as an overall index of vulnerability to climate change for each region. This first order vulnerability assessment also allows prioritising areas within the East Coast Cluster for more detailed high resolution analyses of vulnerability in the future.

Table 4. Geomorphic vulnerability of estuaries in the East Coast Cluster to future climate change (Rogers et al., 2014c)

Region	Marine		Fluvial	
	Erosion	**Inundation**	**Erosion**	**Inundation**
Fitzroy Basin Association	Moderate	Low-Moderate	High	Low-Moderate
Burnett Mary Regional Group	Low-Moderate	Low-Moderate	Moderate-High	Moderate
SEQ Catchments	Low-Moderate	Low-Moderate	Moderate-High	Moderate
North Coast LLS	Moderate-High	Moderate	High	Moderate-High
Hunter LLS	Moderate-High	Moderate	High	Moderate-High
Greater Sydney LLS	-	-	-	-

NB: These categories of low, moderate and high have been derived from the authors' visual interpretation of vulnerability mapping provided by Rogers et al. (2014c).

Some initial observations from Table 4 indicate that regions in the southern parts of the East Coast Cluster appear to have a higher vulnerability to erosion and inundation than regions further north. Fluvial erosion vulnerability is relatively high in all regions of the East Coast Cluster. In the Fitzroy Basin, historically high levels of fluvial erosion from inland catchments have led to the delivery of large amounts of sediment to the coastal zone. Due to this, coastal areas in the Fitzroy Basin have higher elevations, which somewhat reduces the risk of marine inundation (pers.comm with Rogers, 2015). Furthermore, Table 4 shows that vulnerability to fluvial inundation is generally higher in all East Coast Cluster regions than vulnerability to marine inundation.

Socio-economic impacts

Climate change may have a range of socio-economic impacts on the coastal tourism industry in the East Coast Cluster. These can range from direct impacts of extreme events on tourist infrastructure (e.g. beach resorts, roads, marinas) to indirect impacts of extreme events (e.g. coastal erosion, coral bleaching), and short-term adverse tourist perceptions after the occurrence of extreme events (Wong et al., 2014).

Shifts in the geographic distribution and seasonality of climate-sensitive tourism resources are anticipated to have increasing consequences for tourist demand and visitation (Scott et al., 2008). In the Great Barrier Reef area, seasonal visitation patterns are expected to become more pronounced, with lower visitation during the summer when there is higher rainfall and temperatures, and an increased risk of extreme weather events (Stoeckl et al., 2014). Extreme weather events, such as floods and cyclones, may have long-lasting effects on the appeal of some coastal destinations (Turton et al., 2010; Marshall et al., 2013). The media's portrayal of extreme weather events can strongly influence tourists' perceptions of a destination, with the potential for sudden and long-lasting changes in travel behaviour and associated economic losses (Scott et al., 2012). It has been estimated that the 2011 floods and Tropical Cyclone Yasi cost the Queensland tourism industry about $590 million, mainly due to cancellations and damage to the Great Barrier Reef (Reisinger et al., 2014).

Similarly, a series of five East Coast Lows storm events affected coastal regions between Illawarra and the Hunter during June 2007, resulting in mass accommodation cancellations. The tourism industry noted a 9% decline in occupancy throughout June and a 7.3% decline throughout July following the storm events (Verdon-Kidd et al., 2010). Recovery of coastal habitats and marine tourism resources from extreme weather events can take many years (e.g. coastal vegetation and coral regrowth) and such impacts even at a small spatial scale can have significant flow on effects for local and regional economies (Stoeckl et al., 2014).

Coastal erosion is anticipated to be increasingly problematic for tourism infrastructure and amenities at many locations (Turton et al., 2009; Scott et al., 2008), with destinations such as the Gold Coast identified as highly vulnerable (Steffen et al., 2014). Investment in rehabilitative works and coastal engineering in response to extreme weather events and coastal erosion has occurred at many heavily used tourist areas for several decades (Raybould and Mules, 1999). For example, Gold Coast City Council invests heavily in programs to manage beach erosion, with coastal defence measures ranging from beach nourishment to the construction of seawalls and artificial reefs (Harman et al., 2013). These measures are expensive, with beach nourishment alone costing between $2.5 and $3.5 million annually (Steffen et al., 2012). While the benefits to tourism visitation have previously outweighed the costs of such works (Raybould and Mules, 1999), the increased severity of future impacts due to sea level rise are anticipated to drive up the costs of such works significantly (Cooper and Lemckert, 2012). The growing economic burden associated with coastal rehabilitation and sea level rise mitigation is likely to drive up operational costs for coastal tourism businesses (Steffen et al., 2014). High operational costs and low profit margins have been identified among many marine vessel-based tourism operations in the Great Barrier Reef region (Curnock et al., 2014), suggesting that smaller enterprises are particularly vulnerable to fluctuations in visitation and increasing overheads.

Changes in temperature and rainfall may also allow mosquito-borne infectious diseases, such as dengue fever and Ross River virus, to become more widespread in the East Coast Cluster, posing a serious risk to human health. For example, the main carrier of dengue fever, the mosquito *Aedes aegypti*, is typically confined to northern Queensland where outbreaks occur almost annually. However, the geographic range suitable for the transmission of dengue is expected to expand southwards along the Queensland coast and into northern New South Wales during this century (Bambrick et al., 2008; Steffen et al., 2012). The alteration in distribution of these vectors may therefore create significant economic impacts on the tourism industry in the future (Yu et al., 2014).

In sum, without adequate preparation, tourism businesses in the East Coast cluster are likely to experience socio-economic impacts of climate change. Tourists may travel elsewhere or change the focus of their activities within the region. The sorts of impacts that are likely to be experienced by operators are those typically associated with financial hardship or difficultly with changing their business practices or experiences they offer. In extreme situations, tourism operators may be forced out of their business and may need to consider an alternative occupation. However, experience in sectors with strong occupational identity (like that exhibited anecdotally in nature-based tourism) can be so significant that some operators may be unable to consider another occupation, which could result in the emergence of mental health issues (Marshall et al., 2013). Due to the importance of coastal and marine tourism to many local economies, there may also be flow-on effects to local and regional communities.

Adaptive capacity[3]

Adaptive capacity is the ability to convert existing resources (natural, financial, human, social or physical resources) into a successful adaptation strategy (Marshall et al., 2014). Importantly, adaptive capacity is not only about having or providing financial resources. Characteristics of adaptive capacity include: possessing creativity and innovation (for identifying solutions or adaptation options); testing and experimenting with options; recognizing and responding to effective feedback mechanisms; employing adaptive management approaches; possessing flexibility; being able to reorganize given novel information; managing risk; and, having necessary resources at hand (Marshall et al., 2010). Adaptation processes are dynamic, continual and can be influenced at any time. Tourism operators that can anticipate or effectively react to the effects of climate change are more likely to adapt to new climate conditions. Whilst adaptive capacity has not been measured within the tourism industry of the East Coast Cluster, recognising and enhancing adaptive capacity becomes increasingly important for resource-based industries facing significant climate change.

Adaptive capacity can be measured according to four key attributes reflecting skills, circumstances, perceptions and willingness to change (Marshall et al., 2012). These are described as: 1) how risks and uncertainty are managed, 2) the extent of skills in planning, learning and reorganising, 3) the level of financial and psychological flexibility; and 4) the anticipation of the need and willingness to contemplate and undertake change (Marshall, 2011; Park et al., 2011).

These dimensions are mostly skills based and can be learned. Managing climate change and adapting is about planning for the future even though the future is uncertain. A constructive approach for climate adaptation planning is to plan for a range of plausible climate scenarios, and take the path of "least regrets", which accounts for a range of uncertainties about the future. Uncertainty can exist around the level of variability in ecological conditions, failure to observe change, inadequate communication, lack of clear goal setting, and outcome uncertainty.

The tourism industry within the East Coast Cluster may autonomously adapt to climate change impacts through adjusting gradually to changes such as value-adding to businesses in some way (Marshall et al., 2012). However, there will be instances when incremental changes will be insufficient as a strategy and more active planning is needed. In some instances, transformational changes, where the industry considers changes in its structure or function, may be necessary. The industry will benefit from a flexible, risk-based approach that incorporates future uncertainty and provides strategies that can enable them to cope with a range of possible future local climate

[3] Coastal and nature-based tourism businesses are dominated (in terms of no. of businesses) by small and medium sized enterprises. Small and medium-sized tourism operators show similar characteristics to agricultural businesses regarding their dependence on the natural resource base and vulnerability to climate change. Some of the material presented in this section is therefore drawn from studies of the agricultural sector.

change scenarios (Howden and Stokes, 2010). A key challenge for the industry will be to identify and incorporate future business opportunities.

An assessment by Reisinger et al. (2014) described the adaptive capacity of Australian tourism as high overall; however, reduced capacity and limited opportunities were identified among tourism destinations that are heavily dependent on natural assets subjected to cumulative degradation from climate change impacts.

Attributes contributing to higher levels of adaptive capacity within the tourism industry include short investment, high substitutability, and a relatively high proportion of human capital compared with built assets (Reisinger et al., 2014). Barriers to climate change adaptation in Australia's tourism industry include a high degree of uncertainty and/or scepticism concerning climate projections, limited networks and engagement with communities in climate adaptation among many tourist destinations, and a high proportion of small and medium-sized enterprises, particularly in regional areas, that operate with limited capital and capacity to implement major adaptation actions (Turton et al, 2010).

One of the key barriers facing the industry is the lack of regionally-specific or relevant information on impacts or on responses. Instead advice from State-level industry bodies presently relies on broad, global trends and impacts and on general procedural advice for individual businesses to implement adaptive management approaches to sustainability or risk management. This second area of advice encourages approaches to business planning that consider climate-related (unspecified) risks (TQ, 2011a).

Factors that may support industry response, on the other hand, include (i) strong regional identities and collective industry planning at regional scales roughly aligning with NRM and LLS boundaries, (ii) a clear industry strategy around cooperation and partnering with internal and external stakeholders on strategic management issues and development for the industry in those regions, and (iii) links to local government sector with strong representation of councils on regional tourism boards and bodies. Tourism Queensland has also worked together with the CSIRO to develop an online adaptation planning tool called '*Climate Futures'* for coastal tourism operators. It was successfully applied to the Sunshine Coast, allowing tourism operators in this region to implement a business response to climate change (Lim-Camacho and Ashworth, 2012).

Social vulnerability to climate change

The vulnerability of the tourism industry to climate change within the East Coast Cluster depends on how well the industry is able to manage the likely associated ecological/biophysical and socio-economic impacts. Given the high dependence of tourism on the region's natural assets, the industry is likely to be highly sensitive to climate change that affects the quality of the natural resource base (that in turn attracts tourists to the region). However, socio-economic impacts, as outlined above, do not necessarily need to manifest if the industry has sufficient capacity to moderate climate change impacts (Marshall et al. 2013). NRM planners in conjunction with the tourism industry can be a major influence on the vulnerability of the tourism industry in the region. Minimising vulnerability of the tourism industry to climate change within the region will require careful consideration of the likely ecological, biophysical and socio-economic impacts and an investment in enhancing the adaptive capacity of tourism operators and the industry. Vulnerability assessments will be the logical place to start for NRM planners and industry leaders wishing to direct or support efforts to minimise the vulnerability of the region to climate change. By understanding how the industry is sensitive to climate change and identifying how best to invest in the adaptive capacity of the industry, vulnerability assessments can enable planners to prioritise their efforts and provide a basis for engagement with tourism operators. Meaningfully and effectively involving tourism operators in NRM planning, program and project implementation processes can help to provide a politically and culturally supportive environment.

Adaptation opportunities and responses

Considering the range of material presented above, including existing activity by the tourism industry, this section proposes a number of potential adaptation responses.

Enhancing risk management, disaster preparedness and recovery for coastal tourism operators

Both NRM/LLS groups and the tourism industry have demonstrated a commitment to encouraging improved risk management practices for severe weather events amongst businesses in their regions and sectors. These practices will become more important with the anticipated southward expansion of high intensity storm events. NRM/LLS groups are also increasingly acting as intermediaries between local businesses and disaster recovery efforts funded by governments in some regions or as coordinators of related capacity-building programs. There is considerable scope for skill-sharing, resource-sharing or program coordination on disaster management planning and recovery efforts.

Improving coordination of media messaging in post-disaster recovery

Following natural disaster or severe weather events, natural resource managers use the media to draw attention to the scale and impacts of the event to help galvanise effort and draw in resources to assist with the clean-up. In some instances these messages can have negative impacts on tourism operators who may have been unaffected by the disaster but whose livelihoods are affected by national or international perceptions about the regional damage projected in the media, and which may unnecessarily prolong reduced visitation rates.

Identifying shared regional assets and exploring opportunities for joint-management

NRM/LLS groups could work with regional tourism boards or associations in a participatory way to identify natural or ecological assets in the region that have high values for both sectors. Identifying these shared natural assets may then provide a focus for discussion on likely future risks to those assets (including from climate change) and strategies to mitigate or adapt to those risks. The focus here could be on developing joint management arrangements, alignment of NRM and regional tourism plans and investment programs. For example, in the past, NRM organisations, local communities and government programs have invested in the protection and maintenance of foreshore environments (e.g. dune stabilisation and restoration) and worked to protect and draw awareness to threatened marine species that are also valued by visitors to those locations

Enhancing the multiple benefits from changing coastal wetlands

Under some GHG emission scenarios, estuaries in the East Coast Cluster are likely to see an expansion in the spatial extent of mangrove communities, often at the expense of saltmarsh communities. Government and community managers of the coastal environment could explore the likely future benefits of encouraging coastal defence options such as "living shorelines" which are increasingly used globally to strong effect.

This measure, which is based on the protection and restoration of coastal ecosystems, can reduce the need for harder coastal defence structures such as seawalls that may deflect erosive potential of storm surges to areas of high ecological value, or that may detract from the natural coastal setting that is of value to tourists seeking nature-based coastal experiences. Such a strategy is also likely to improve or help maintain fish recruitment or provide species habitat that, in turn, may have economic value to local tourism operators.

Coastal wetlands and tourism operators as 'carbon sinkers'

Given the propensity of coastal wetlands to serve as carbon sinks, enhanced management and/or protection of existing and future wetlands may generate considerable benefits. Coastal tourism operators are known to hold high environmental stewardship ethos for the local environments in which they work and live. This stewardship ethic could help underpin the exploration of a coastal carbon 'farming' initiative where local operators support the enhanced management, monitoring and protection of their local wetland communities by following agreed methods and management practices. Any income associated with this role could also diversify tourism operators' income, reducing their financial vulnerability to climate change and reducing the need to increase visitation pressure to compensate.

Improving industry level coordination and networking amongst local tourism operators

A well connected industry will enhance the adaptive capacity of the sector to respond to climate change. Connections between local tourism operators, as well as between operators in neighbouring regions, can support the sharing of experiences, plans, information and generally enhance collective learning. Such networks, depending on the issue at hand, could be supported through community-based NRM arrangements, local governments, or existing tourism industry bodies and networks. Accessing information and knowledge beyond immediate tourism industry networks can improve adaptive capacity. A more connected industry is also better positioned to contribute to discussions on best practice coastal development approaches, and infrastructure and management strategies under rising sea levels, or on building in flexibility to the permitting system as the condition and extent of coastal ecosystems and related natural assets change over time. As many tourism operators are small-to-medium sized business – which can experience relatively shorter life-cycles and shorter planning timeframes – there is a key role for tourism boards. Boards, with a more strategic orientation, are well positioned to work with groups such as regional natural resource management bodies, have a greater investment in securing the future of the industry for specific destinations, and to support existing and new tourism operators to adapt.

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Appendix 1. Types of nature-based coastal and marine tourism activities in the East Coast Cluster

Indicative number of nature-based coastal and marine tourism businesses operating in the East Coast Cluster, identified via a spatially explicit, systematic web search method (at March 2015).

Area (listed north to south)	Scuba diving / snorkel tour	Water sports rental / lessons	Charter fishing	Boat cruise / rental	Whale watching	Other wildlife / nature tour
Rockhampton area	3	1	7	5	-	-
Gladstone area	6	-	16	1	-	-
1770-Agnes Waters area	3	2	4	-	-	-
Bundaberg area	6	2	3	-	-	1
Hervey Bay	9	2	9	5	8	6
Sunshine Coast area	11	18	20	30	1	4
Bribie Island	-	1	-	7	-	-
Brisbane area	9	5	10	14	4	-
Gold Coast area	8	21	13	13	5	2
Byron Bay area	6	20	10	1	6	3
Coffs Harbour area	7	15	7	2	1	-
Forster area	3	10	5	5	4	-
Newcastle area	4	10	17	13	3	-
Avoca Beach area	2	2	5	-	1	-
Sydney area	9	19	10	37	9	-
TOTALS	**86**	**128**	**136**	**133**	**42**	**16**

Six major categories of tourism businesses offering the most common coastal/marine activities were chosen: diving and snorkelling, waters sport rentals and/or lessons, charter fishing, whale-watching, boat cruises and/or rentals, and other wildlife/nature observation tours. Key words relating to each category were combined with the name of each coastal city/town (160 in total for the cluster). The first five pages of each Google™ web search results were examined and all relevant links to a tourism operator were recorded.