SEDIMENTATION IMPACTS IN MORETON BAY

a priority knowledge synthesis

DBC
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The Moreton Bay Foundation

March 2026

David Brewer Consulting (DBC) has prepared this report for The Moreton Bay Foundation under the contract titled 'TMBF Priority Knowledge Synthesis: Sedimentation Impacts in Moreton Bay'. Information about the Moreton Bay Foundation can be found at: https://moretonbayfoundation.org/

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Approved:	David Brewer (Director)
Version:	Final Report
Date issued:	March 2026
Issued to:	The Moreton Bay Foundation
Citation:	Brewer, D. T. and Milward, A. S. E. (2026) 'Sedimentation Impacts in Moreton Bay: a Priority Knowledge Synthesis for The Moreton Bay Foundation'. TMBF, Brisbane, Australia. 244 pp.
Cover image:	Left: Sediment river outflow. Photo credit: A. Grinham. Centre: Eastern Curlew. Photo credit: C. Walker. Right: Corals in Moreton Bay. Photo credit: K. Walters

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Acknowledging Country

The Moreton Bay Foundation and David Brewer Consulting acknowledge the Quandamooka, Kabi Kabi/Gubi Gubi and Kombumerri peoples, the Traditional Custodians of Moreton Bay, Quandamooka, who manage Moreton Bay as their sea country under Aboriginal customary law encompassed by this plan. We also acknowledge the Traditional Custodians of the catchment areas adjacent to Moreton Bay include the Jinibara, Mulinjarlie, Jagera, Yuggerra and Ugarapul people.

The Traditional Custodians of this region maintain an unbroken connection with the area and we recognise the cultural, spiritual, social, and economic significance that these lands and waters hold to these people. We pay our respects to past, present, and future Traditional Custodians and Elders, and to their commitment to the continuation of cultural, spiritual, and educational practices of Aboriginal and Torres Strait Islander peoples.

Acknowledgement of contributors

Many people have contributed their time and input to the preparation of this report. David Brewer Consulting thanks all the subject matter experts who kindly reviewed content and/or provided images, ideas and/or personal communications for the report. The list of experts who provided expert review of particular sedimentation impact statements is provided in Table 1.

Thanks also to The Moreton Bay Foundation for their assistance with (and funding of) this project, including Robert McTaggart, Katie Walters, Mark Gibbs, Ainsley Leaning and Sam Capon. Particular thanks to Assoc. Prof Ian Tibbetts for his assistance and guidance on a range of matters that supported the development of the project report.

David Brewer Consulting would also like to acknowledge the input, insights and advice provided by Traditional Custodians of the Moreton Bay region, especially Djarra Delany and Darren Burns.

Expert Review

Table 1. Selected Moreton Bay values, key processes and planning issues were reported in the current study and the subject matter experts who kindly agreed to review each section. Experts' affiliations and roles are also provided.

Value	Expert reviewer/s	Affiliation
Traditional cultural values	• Dr Djarra Delaney	World Wildlife Fund, Indigenous Research & Indigenous Land Management
	• Em Prof Helen Ross	University of Queensland, School of Agriculture and Food Sustainability
	• Darren Burns	Quandamooka Yoolooburrabee Aboriginal Corporation
Sedimentation sources and issues	• Hon Assoc Prof Alistair Grinham	University of Queensland, School of Civil Engineering
Seagrass	• Dr Paul Maxwell	EcoFutures Consulting
Mangroves	• Vicki Bennion	University of Queensland, School of the Environment
Saltmarshes	• Vicki Bennion	University of Queensland, School of the Environment
Phytoplankton	• Dr Jing Lu	Griffith University, Australian Rivers Institute
Zooplankton	• Prof Kylie Pitt	Griffith University, School of Environment and Science
Benthic macrofauna	• Dr Tim Stevens	Griffith University, School of Environment and Science
Hard corals	• Dr Nicholas Hammerman	University of Queensland, School of the Environment
	• Dr Nicola Browne	University of Queensland, School of the Environment
Epibenthic bivalve reefs	• Assoc Prof Ben Gilby	University of the Sunshine Coast, Animal Ecology
	• Robbie Porter	Ozfish, Shellfish Revolution
Sharks and rays	• Assoc Prof Ian Tibbetts	University of Queensland, School of the Environment
	• Dr Christine Dudgeon	University of Queensland, School of Biomedical Sciences

Value	Expert reviewer/s	Affiliation
Teleost Fish	• Dr Chris Henderson	University of the Sunshine Coast, School of Science, Technology & Engineering
Sea turtles	• Dr David Booth	University of Queensland, School of the Environment
Shorebirds	• Prof Richard Fuller	University of Queensland, School of the Environment
	• Dr Penn Lloyd	Biodiversity Assessment and Management Pty Ltd
Marine mammals	• Prof Helene Marsh	James Cook University, Graduate Research Studies
Fisheries	• John Page	Commercial Net Fisher
	• Anonymous expert	Queensland Department of Primary Industries
Visual amenity	• Em Prof Helen Ross	University of Queensland, School of Agriculture and Food Sustainability
Catchment management	• Ross Bigwood	Healthy Land and Water Catchments

Acronyms

Acronym	Full name
BAAM	Biodiversity Assessment and Management
CMR	Capture-Mark-Recapture
FRDC	Fisheries Research and Development Corporation
GBR	Great Barrier Reef
GU	Griffith University
HLW	Healthy Land & Water
IUCN	International Union for Conservation of Nature
JCU	James Cook University
QDAF	Queensland Department of Agriculture and Fisheries
QDPI	Queensland Department of Primary Industries
QYAC	Quandamooka Yoolooburrabee Aboriginal Corporation
RRI	Resilient Rivers Initiative
SEQ	South East Queensland
UQ	University of Queensland
USC	University of the Sunshine Coast
WWF	World Wildlife Fund for Nature

Definitions

Term	Definition/meaning
Advection	The transport of a substance via the bulk motion of a fluid.
Autotrophic	Self-feeding, converting abiotic sources of energy (such as sunlight) into organic compounds.
Benthic	Relating to or inhabiting the lowest levels of the sea or other bodies of water.
Channel erosion	The erosion that occurs within the river channel itself involves the redistribution or removal of riverbed and bottom sediment. In the context of Moreton Bay, channel erosion is the dominant (>90%) source of sediment delivered to the Bay.
Chimaeras	Ghost sharks, rat fish, spookfish, or rabbit fish. Chimaeras are cartilaginous fish belonging to the order Chimaeriformes and are relatives of sharks and rays. They are part of the broader group Chondrichthyes.
Chondrichthyan species or Chondrichthyes	A class of cartilaginous fishes that includes sharks, rays, skates and chimaeras.
DDT	Dichlorodiphenyltrichloroethane, commonly known as DDT, is a synthetic insecticide that is now widely banned due to its environmental and health impacts.

Term	Definition/meaning
Demersal	Relating to or inhabiting the part of the sea or water body close to the floor.
Detritivore	Feeds on organic matter made up of dead plant and animal material (detritus).
Epibionts	An organism that lives on the surface of another living organism.
Epifauna	Animals living on the surface of the seabed, or attached to submerged objects, aquatic animals or plants.
Gully erosion	The removal of soil along drainage channels by surface water runoff.
Heterotrophic	Other-feeding, obtaining nutrition by consuming other organisms.
Infauna	Animals living in the sediments of the ocean or estuary floor.
Nekton	Aquatic animals that can swim and move independently of water currents.
PCBs	Polychlorinated biphenyls, or PCBs, are a group of artificial chemicals that were formerly used in industrial and electronic products. They are highly toxic and carcinogenic, readily penetrate skin and persist in the environment. PCBs have been banned due to their persistence and harmful effects on health and the environment.
Pelagic	Relating to or inhabiting the upper layers of the sea.
Phytoplankton	Plant-like plankton (cyanobacteria and microalgae) - autotrophic (self-feeding) components of the plankton community.
Plankton	Plankton are organisms that drift in water but are unable to propel themselves against active currents. Marine plankton include drifting organisms that inhabit the saltwater of oceans and the brackish waters of estuaries.
Reefal habitats	Elevated substrate (mound, ridge, sediment or rock), most commonly produced by and associated with hard corals.
Resuspension	Advection of deposited material into the water column.
Sedimentation	Movement of (organic?) particles from the mixed layer toward deeper water, usually as a result of the reduction in current velocity and wave energy.
Teleost	A type of bony fish and the largest group of ray-finned fishes
Zooplankton	Animal-like plankton – the heterotrophic component (other-feeding) component of the plankton community.
Value	A benefit or belief of important worth. See The TMBF Blueprint for in-depth usage.

Executive Summary

This report was commissioned by The Moreton Bay Foundation (TMBF) to develop a summary 'evidence pack' of key knowledge regarding the impacts of sedimentation on the coastal and marine ecosystems of Moreton Bay and the values they support. It stemmed from the TMBF *Blueprint for a Sustainable Moreton Bay for People and Nature (2025-2035), or the* 'TMBF Blueprint', which identifies catchment-derived sediment as one of the main threats to the ecological and other values of the Bay.

The project's objectives are to:

1. Conduct a high-level review and synthesis of key existing knowledge concerning impacts of sedimentation on coastal and marine ecosystems, and the ecological and traditional cultural heritage values they support, in the Bay
2. Provide a register of key knowledge sources to impacts of sedimentation on coastal and marine ecosystems, and the ecological and traditional cultural heritage values they support, in the Bay
3. Develop high-level conceptual models of sedimentation impacts in Moreton Bay.

To develop the knowledge synthesis, a set of key representative values was identified to review. The TMBF Blueprint guided these efforts. The TMBF Blueprint guided these. 'Sedimentation impact statements' were then developed for each selected Moreton Bay value through a written review of published information. Additional sections that summarise (i) sedimentation sources and the processes associated with sedimentation delivery into Moreton Bay and (ii) catchment management were also developed. The sedimentation impact statements and other sections were separately reviewed by subject matter experts to provide validation of the information. A knowledge register (Excel database) has also been established for all referenced information.

Moreton Bay

Moreton Bay's unique natural environment, high biodiversity and spectacular land and seascapes are of international importance, contributing to the lifestyles and livelihoods of communities across South-East Queensland. However, its proximity to one of Australia's most densely populated regions presents a substantial challenge: to preserve the Bay's unique values amid the relentless pressures of urban development and human activity.

Since European settlement, Moreton Bay has been subject to a range of ecological changes, including the mining of substantial areas of coral reef (>30 million tonnes of coral around Mud Island, St Helena Island and the other regions); the harvesting of >90% of its shellfish reefs; substantial benthic habitat modification from prawn trawling; and high recreational fishing effort. Some ecological communities that range more widely than the Bay are also vulnerable due to external impacts, including declines in migratory birds declines resulting from habitat loss on their international flyways and declines in sea turtle, shark, and ray populations due to international fishing and other harvesting mortalities. These impacts have reduced the Bay's capacity to maintain its unique ecological habitats and, consequently, its biodiversity, productivity, and resilience.

Most sedimentation occurs below the water surface. The impacts of catchment-based sedimentation in the Bay represent a relatively hidden but significant impact that has widespread effects on most ecological values, as well as Indigenous cultural values, fisheries and amenity values.

Sedimentation processes

Sedimentation poses a significant and increasing threat to the ecological systems of Moreton Bay, primarily driven by extensive land clearing and development in its large catchment since European settlement. Current sediment export rates are estimated to be approximately 100 times (and may be up to 1000 times) greater than pre-European levels, stemming dominantly from channel and gully erosion upstream.

Flood events are the dominant mechanism delivering vast amounts of fine sediment (mud) to the Bay. Recent major flood events, such as those in January 2011, January 2013, and February 2022, have deposited millions of tonnes of sediment, leading to widespread fine sediment deposition across the entire Bay. This has resulted in a dramatic increase in mud distribution, doubling mud cover between 1970 and 2015, and decreasing the area of clean sand substrate from 442 km^2 to 30 km^2 over 50 years.

Suspended sediments reduce water clarity (turbidity) and restrict sunlight penetration, which smothers and inhibits the reproduction and growth of key benthic habitats such as seagrass and corals. This reduced light availability causes benthic primary production to decline, leading to a larger ecological shift from benthic to pelagic (open-water or upper layers of a water body) productivity.

The influx of fine sediments results in severe physical and biological degradation throughout the Bay. The benthic zone is dramatically altered as the surface area of clean sand has been reduced by approximately 93% (from 442 km^2 to 30 km^2) over the last 50 years. Furthermore, benthic communities in over 98% of the Bay's benthic habitats have been altered and impacted.

Given that the Bay is functioning as a sink for terrestrial sediment inputs and hypothesised to be receiving sediment at a rate that far exceeds its natural capacity to move material offshore, the adverse effects — such as more frequent resuspension events and long-term water clarity issues — are likely to increase. Continued population growth will place the system under even greater pressure, given the ongoing development and land clearing in the Bay's catchment that is required to support this growth.

Impacts of sedimentation on Moreton Bay values

Of the 13 ecological values assessed, four are currently in 'poor' condition (saltmarshes, benthic macrofauna, epibenthic bivalves and sea turtles), with another six in 'fair' condition (Table I) due mainly to the relatively recent impacts of sedimentation. No values were assessed as being in 'excellent' condition. Only mangroves and marine mammals are currently in 'good' condition. Fisheries and visual amenity of the bay are also considered to currently be in 'fair' condition, also mainly due to the impacts of sedimentation.

However, the condition trend for these selected ecological values is more concerning than their current condition. The condition trend is assessed as declining for ten of the 13 ecological values, as well as for fisheries and visual amenity. The majority of those are assessed as being in decline due to the contribution of sedimentation. Only mangroves, phytoplankton and marine mammals are thought to have a stable condition trend.

Of the 16 culturally important Moreton Bay values to Traditional Custodians, six are considered to be in 'good' condition, four in 'fair' or 'variable' condition and six in 'poor' condition (Table II). Of those in 'poor' condition, the degradation of seagrasses can be attributed to sedimentation impacts. At the same time, the role of sedimentation may also be partly attributed to relatively recent sedimentation impacts for oyster and shellfish reefs, sea turtles, and beche-de-mer.

The decline in Moreton Bay's ecological, cultural, socio-economic, and amenity values due to the direct or indirect effects of sedimentation is of considerable concern, given the decades of previous environmental impacts and the prediction of large-scale perturbations to the marine environment. The effects of climate change (such as a warming climate and rising sea levels) are likely to exacerbate sedimentation issues in the Bay.

An increasing trend in the frequency of major floods in coastal catchments has been demonstrated for an area spanning from Brisbane (SE Qld) to Eden (NSW), since the late 19th century. Climate change is also predicted to drive an increase in the frequency of extreme rainfall events and associated flows from catchments to receiving waters along Australia's eastern seaboard, including for south-east Queensland. Without large reductions in sediment retention in the Moreton Bay catchment, future large floods will exacerbate the current impacts of sedimentation on the Bay's ecological values. Furthermore, the impacts of increasing plastic pollution and recreational fishing effort are likely to put additional pressure on the populations of many taxa.

If sedimentation into the Bay can be substantially reduced, it would reduce smothering of benthic communities and improve water clarity. This would lead to increased resilience and survival of photosynthetic communities (e.g., phytoplankton, seagrasses, algae, and hard corals) and reduce the frequency of toxic algal blooms. Furthermore, there would be a range of beneficial ecological cascading effects for other species (e.g. zooplankton, fish, marine mammals and sea turtles) that rely on those communities more directly impacted by sedimentation. Most fisheries and other socio-economic interests would also benefit from healthier and more abundant ecological communities.

Recommendations

A series of recommendations has been summarised from the published literature and is presented below. They include six high-level recommendations and three categories of more specific recommendations for marine ecosystems and other values.

High-level recommendations are to:

1. Urgently reduce the overall diffuse sediment and nutrient loads entering Moreton Bay from its catchments, including urgent implementation of the explicit, quantifiable regional management target to achieve a 50% reduction in sediment loads to maintain the Bay's current condition and improve ecosystem health.
2. Prioritise the stabilisation and rehabilitation of land and channel networks.
3. Improve control of sediment and pollutants from urbanised areas and development sites.
4. Develop an integrated, multi-faceted, adaptive management and monitoring approach for sedimentation impact management, spanning the land and sea.
5. Actively weave Traditional Knowledge and traditional science with Western science to inform policy development.
6. Improve governance of water quality management by adopting a common-pool resource approach for water quality management, fostering cooperation between upstream landholders and downstream beneficiaries.

Specific recommendations for marine ecosystems and other values are to:

1. Enhance habitat restoration and protection for a range of at-risk ecological values, including seagrass, mangrove, saltmarsh, benthic macrofauna, epibenthic bivalve and fish communities.
2. Improve specialised spatial planning and ecological controls for a range of at-risk ecological values, including mangrove, seagrass, hard coral, fish, shark, ray, sea turtle, shorebird and mammal communities.
3. Implement monitoring and research to assess the health of all key ecological groups and disentangle the impacts on, and responses of, these ecological values to sediments, nutrients, microplastics and other pollutants.

Further details of these are provided in the Recommendations section of the report.

Table I. Qualitative assessment of the overall status and trend in condition for 16 key Moreton Bay values, including an assessment of the contribution of sedimentation to the current condition and condition trend.

Value	Current condition	Condition trend	Contribution of sedimentation to the trend
1. Traditional Custodian values	*See separate table*		
2. Seagrass	Fair*	Declining	Major
3. Mangroves	Good	Stable	Moderate
4. Saltmarsh	Poor	Declining	Major
5. Phytoplankton	Fair	Stable	Moderate
6. Zooplankton	Variable	Declining	Moderate
7. Benthic macrofauna	Poor	Declining	Major
8. Hard corals	Fair	Declining	Moderate
9. Epibenthic bivalves (shellfish reefs)	Poor	Declining	Major
10. Sharks and rays	Fair	Declining	Unknown
11. Teleost fish	Variable	Declining	Major
12. Sea turtles	Poor	Declining	Moderate
13. Shorebirds	Fair	Declining	Minor
14. Marine mammals	Good	Stable	Moderate
15. Fisheries	Fair	Stable	Unknown
16. Visual amenity	Fair	Declining	Major

* depending on the region in the Bay, as per the Healthy Land & Water report card (Healthy Land & Water, 2023).

Table II. Ecological groups with high cultural value to the Quandamooka people and the status and trend of these groups, as described in other Impact Statements within the report.

Culturally important group	Customary role	Current condition	Condition trend
Seagrass	Traditional harvesting and ceremony	Fair*	Declining
Mangrove-fringed coastlines	Spiritual and totemic importance	Good	Stable
Oyster and shellfish reefs	Supports culturally important food species	Poor	Declining
Coral reefs	Significant in Dreaming stories and totems	Fair	Declining
Crustaceans	Culturally important species	Variable	Stable
Mud crabs	Culturally important food species	Good	Stable
Beche-de-mer	Culturally important species	Poor	Declining
Shovel-nosed sharks	Totemic importance	Poor	Declining
Finfish	Culturally important group	Variable	Declining
Sea snakes	Significant in Dreaming stories and totems	Variable	Stable
Sea turtles	Spiritual and totemic importance	Poor	Declining
Sea eagles	Significant in Dreaming stories and totems	Good	Stable
Curlews	Significant in Dreaming stories and totems	Poor	Declining
Dugong	Spiritual and totemic importance	Good	Stable
Dolphins	Spiritual and totemic importance	Good	Stable
Whales	Spiritual and totemic importance	Good	Stable

* depending on the region in the Bay, as per the Healthy Land & Water report card (Healthy Land & Water, 2023).

1. Project Purpose and Objectives

1.1 Background

Moreton Bay's unique natural environment, high biodiversity and spectacular land and seascapes are of international importance, contributing to the lifestyles and livelihoods of communities across South-East Queensland (SEQ) (EcoFutures, 2024). However, its close proximity to one Australia's most densely populated regions presents a substantial challenge: to preserve the Bay's unique values amid the relentless pressures of urban development and human activity.

The Moreton Bay Foundation (TMBF) funds evidence-based, robust and credible research to solve the significant threats facing Moreton Bay (Quandamooka). In 2024, TMBF commissioned the development of a blueprint to identify priority programs and actions for promoting the sustainable management of Moreton Bay (the Bay) over the next decade. TMBF's *Blueprint for a Sustainable Moreton Bay for People and Nature (2025-2035) — the TMBF Blueprint — guides relevant research, action, engagement, communication,* and advocacy (Ecofutures, 2024). It includes an underpinning principle that recommendations in the TMBF Blueprint are developed and delivered in collaborative partnership with First Nations people and organisations.

The TMBF Blueprint identifies catchment-derived sediment as one of the main threats to the ecological and other values of the Bay. The Blueprint cites evidence of the smothering of coastal habitats, including seagrasses, shellfish, coral reefs, and sandy intertidal zones, as well as the creation of poor water quality that impacts the types of plants and animals that can inhabit the Bay. Catchment-derived sediment also impacts the amenity and related tourism values of the Bay (Ecofutures, 2024).

The TMBF Blueprint acknowledges the critical importance of reducing catchment sedimentation by including it as the focus of Program 4, one of its four recommended programs. *Program 4: Increasing catchment sediment reduction at a Bay-wide scale* consists of the following key actions:

- Action 4.1: Develop a business case for catchment sediment reduction at a regional scale
- Action 4.2: Develop regional prioritisation of sediment reduction projects
- Action 4.3: Develop an education campaign about the threats of sediment on Moreton Bay
- Action 4.4: Advocate for enhanced sediment reduction legislation to underpin a regional program of sediment reduction

The current project aims to support these actions.

1.2 Project Purpose

The purpose of the *TMBF Priority Knowledge Synthesis: Sedimentation impacts in Moreton Bay Project* (the project) is to develop an 'evidence pack' of key knowledge regarding the impacts of sedimentation on the coastal and marine ecosystems of Moreton Bay and the values they support. The project was focused on existing published or readily accessible literature and targeted expert reviews of the collated information. The evidence developed through this project is intended to inform and support the future implementation of Blueprint Actions 4.1-4.4 (see above).

The overarching goal is to use the initial knowledge synthesis from this project to support regional decision-makers in determining future priority actions related to sedimentation in Moreton Bay. These actions may include the development of knowledge products, research, advocacy, engagement and communication over the next decade. Decision-makers' consideration of priority sedimentation actions will also need to be integrated with (i) planning for large-scale perturbations, such as the impacts of a warming climate and rising sea levels, and (ii) addressing and/or reversing other long-term environmental impacts.

1.3 Objectives

The project's objectives were to:

1. Conduct a high-level review and synthesis of key existing knowledge concerning impacts of sedimentation on coastal and marine ecosystems in the Bay, and the ecological and traditional cultural heritage values they support
2. Provide a register of key knowledge sources pertaining to impacts of sedimentation on coastal and marine ecosystems in the Bay, and the ecological and traditional cultural heritage values they support
3. Develop high-level conceptual models of sedimentation impacts in Moreton Bay.

An optional objective, to provide a register of spatial information pertaining to impacts of sedimentation on coastal and marine ecosystems in the Bay, and the ecological and community values they support, has not been delivered due to the size of the scope and workload of the first three objectives.

The use of published, cited information sources (the references) is a key component of this project. It is the foundation for developing a credible 'evidence pack' of key knowledge regarding the impacts of sedimentation on Moreton Bay. Information on the references used for this project, reference citation style (Harvard) and naming conventions (e.g. for species names) is provided in Appendix A and Appendix B. A complete reference list is provided in the References section at the end of this report.

2. Introduction

Moreton Bay is a large, semi-enclosed coastal embayment located on the east coast of Australia, adjacent to the Queensland capital city of Brisbane. The Moreton Bay catchment is approximately 22,000 km^2, while the Bay itself is around 1,500 km^2 – representing a large catchment:bay ratio of approximately 15:1 (Figure 1) (Douglas *et al.*, 2003). It is one of the largest estuarine bays in Australia, supporting a wide variety of ecosystems ranging from intertidal wetlands and seagrass beds through to coral reefs (Saeck *et al.*, 2019a). The current configuration of the Bay occurred when the Bay filled from around 11,000 years ago, reaching current sea level around 7,800 years ago and reaching 1.5 m above current sea level by 7,400 to 2,000 years ago, when sea level returned to current levels (Gibbes *et al.*, 2014). This was in direct response to rising sea levels that occurred at the end of the last glacial period, in which sea levels were up to 120 m lower and Moreton Bay would have been a dry plain (Lewis *et al.*, 2013; Moss *et al.*, 2013).

The Traditional Custodians of Moreton Bay have continuously inhabited and cared for this region for over 50,000 years (Adams *et al.,* 2024). These include the Quandamooka people (Nunukul, Geonpul and Ngugi clans [Fischer *et al.*, 2019]), the Kabi Kabi/Gubi Gubi and Kombumerri peoples, who manage Moreton Bay as their sea country under Aboriginal customary law (Ross *et al.*, 2019b). The Traditional Custodians of the catchment areas adjacent to Moreton Bay include the Jinibara, Mulinjarlie, Jagera, Yuggerra and Ugarapul people. The cultural values of the Traditional Custodians of Moreton Bay include deep ancestral connections to water, as reflected in place names, dreaming stories, and totemic associations with habitats, animals, and plants (Pinner *et al.*, 2019). They continue to harvest culturally important species such as Sea mullet and Quampies (Pearl shell) and continue to recognise and subscribe to customary law regarding communal ownership rights over their native estate (Thurstan *et al.*, 2019).

Moreton Bay supports a highly diverse fauna, partly based on its subtropical location at the interface between temperate and tropical biomes (Tibbetts *et al.*, 1998), and partly on the age and current configuration of the Bay (see above). This diversity includes:

- two species of resident dolphins (Chilvers *et al.*, 2005), a dugong (*Dugong dugong*) population of global significance (Fuentes *et al.*, 2016) and a range of visiting migratory whales
- 32 species of migratory shorebirds and nine resident species (Fuller *et al.*, 2021; Lloyd *et al.,* 2024)
- five species of sea turtles that are year-round foraging residents, and another as a migratory visitor
- a relatively species-rich composition of sharks and rays (Pierce, 2008)
- a unique and diverse fish fauna of at least 1,190 species (Dudgeon *et al.*, 2019; Olds *et al.*, 2019)

- highly diverse benthic communities of over 3000 species that function as an important biological refuge (Davie and Hooper, 1998; Ellegard and Harrison, 2008), and include unique, high-latitude marginal reefs comprising 63 scleractinian coral species (Roelfsema *et al.*, 2017)
- a range of marine plants, including seven species of mangroves (Tibbetts *et al.*, 1998) and seven species of seagrass (Maxwell *et al.*, 2015).

However, many of the Bay's ecological communities (or values) have undergone substantial change since colonisation. For example, Dugong were harvested to very low numbers by the 1960s (Chivers *et al.*, 2005), shellfish reefs were harvested to the point of functional extinction (Wills *et al.*, 2024) and an estimated several hundred million tonnes (>850 hectares) of coral reef was mined and removed from around Mud Island, Green Island, St Helena Island, Ormiston and other areas until the 1990s (Butcher 2022).

In recent decades, there has been increasing concern over the impacts of sedimentation as human population growth and other development increased in the Moreton Bay catchment (Olley *et al.*, 2006; Gibbes *et al.*, 2014; Saeck *et al.*, 2019b) and the frequency of large floods has significantly increased in the 21st Century (Grinham *et al.*, 2024). Nasplezes *et al.* (2019, p.74) noted 'Continued population growth and urban expansion, coupled with sediment and nutrient addition, associated with erosion in upstream primary production landscapes due to historical land-clearing practices, continue to place pressure on the environmental condition… and closely related social and economic values of Moreton Bay'.

Sediment influx into coastal systems is an essential part of their ecological functioning, through mechanisms including nutrient loads that support system productivity, and organic matter as food and sediment to support the structure and function of benthic communities (Kolker *et al.*, 2018). However, substantially increasing sediment loading decreases ecosystem health by increasing siltation, which reduces water clarity, restricts the penetration of the sun, and decreases photosynthesis (e.g., Kovacs *et al.*, 2019; Coates-Marnane *et al.*, 2020). This increased siltation also smothers the benthos, creating a shift from benthic to pelagic productivity (Saeck *et al.*, 2019b). Sedimentation impacts can also diminish the supporting services of ecosystems, directly influencing water quality, recreational value, and human health outcomes (Roiko *et al.*, 2019).

This report reviews recent literature on the effects of sedimentation on environmental systems and values in Moreton Bay. The aim is to provide a synthesised description of the state of knowledge on the current health of Moreton Bay ecological values, with an emphasis on the impacts of sedimentation. The information used to build this synthesis has also been compiled into a knowledge register to enable further investigation and/or communication of the evidence base. The knowledge register is provided as a separate product, using an Excel database.

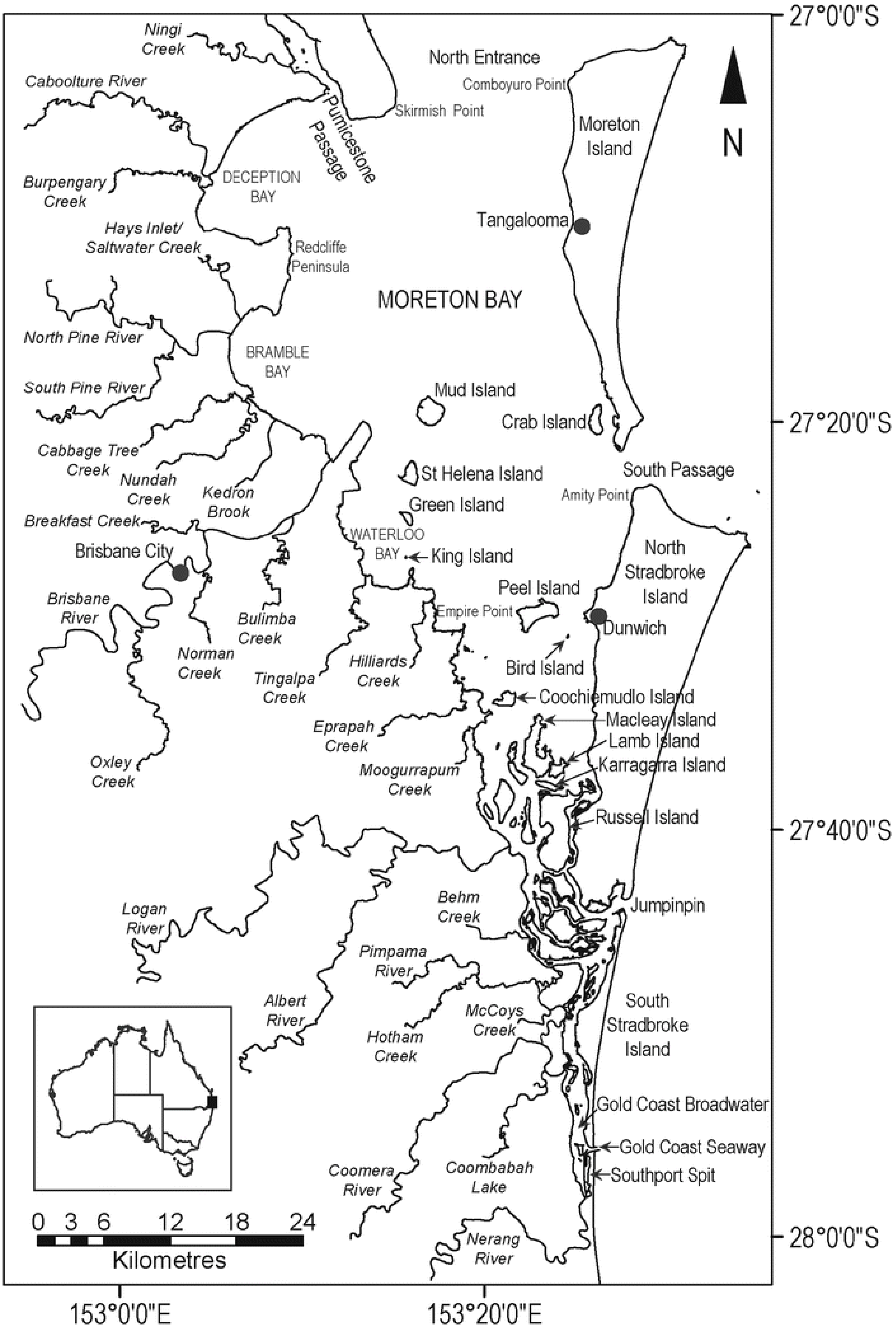


Figure 1. The Moreton Bay estuary illustrates the large catchment area, major river systems draining to the Bay and the major tidal entrances that connect the Bay to the adjacent Coral Sea (extract from Tibbetts et al., 2019).

3. Methods

3.1 Broad Approach

The approach for developing a knowledge synthesis of sedimentation impacts on Moreton Bay ecosystems focused on the following steps:

1. Identify and select key values to review, informed by the TMBF Blueprint.
    - Align key report elements (e.g. the values, and condition and trend assessment categories for the values) with the TMBF Blueprint.
2. Undertake a high-level review, analysis and synthesis of relevant published information, with expert input/validation, for each value. Use these reviews to develop a *sedimentation impact statement*, including a conceptual model diagram, for each selected Moreton Bay value.
3. Establish a knowledge register (Excel database) for all referenced information.
4. Package project outputs into an information pack (the 'evidence pack'), incorporating the full report, summary reports, stand-alone sedimentation impact statements and the associated knowledge register.

Each of these is described below.

3.2 Key Values

To assess the impacts of sedimentation on Moreton Bay ecosystems, a series of separate reviews was undertaken to cater for the diversity of ecological and other selected values. This approach enabled a detailed account of the impacts of sedimentation on each value to highlight the range and variability of sedimentation impacts on different Bay values.

An initial broad review of studies describing the physical processes of sedimentation into the Bay was conducted. Following this, individual reviews of sedimentation impacts were conducted for a select range of Bay values. The values selected for these reviews were guided by the TMBF Blueprint (see below). They included a range of 13 representative, ecologically important and/or high-profile ecological values, a cultural heritage value (Traditional Custodian cultural values), a socio-economic value (Fisheries) and a visual amenity value (Visual amenity). Although there is substantial overlap between the values in the TMBF Blueprint and the values selected for this knowledge synthesis, some new ecological values (e.g. phytoplankton, zooplankton and sharks and rays) have been included in this report to provide additional, targeted information relevant to sedimentation impacts. The alignment of values and other aspects of the current study with the TMBF Blueprint is described in the section below.

3.2.1 Alignment with TMBF Blueprint

The ecological values used for this project have been based on the 'values' used in the TMBF Blueprint, wherever possible. However, given this project's specific focus on the impacts of sedimentation, some variations to the TMBF Blueprint values were made -

including the addition of new ecological values (such as zooplankton). Table 2 provides further detail on the alignment of values in this report with the TMBF Blueprint.

The sedimentation impact summary tables developed for this project have been based on the assessment of 'condition' and 'trend' for identified values in the TMBF Blueprint. However, the summary tables in this report provide an assessment of the 'current condition' and 'condition trend' for values using a sedimentation-focused lens.

Where possible, the current report uses the same terms and colours to describe 'current condition' ('Poor', 'Fair or variable', 'Good', 'Excellent', or 'Unknown or no data') and 'condition trend' ('Declining', 'Stable', 'Improving' or 'Unknown or no data') as used in TMBF Blueprint. The only change to the TMBF Blueprint colour scheme is to the 'Poor' or 'Declining' categories: the TMBF Blueprint used orange in its traffic light system, while this report uses red instead. The red colour is more in line with a traditional traffic light system (red-yellow-green, rather than orange-yellow-green) and reflects the red colour used by the International Union for Conservation of Nature (IUCN) for a decreasing trend.

3.3 Review of Published and Expert Information

The review of information for this project was centred around two main knowledge sources: (i) published scientific papers in internationally refereed journals and specialist articles, and (ii) expert input (described below). This approach was used to help ensure that the knowledge summaries represent an up-to-date and highly credible source of information on the impacts of sedimentation on Moreton Bay values. Consequently, these summaries can be used with confidence to support planning for future initiatives aimed at enhancing the health and sustainability of Moreton Bay's ecological values.

The information review focused on collating, synthesising and summarising the known information published to date. Emphasis was placed on recent papers and, to some extent, review articles. Hence, each of the summary narratives, including, for example, the 'Recommendations' sub-section, is a summary from the relevant suite of published papers and reports. *NotebookLM* was used to assist with collating and summarising information.

For each reviewed value or topic, subject matter experts (see Table 1) were engaged to (i) validate that the draft written summary from the published literature was accurate and (ii) to input additional key expert information (e.g. that may be very recent or unpublished). Where subject matter experts provided new information from scientific studies that are yet to be published, they have been noted as 'personal communications' (pers. comm.).

Table 2. Key values used to develop sedimentation impact statements and their alignment with the TMBF Blueprint values and value themes. Ecological values in this report are listed in order of increasing phylogenetic or evolutionary complexity.

Value (current report)	TMBF Blueprint	
	Aligned TBMF Values	TMBF Value Theme
1. Traditional Custodian values	Cultural heritage, Quandamooka cultural knowledge, traditional hunting and resources, access to undertake cultural & spiritual activities	Traditional Owner cultural values
2. Seagrass	Seagrass	Resilient natural & unique ecosystem
3. Mangroves	Mangroves	
4. Saltmarsh	Saltmarsh	
5. Phytoplankton	*NEW - not a TMBF Blueprint value*	
6. Zooplankton	*NEW - not a TMBF Blueprint value*	
7. Benthic macrofauna	*NEW - not a TMBF Blueprint value*	
8. Hard corals	Coral reefs	
9. Epibenthic bivalves	Shellfish reefs	
10. Sharks and rays	*NEW - not a TMBF Blueprint value*	
11. Teleost fish	Fish communities	
12. Sea turtles	Marine turtles	
	IUCN listed species	
13. Shorebirds	Shorebirds	
	IUCN listed species	
14. Marine mammals	Marine mammals	
	IUCN listed species	
15. Fisheries	Fisheries	Sustainable use of ecosystems
16. Visual amenity	Natural beauty	Coastal living

3.3.1 Sedimentation impact statements

The review of sedimentation impacts on Moreton Bay values was conducted using a series of *sedimentation impact statements* (one for each value). The statements address: a cultural value ('Traditional Custodian values');13 different ecological values; a socio-economic value ('Fisheries'); and a 'Visual amenity' value. Two additional statements help describe (i) the physical processes of sedimentation and (ii) the catchment management and regulation environment.

These sedimentation impact statements have been structured as stand-alone sections (see Sedimentation Impact Statements) and aim to provide a broad understanding of each selected value/ecological group within the Bay. Each sedimentation impact statement includes a status and trend summary; summary statements about the ecological, cultural and economic value of each value; a brief description of the history around the value (usually post-colonisation); as well as information on how sedimentation interacts with the value's condition and status. Table 3 lists the headings and associated content for each sedimentation impact statement. The information summarised in each sedimentation impact statement forms the basis of a qualitative assessment, which is presented as a 'Value condition assessment' table for each value.

Table 3. List of main headings and their purpose for the 'Sedimentation impact statements' used in the report.

Impact statement subheading	Summary description
Status and trend summary **Or** **Summary**	A brief summary of the ecological value as described in the expanded impact statement but focusing on summarising the 'current condition' (status), 'condition trend' (trend) and 'contribution of sedimentation' to each of those two conditions. Simplified as 'Summary' for sections where 'Status and trend' are not appropriate.
Overview	A brief scene-setting summary of the ecological value (usually a high-level, well-recognised taxonomic group) in Moreton Bay, including aspects such as their taxonomic diversity, distribution and abundance, habitats and life history characteristics.
Population status	A summary of the current population size and health, usually in relation to any historic changes. For relatively vulnerable groups (mammals, sea turtles, shorebirds, sharks and rays) the IUCN conservation status is also used to indicate vulnerability of these populations.
Value (ecological, cultural, economic)	Very brief descriptions of the value (or importance) of each ecological value through three different lenses: ecological value, cultural value (mainly to indigenous communities) and economic value.
History	A summary of events and interactions from the post-colonisation history for each ecological value. This is used to help define the current condition of the value, which sets a current baseline for future trends in their population health and status.
Impacts of sedimentation	A summary of how sedimentation dynamics and impacts in Moreton Bay have influenced the health and status of ecological values, including direct and indirect impacts.
Recommendations	A summary of the published recommendations for each value.
Expert review(s)	A statement acknowledging the contribution of the subject matter expert reviewer(s) who were engaged to review the sedimentation impact statement.
Conceptual model	A diagram used to visually summarise the impacts of sedimentation on each ecological value and other relevant interactions.
References	A citation list of the scientific studies published in the internationally refereed literature that were referenced in the sedimentation impact statement.

The qualitative assessments use the categorisation and colour coding shown in Table 4, Table 5, Table 6 and Table 7. The assessments consider 'current condition', 'current condition trend', the 'level of contribution of sedimentation' to the current condition and current condition trend, as well as a qualitative assessment of the level of confidence in each of these assessments.

Table 4. The qualitative categories used to describe the condition of each value.

Status of the current condition	Description of category
Poor	• The condition of the value is much lower than its likely pre-colonisation condition. • The value is modified via ecosystem disturbance that does not resemble pre-disturbance structure and function.
Fair or variable	• The condition of the value is between degraded and reference condition or benchmark. • The value is modified and likely to be variable over time; having partial elements that resemble pre-disturbance structure and function.
Good	• The condition of the value is in a similar condition to the reference or benchmarks. • The value may be disturbed and slightly modified, but still resembles remnant ecosystems in structure and has many of the same ecological functions.
Excellent	• The value is in a similar condition to reference and/or appears undisturbed and unmodified, and resembles a remnant ecosystem in structure and ecological function.
Unknown or no data	• Where no data, baseline information or confident expert opinion is available to determine the current condition.

Table 5. The qualitative categories used to describe the trend of the condition of each value.

Status of the trend of the value condition (Condition trend)	Description of category
Declining	• Condition is declining in the short to medium term compared to its likely pre-colonisation condition.
Stable	• Condition is not changing (neither improving nor declining) in the short to medium term compared to its likely pre-colonisation condition.
Improving	• Condition is improving in the short to medium term compared to its post-colonisation degraded condition.
Unknown or no data	• Where no data is available and/or no baseline information is available to determine the current trend in the condition.

Table 6. The qualitative categories used to describe the contribution of sedimentation to the current condition in relative terms compared to other sources of modification to the ecological value (e.g. nutrient influx, pollution, sea level rise, plastics, harvesting).

Level of contribution of sedimentation to the current condition and trend	Description of category
Major	• The contribution of sedimentation to the current condition is substantial and likely has the overriding impact on the value compared to other impacting sources of modification.
Moderate	• The contribution of sedimentation to the current condition is significant and likely to have an impact on the value at similar levels to other impacting sources of modification.
Minor	• The contribution of sedimentation to the current condition is negligible or minor compared to the contribution of other impacting factors.
Unknown or no data	• Where no data is available to determine the current contribution of sedimentation to the current condition.

Table 7. The qualitative assessment categories used to describe confidence in the condition and trend assessments.

Confidence level	Description of category
Low	• Confidence in the condition assessment has little or no validating published or expert opinion.
Medium	• Confidence in the condition assessment has some, but not comprehensive, validating published and/or expert opinion.
High	• Confidence in the condition assessment has comprehensive and/or consistent validating published and/or expert opinion.

3.3.2 Conceptual models

Conceptual model diagrams were developed to provide a visual product to help describe the impacts of sedimentation on the ecological values. They include linked depictions and brief descriptions of (i) how sediment sources impact each ecological value, both directly and indirectly, (ii) other (non-sediment) factors that simultaneously interact with each value and (iii) ecological cascading impacts. Hence, they attempt to provide a single visual diagram that describes the main factors driving the condition and trend of ecological values in the Bay. Colour coding is used to help delineate between different types of impacts and interactions. The information contained within the diagrams is based on the information gleaned from the literature and summarised in the narrative of the sedimentation impact statement.

3.4 Knowledge Register

A 'Register of Knowledge Sources' (knowledge register) has been developed to collate and log key information for all references used in this report. The knowledge register serves as a repository of core resources regarding sedimentation impacts on key

Moreton Bay values. It can also function as a base for, or inform, future TMBF work on scientific and other publicly available resources relevant to Moreton Bay.

The knowledge register is a searchable Excel database. It has been provided as a separate project output for TMBF and can be added to or amended by TMBF, as required. The database categorises each reference based on the key value/s (or impact statement/s) relevant to the reference (see section 3.2 — Key Values and Sedimentation Impact Statements). The database includes basic search and analysis functions regarding the references (such as the number of references, types of references and lists of references for each key value or impact statement). Additional information on the Knowledge register is in Appendix C.

3.5 Project Outputs and Information Pack

Project outputs have been structured to provide an overarching information pack (the 'evidence pack'), delivering a range of products with different levels of information. These are summarised in Table 8.

Table 8. A summary of the project outputs that form the overarching 'information pack', comprising the knowledge synthesis on the impacts of sedimentation on Moreton Bay values.

INFORMATION PACK (the 'evidence pack')	
Project outputs	**Brief description**
Full report (approx. 244 pages)	Complete report containing all report sections
Non-technical summary report (5 pages)	Overall summary plus sedimentation impact statement summaries
Two-page summary (2 pages)	Concise summary narrative and summary impact assessment tables
Individual sedimentation impact statements (5 to16 pages each)	16 stand-alone sedimentation impact statements for each of the values described in the full report
Knowledge register (database)	An Excel database that stores and categorises all referenced information sources and allows for specific searches and data analysis.

4. Sedimentation – Sources and Issues

Moreton Bay faces a significant challenge from sedimentation, which can profoundly impact the Bay's ecosystem health. This is primarily driven by human-induced land-use changes in its vast catchment and exacerbated during episodic flood events (Grinham *et al*., 2024; Coates-Marnane *et al*., 2020). A summary of the sediment sources, transport, deposition, remobilisation, impacts and challenges is presented below.

4.1 Sediment sources

Sedimentation involves a cycle of input (from a source or sources), transport, deposition and remobilisation of sediments. Sedimentation in Moreton Bay is predominantly catchment-derived, originating from an expansive catchment area of approximately 21,220–22,000 km^2 (Coates-Marnane *et al*., 2020) (Figure 1). Since European settlement, substantial human disturbance, including large-scale clearing of native woody vegetation for agriculture and grazing from the late 1700s, has destabilised the channel network and dramatically increased sediment supply (Coates-Marnane *et al*., 2020; Grinham *et al*., 2024; Olley *et al*., 2024). Approximately two-thirds of the native woody vegetation in the region has been cleared since European settlement (Olley *et al*., 2024).

Current sediment export rates vary and are estimated to be four to five times (Diggles, 2013), 30 times (Leigh *et al*., 2013), or even 100 times (Saeck *et al*., 2019b; Olley *et al*., 2024) greater than pre-European settlement levels, leading to a three-to-nine-fold increase in sediment accretion over the last century.

Geochemistry and fallout radionuclide research (Laceby *et al*., 2015) demonstrate that channel and gully erosion are now the primary sedimentation sources, accounting for over 90% of sediment supply, with surface soil erosion being a minor contributor (Kemp *et al*., 2019; Grinham *et al*., 2024; Olley *et al*., 2024). For example, in key sub-catchments like the Lockyer and Brisbane rivers, channel erosion contributed 99% of the sediment supply (Olley *et al*., 2013). Channel erosion also dominates sediment supply in other Bay catchment rivers, including Stanley (67%), Kobble (74%), Emu (99%), Cressbrook (99%), and North Pine (99%) (Olley *et al*., 2013). This highlights the need for management efforts to focus on stabilising the channel network (Olley *et al*., 2024).

Sediments enter the Bay from the catchments primarily in abrupt pulses during high-magnitude flood events (Grinham *et al*., 2024). The 2011 flood alone delivered an estimated 10–30 million tonnes of sediment, equivalent to at least 20–50 years of average annual delivery (Gibbes *et al*., 2014, Nielson, 2018). Following the major flood in 2022 a study demonstrated that fine sediment had been deposited across 98% of the Bay's benthic zone (Grinham *et al*., 2024).

4.2 Sediment transport, deposition, and remobilisation

Sedimentation in Moreton Bay is largely determined and controlled by major flood events, wind-wave sediment transport and remobilisation processes and tidal currents (Morelli and Gasperon, 2019, Beecroft *et al.*, 2024).

Large flood events are episodic determinants of sediment distribution into the Bay. After large floods, wind and waves rework and transport sediments from shallow coastal areas to deeper, central regions (or sediment sinks) of the Bay where they gradually accumulate (see below) (Morelli and Gasperon, 2019; Beecroft *et al.*, 2024). The Bay is hypothesised to be receiving sediment at a rate that exceeds its natural capacity to move material offshore. This is leading to the gradual infilling of deeper channels where fine sediments are more difficult to remobilise. (Coates-Marnane *et al.*, 2020; Grinham *et al.*, 2024; Saeck *et al.*, 2019a). Ongoing terrestrial sedimentation will exhaust the key sediment sinks within Moreton Bay, effectively reducing the system's ability to buffer future sedimentation events (Beecroft *et al.*, 2024).

Tide-induced resuspension is also a major driver of turbidity regimes and sediment transport within Moreton Bay. Upon entry to the Bay, fine sediments (silt and clay) suspended in the water from rivers cause elevated turbidity (a measure of suspended sediments) across central and northern Moreton Bay as buoyant, lower-salinity floodwaters spread over denser marine waters (Gibbes *et al.*, 2014; Coates-Marnane *et al.*, 2020; Grinham *et al.*, 2024).

Transport and dispersal of suspended sediments within the Bay are also influenced by an enduring northerly water movement on the western edge and tidal flushing through the north, south, and Gold Coast Seaway entrances (Gibbes *et al.*, 2014; Coates-Marnane *et al.*, 2020). General tidal circulation in the Bay is clockwise, tending south along Moreton Island and north along the landward margin of the Bay (Lybolt and Pandolfi, 2019). The dominant tidal flow and circulation in the Bay is through the northern entrance.

Sediments suspended in the water column fall through the water due to gravity and settle out or deposit on the ocean or estuary floor (Egan *et al.*, 2022). Predicting where suspended sediments will be transported and settle is complicated by the tendency for individual sediment particles to stick together, or “flocculate,” which can cause them to settle more quickly. Factors like wave stress can promote floc breakup, while some biological processes may encourage floc growth (Egan *et al.*, 2022).

Fine sediments, once settled, result in higher mud content benthic areas. The western and southern parts of Moreton Bay receive the highest terrigenous (land-derived) sediment and nutrient input, leading to high mud content and consistently low water clarity (Gibbes *et al.*, 2014). The area of mud covering subtidal regions has roughly doubled since the 1970s (Coates-Marnane *et al.*, 2020). Over the last 50 years, fine sediment pollution has drastically reduced the surface area of clean sand by 93% (from 442 km^2 to 30 km^2), impacting over 98% of the benthic zone (Grinham *et al.*, 2024).

Sediments that accumulate in benthic depositional (often deeper) areas and are often referred to as 'legacy sediments' (Coates-Marnane *et al.*, 2020; Grinham *et al.*, 2024). Once deposited, these muddy legacy sediments, rich in organic matter and particulate nutrients, undergo microbial remineralisation, converting particulate nitrogen into dissolved ammonium (Grinham *et al.*, 2024). This process creates a large standing pool of ammonium in sediment porewaters (water in the space between sediment particles), estimated at ~280 tonnes in the upper ten centimetres with concentrations typically three orders of magnitude higher than in the overlying surface waters (Grinham *et al.*, 2024).

These deposited sediments are frequently remobilised through resuspension caused by tidal and wind events (Grinham *et al.*, 2024). This mixes nutrient-enriched porewaters with the overlying water column, leading to episodic periods of elevated ammonium flux or movement and reduced light availability (Gibbes *et al.*, 2014; Coates-Marnane *et al.*, 2020; Grinham *et al.*, 2024). Suspended sediments can then be transported to deeper areas or, through tidal flushing, moved outside the Bay into oceanic waters (Gibbes *et al.*, 2014; Grinham *et al.*, 2024).

Water residence times, which indicate tidal flushing rates, vary significantly across the Bay (Gibbes *et al.*, 2014):

- Ocean boundaries: 3–5 days (highest flushing)
- Pumicestone Passage: 43–53 days
- Central Bay: 50–55 days
- Bramble Bay: 59–62 days
- Mouth of Brisbane River: 63–68 days
- Logan River: 66–75 days
- Lower Brisbane River: 110–120 days
- Middle Brisbane River: 154–162 days
- Bremer/Brisbane junction: 187–189 days (lowest flushing).

Areas with higher flushing rates and oceanic exchange, such as the ocean boundaries, experience higher rates of sediment transport out of the Bay into oceanic waters (Gibbes *et al.*, 2014). Conversely, regions with longer residence times exhibit significantly reduced flushing, which contributes to these areas having the highest terrigenous sediment and nutrient input and lowest water clarity (Gibbes *et al.*, 2014).

4.3 Impacts of sedimentation

The influx and remobilisation of sediments have widespread detrimental effects on Moreton Bay's ecosystem health, as outlined below:

1. Nutrient cycling and eutrophication

The remineralisation and resuspension of muddy sediments drive eutrophication across the entire Bay (Coates-Marnane *et al.*, 2020; Grinham *et al.*, 2024). An estimated 17,700 tonnes of ammonium (ranging from 13,525 to 21,860 tonnes) are released annually from sediments to the water column (Grinham *et al.*, 2024). This constitutes about 35% of the Bay's water column nitrogen recycling budget and is 180 times higher than the annual ammonium discharge from the region's sewage treatment plants (Grinham *et al*., 2024).

This elevated ammonium flux fuels the growth of phytoplankton, including bloom-forming marine planktonic diatoms (which have increased since the mid-20th century) and toxic algal blooms, such as *Lyngbya majuscula* (Leigh *et al*., 2013). Excessive algal growth smothers vital seagrass meadows, a critical habitat for numerous marine species (e.g., dugongs and turtles), leading to biodiversity loss (Maxwell *et al*., 2019; Grinham *et al*., 2024).

Overall, increased siltation reduces water clarity, restricts sunlight penetration, decreases photosynthesis, smothers the benthos, and causes a shift from benthic to pelagic productivity (Saeck *et al*., 2019a). The elevated levels of total nitrogen and organic carbon in muddy sediments mean these impacts can be sustained for prolonged periods, representing a long-term threat (Grinham *et al*., 2024). The impacts of reduced water clarity, elevated nitrogen, and organic carbon on specific ecological groups are described in other sections.

2. Contaminant mobilisation

Sediments act as a significant reservoir for trace metal contaminants such as lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), nickel (Ni), chromium (Cr), arsenic (As), and mercury (Hg) (Morelli and Gasparon, 2019). These trace metals, which can be toxic and persistent, bind to fine particles and organic matter in sediments (Morelli and Gasparon, 2019). When disturbed by natural events (such as storms and waves) or anthropogenic factors (like dredging), sediment-bound trace elements are liberated and become bioavailable, posing a threat to marine organisms (Coates-Marnane *et al*., 2016a; Morelli and Gasparon, 2019; Townsend *et al*., 2019).

The rising trends in Pb, Zn, Cd, and Ni are linked to Moreton Bay's catchment development, with metal concentrations increasing one to two orders of magnitude since 1920 (Morelli *et al*., 2012). The concentrations of these trace metals in Moreton Bay are currently above natural background levels, indicating ecological deterioration (Morelli and Gasparon, 2019). The impacts of these metals, as well as pesticides, microplastics, and other pollutants, on mammals, sea turtles, and other ecological groups (e.g., see Grinham *et al*., 2021; Yenney *et al*., 2024; Okoffo *et al*., 2024) are described in other sections.

4.4 Challenges to recovery and future outlook

A critical concern is that large parts of Moreton Bay are not recovering from catchment sediment loads between major flood events (Lockington *et al*., 2017; Saeck *et al*., 2019a; Coates-Marnane *et al*., 2020; Grinham *et al*., 2024). The sheer volume of deposited sediments and ongoing resuspension requires extended periods of tidal flushing to reduce turbidity to average levels, resulting in relatively high turbidity levels for longer periods. This continuous cycle results in the gradual infilling of deeper areas, an increase in the extent of fine sediments, and progressively more turbid waters (Coates-Marnane *et al*., 2020; Grinham *et al*., 2024).

Future projections for population growth and climate change are likely to exacerbate the Bay's diminished capacity to recover from sedimentation impacts. Increased land disturbance, clearing and inadequate or poorly regulated catchment management associated with an increasing population in SEQ is likely to increase sediment catchment loads and increase sedimentation impacts in the decades ahead. The frequency of major flood events is also likely to increase due to climate change, thereby intensifying the delivery of sediment, nutrients, and trace metals (Grinham *et al*., 2024). This could lead to further expansion of muddy sediment classes and continued high rates of sediment ammonium flux and pollutants (Grinham *et al*., 2024).

Without effective catchment management, particularly focused on stabilising the channel network, the threat to Moreton Bay's ecosystem health from accelerated sedimentation and nutrient flux, is likely to persist or increase, especially given the projections of more frequent and intense floods (Grinham *et al*., 2024). Olley *et al*. (2006) conclude that achieving a 50% reduction in the supply of sediment and associated nutrients into Moreton Bay must be prioritised to maintain the Bay in its current condition. Deeper insights into management strategies and recommendations are dealt with in a 'Catchment management' section.

4.5 Expert review

Associate Professor Alistair Grinham kindly provided an expert review of the Sedimentation sources and issues section.

5. Sedimentation Impact Statements

A core part of the knowledge synthesis for sedimentation impacts on Moreton Bay values was to develop a series of *sedimentation impact statements* (one for each value). These statements summarise the key information from the literature and expert opinion. They are presented in the following sections – one for each of the 13 ecological values, one cultural value ('Traditional Custodian values'), one socio-economic value ('Fisheries') and one lifestyle or coastal living value ('Visual amenity'). The ecological values are presented in a general order of increasing phylogenetic order or evolutionary complexity.

Each 'sedimentation impact statement' is also available as a stand-alone document. The stand-alone versions include a reference list section that is specific to that section. In this report, all references used in the project are compiled together in Chapter 9 References.

5.1 Traditional Custodian Values: Sedimentation Impact Statement

Quandamooka Traditional Custodian: 'white man came and cut the trees down and loosened all the dirt up and then the rain would come and then wash it [away]... to make it so muddy, because when the floods come through... it's just like a big sheet of mud going over the bridge...'. (Pinner *et al.*, 2019).

5.1.1 Summary

The Traditional Custodians of Moreton Bay (part of Quandamooka Country) have continuously inhabited and cared for this region for over 25,000 years. Their cultural values also include deep ancestral connections to water, as reflected in place names, dreaming stories, and totemic associations with habitats, animals, and plants, such as the dugong, oysters, sea snakes, mud crabs, dolphins, sea eagles, and curlews. They continue to harvest culturally important species such as Mullet and Quampies (Pearl shell), and continue to recognise and subscribe to customary law regarding communal ownership rights over their native estate.

The Quandamooka Yoolooburrabee Aboriginal Corporation (QYAC) (see Quandamooka Yoolooburrabee Aboriginal Corporation |) manages the recognised Native Title rights and interests on behalf of the Quandamooka People, which includes a focus on fostering Quandamooka culture and environmental protection for their land and sea country. Their current custodianship encompasses roles in management and monitoring the health of key habitats and species, often in partnership with government, non-governmental organisations, and researchers. However, the impacts of water quality and sedimentation on their cultural values are deeply felt and have created a great sense of loss and despair for many Aboriginal people.

5.1.2 Overview

Traditional Custodian history in Moreton Bay

Moreton Bay, also known as Quandamooka, has a rich history of Traditional Custodian occupation and custodianship of its ecological values, which continues to evolve and strengthen in contemporary management practices (Fischer *et al.*, 2019). Quandamooka Country, encompassing Moreton Bay, its islands (Mulgumpin/Moreton Island, Minjerribah/Stradbroke Island, and southern Bay islands) and adjacent mainland areas, is the ancestral homeland of the Nunukul, Goenpul, and Ngugi peoples, collectively known as the Quandamooka People (Adams *et al.*, 2019). They have continuously inhabited and cared for this region for over 50,000 years (Fischer *et al.*, 2019). Their clans have upheld their own laws, customs, beliefs, and culture throughout their occupation and have never ceded sovereignty of their Country (Fischer *et al.*, 2019).

European settlement began around 1825, which displaced many Traditional Custodian groups and disrupted their ability to care for their Country in traditional ways

(Fischer *et al.*, 2019). However, the Quandamooka People continue to maintain their cultural practices on their Country (Fischer *et al.*, 2019).

On July 4, 2011, the Federal Court of Australia recognised the Quandamooka People as the Traditional Custodians and original inhabitants of Minjerribah and parts of Moreton Bay (Fischer *et al.*, 2019; see also Native Title | Quandamooka Yoolooburrabee Aboriginal Corporation). This determination recognised their Native Title rights and interests over 54,408 hectares of land and sea in the Moreton Bay area, including exclusive and non-exclusive rights (Fischer *et al.*, 2019). The non-exclusive rights allow them to be present on the location, access and traverse it, and take, use, share, and exchange traditional natural resources for non-commercial purposes (Fischer *et al.*, 2019; Thurstan *et al.*, 2019).

Traditional custodianship of Moreton Bay ecological values

QYAC, established in 2011 as a Prescribed Body Corporate (PBC), manages the recognised Native Title rights and interests on behalf of the Quandamooka People (Fischer *et al.*, 2019). QYAC has one of the largest memberships of any Native Title Body Corporate in Australia (Nasplezes *et al.*, 2019) and employs a visionary and professional management approach to land and sea management, based on contemporary practices with an evidence-based approach (Fischer *et al.*, 2019). What makes QYAC's approach unique is its focus on fostering Quandamooka culture and environmental protection for their land and sea country (Fischer *et al.*, 2019). This involves ‘blending Traditional Knowledge and Traditional Science with Western Science to inform policy and management decisions’ (Fischer *et al.*, 2019).

The Quandamooka People’s customary arrangements are based on a holistic belief system where humans and the natural world are closely intertwined (Ross *et al.*, 2019b), and an appreciation of natural processes is described as ’a beautiful chain of command by Mother Nature’ (Pinner *et al.*, 2019). Environmental management is considered a customary responsibility, informed by deep traditional ecological knowledge (Ross *et al.*, 2019b).

Historically, Indigenous Australians have been important fishers in the region, harvesting seafood such as finfish (e.g., mullet), crustaceans, shellfish (e.g., rock oysters), turtles, and Dugong for thousands of years (Olds *et al.*, 2019). They were active stewards of resources, such as oyster beds (Ross *et al.*, 2019b). They made practical use of rivers, creeks, and the Bay for drinking water, food sources, and livelihoods (Pinner *et al.*, 2019).

Their cultural values also include deep ancestral connections to water, as evidenced by place names and totemic associations. For example, they have dreaming stories and totems about many of the Bay's habitats, animals and plants, including Dugong, oysters, sea snakes, mud crabs, dolphins, sea eagles and curlews (Delaney, 2013) (Table 9).

Current activities and interactions

1. Caring for Country responsibilities

The Quandamooka Land and Sea Management Agency (QALSMA) is the unit within QYAC responsible for planning, managing, and protecting the Quandamooka Estate (see QALSMA | Quandamooka Yoolooburrabee Aboriginal Corporation). QYAC rangers are actively involved in managing and monitoring Sea Country (Fischer *et al.*, 2019). Examples include implementing (and improving) their skills in seagrass assessments, coral reef monitoring, understanding dugong and turtle populations, and assessing the health of mangrove-fringed coastlines within the Quandamooka Native Title area (Fischer *et al.*, 2019).

2. Partnerships and Collaboration

QYAC collaborates with various organisations, including the Queensland Parks and Wildlife Service, State government departments, local authorities, non-government organisations, and research institutions like the University of Queensland, Griffith University, Queensland University of Technology and James Cook University as well as Healthy Land & Water (Nasplezes *et al.*, 2019). They have expanded the protected area of Minjerribah from 2% in 2010 to currently 50% through work with the Queensland Parks and Wildlife Service (Nasplezes *et al.*, 2019).

3. Resource Use

Fishing and traditional hunting are important affirmations of cultural identity and continue to be essential aspects of Quandamooka life (Townsend *et al.*, 2019). Quandamooka people continue to fish and harvest shellfish, with mullet being culturally and economically significant (Thurstan *et al.*, 2019). They recognise and subscribe to customary law regarding communal ownership rights over their native estate, in addition to state law (Thurstan *et al.*, 2019). While Queensland fisheries regulations require permits for commercial-sized nets for traditional or ceremonial purposes, fish traps and recreational gear do not require a license, and seasonal closures or size/possession limits typically do not apply when fishing in traditionally accessed waters or with permission from Traditional Custodians (Thurstan *et al.*, 2019). Indigenous peoples have also historically imposed their own moratoria on hunting dugong when populations were deemed too low (Thurstan *et al.*, 2019).

4. Ecotourism

QYAC's growing role in land and sea management provides opportunities for new sources of economic development, such as ecotourism (Fischer *et al.*, 2019).

5. World Heritage Listing

Quandamooka Country is being proposed for a World Heritage listing due to its outstanding and unique cultural and natural values. QYAC are leading the submission in partnership with the Queensland and Australian Governments to ensure it reflects the Quandamooka People's ancient and living heritage, connection to Country, and aspirations (Queensland Government and QYAC, 2025).

5.1.3 Impacts of sedimentation

The Quandamooka people deeply value the overall health of the ecosystem, the ecological functions of Moreton Bay (Quandamooka), and the diversity of animal and plant species in the region, linking these to moralistic values and a desire to enhance knowledge for better care (Fischer *et al*., 2019; Ross *et al*., 2019a). This highlights a custodial ethic and a deep sense of identity tied to their Country, with a strong sense of personal loss associated with damaged waterways (Fischer *et al*., 2019). Fisher *et al*. (2019) stated that 'Colonisation displaced many Traditional Custodian groups from their Country and resulted in their inability to be on, and to care for, their Country in traditional ways. This has created a great sense of loss and despair for many Aboriginal people'.

Both the status and trends of the selected culturally important ecological groups indicate that the Quandamooka people's values in Moreton Bay have been substantially degraded by the impacts of sedimentation (Table 9). Fischer *et al.* (2019) noted the threat to marine values, such as sacred or heritage sites, through erosion and sediment loading. They note changes have occurred to water quality, impacting marine habitats (like seagrass and mangroves) used for cultural harvesting and state that 'the disruption of spiritual and cultural practices due to ecosystem degradation caused by runoff and altered hydrology'.

The Quandamooka people are clearly not responsible for this degradation of Moreton Bay ecology, which has its source in the catchments of the Bay (see Section 4, 'Sedimentation - Sources and Issues'). Rather, their traditional management practices are aimed at working with nature, not seeking to control it (Pinner *et al*., 2019).

5.1.4 Recommendations

The following recommendations are a summary from the published literature.

1. Integrate traditional knowledge and Western science in management

Actively weave 'Traditional Knowledge and Traditional Science with Western Science' to inform policy development and management decisions (Fischer *et al.,* 2019). This approach leverages the Quandamooka People's observations and repeated practices over thousands of years, which often align with Western scientific practice and offer a more extended dataset than post-colonisation scientific observations (Fischer *et al.,* 2019).

Recognise that Quandamooka knowledge encompasses all aspects of the natural environment and tells stories that enable future custodians to build upon it (Fischer *et al.,* 2019).

Table 9. Ecological groups with high cultural value to the Quandamooka people and the status and trend of these groups, as described in other Impact Statements within the report. References used are: 1. Saeck et al., 2019a; 2. Fischer et al., 2019; 3. Pinner et al., 2019; 4. Olds et al., 2019; 5. Thurstan et al., 2019; 6. Delaney, 2013.

Culturally important group	Customary role	Current condition	Trend
Seagrass	Traditional harvesting and ceremony[1]	Fair*	Declining
Mangrove-fringed coastlines	Spiritual and totemic importance[3]	Good	Stable
Oyster and shellfish reefs	Supporting culturally important food species[3]	Poor	Declining
Coral reefs	Significant in Dreaming stories and totems[2]	Fair	Declining
Crustaceans	Culturally important species[5]	Variable	Stable
Mud crabs	Culturally important food species[3]	Good	Stable
Beche-de-mer	Culturally important species[2]	Poor	Declining
Shovel-nosed shark	Totemic importance[3]	Poor	Declining
Finfish	Culturally important group[4]	Variable	Declining
Sea snakes	Significant in Dreaming stories and totems[6]	Variable	Stable
Turtles	Spiritual and totemic importance[3]	Poor	Declining
Sea eagles	Significant in Dreaming stories and totems[6]	Good	Stable
Curlews	Significant in Dreaming stories and totems[6]	Poor	Declining
Dugong	Spiritual and totemic importance[3]	Good	Stable
Dolphins	Spiritual and totemic importance[3]	Good	Stable
Whales	Spiritual and totemic importance[3]	Good	Stable

** depending on the region in the Bay, as per the Healthy Land & Water report card (Healthy Land & Water, 2023).*

2. Strengthen Indigenous governance and management leadership

Support the Quandamooka Yoolooburrabee Aboriginal Corporation (QYAC) in its leading role in land and sea management (Fischer *et al.*, 2019; Nasplezes *et al.*, 2019). QYAC's management philosophy emphasises an evidence-based approach, guided by their vision of "Quandamooka Peoples caring for Country in a viable economy using traditional and modern knowledge" (Fischer *et al.*, 2019).

3. Promote a holistic and place-based management approach

Adopt a management philosophy of ‘shared use’ that safeguards Quandamooka's values, interests, and vision, recognising Quandamooka Country as a sanctuary managed for thousands of generations (Fischer *et al.*, 2019).

Embrace the Indigenous holistic and social-ecological perspective of land and sea management, which contrasts with the sectoral approach of government. This includes connecting land and sea management, similar to how Indigenous people view their coastal estates (Ross *et al.*, 2019b).

4. Enhance stewardship and environmental education

Foster the 'custodial ethic' that is a core part of Indigenous values, emphasising the obligation to maintain a reciprocal relationship with the environment (Pinner *et al*., 2019).

Prioritise education of younger generations and the broader community on environmental sustainability and the ecological significance of waterways (Pinner *et al*., 2019; Ross *et al*., 2019b).

Use experiential and place-based learning strategies, such as hands-on exploration and investigation of local real-life issues, to foster a connection to place and encourage care for the Bay (Casey *et al*., 2019).

Support the Quandamooka Ranger Program, which is key to managing cultural heritage rights and interests, and contributing to collaborative research initiatives (Fischer *et al.,* 2019).

Encourage partnerships between Quandamooka and environmental not-for-profit groups, which have proven to produce mutually beneficial outcomes for land and sea country management and build community capacity (Fischer *et al.,* 2019).

5. Safeguard cultural heritage and natural values

Protect and manage archaeological heritage sites (e.g. shell middens, stone artefact scatters, burials, scarred trees, fish traps) as they are tangible evidence of cultural identity, belonging, and knowledge of the place (Pinner *et al*., 2019).

Maintain the ecological integrity of the Bay, including its diverse habitats (seagrass, mangroves, coral reefs), as Traditional Custodians value these as indicators of ecosystem health (Pinner *et al*., 2019; Ross *et al*., 2019b).

6. Implement adaptive and collaborative management practices

Continue and strengthen collaborative environmental monitoring programs that collect ongoing data about key habitat types in the Bay, such as coral reefs (Reef Check), seagrass communities (Seagrass-Watch), and mangroves (MangroveWatch) (Fischer *et al.,* 2019).

Adopt sustainable management practices for resource use, such as the cautious assessment of fisheries (e.g. beche-de-mer) to prevent declines in populations (Fischer *et al.,* 2019).

Move towards a 'new governance' approach that recognises and formalises the contributions of both formal and informal management actors, including Traditional Custodians, rather than focusing solely on top-down control (Ross *et al*., 2019b).

Expand monitoring and evaluation beyond biophysical threats to include social, economic, and cultural benefits and contributions of management efforts (Ross *et al*., 2019b).

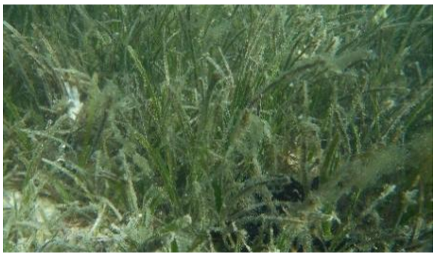
7. Pursue World Heritage listing

Continue to progress the Quandamooka submission for inclusion on Australia's World Heritage Tentative List, recognising its unique cultural and natural values. The proposed listing includes the Moreton Bay Marine Park, Minjerribah, and Mulgumpin, with a focus on Criterion (v) for traditional human land and sea-use and Criterion (x) for significant natural habitats for biodiversity conservation. This could offer integrated management opportunities and increased tourism and employment benefits.

5.1.5 Expert reviews

Dr Djarra Delaney (Quandamooka), Prof Helen Ross (School of Agriculture and Food Sustainability, University of Queensland) and Darren Burns (Quandamooka, QYAC) have kindly provided an expert review of the Traditional Custodian Values: Sedimentation Impact Statement.

5.2 Seagrass: Sedimentation Impact Statement



Moreton Bay seagrass and epiphytes
Photo credit: T. Skewes

5.2.1 Status and trends summary

Table 10 provides a qualitative assessment of seagrass communities in Moreton Bay, highlighting their current condition, future trajectory and the impacts of sedimentation. Seagrasses are a prominent feature of the Moreton Bay ecosystem, providing important nursery, shelter and critical feeding habitat for many species. However, the steady increase in flood events since the 1990s has brought corresponding increases in sporadic terrigenous sediment influxes, reducing the light availability and healthy oxygenated sediments they rely on. Consequently, healthy seagrass beds have substantially reduced in area, mainly due to accretion and smothering, and low light penetration from resuspended sediments in turbulent conditions. Hence, their current condition has been assessed as ‘Fair’ with ‘High’ confidence (Table 10).

The condition trend is assessed as ‘Declining’, with ‘High’ confidence (Table 10). This mainly reflects the increasing trend in the frequency of large floods and associated sediment loads. It seems clear that without substantial reversals in sediment loads, seagrass communities will continue to experience unsustainable mortalities through high frequency of (i) light reduction via high ongoing loads of suspended sediments, (ii) smothering and burial and (iii) degradation of rhizosphere physico-chemistry and healthy oxygenated sediments. The consequent degradation of seagrass communities will flow on to corresponding declines in a wide range of species groups that rely on seagrass habitats.

Table 10. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for seagrass populations in Moreton Bay
[depends on region within the Bay (Healthy Land & Water, 2023)].*

Value condition assessment	Assessment	Confidence
Current condition	Fair*	High
Contribution of sedimentation to the current condition	Major	High
Condition trend	Declining	High
Contribution of sedimentation to trend	Major	High

5.2.2 Overview

Seagrasses are marine flowering plants that form meadows in intertidal and subtidal areas of Moreton Bay up to five meters in depth (Kovacs *et al*. 2019; Maxwell *et al*., 2019) (Figure 2), although some *Halophila* species in the northern Bay can be found below ten meters (Maxwell *et al*., 2019). They are a prominent feature of the Moreton Bay ecosystem, which includes seven species such as *Halophila ovalis* (a colonising species), *Zostera muelleri* (an opportunistic species), and *Cymodocea serrulata* (a persistent species) (Maxwell *et al*., 2019).

The largest continuous seagrass community is located on the Eastern Banks, situated between Moreton (Mulgumpin) and North Stradbroke (Minjerribah) Islands (Kovacs *et al*., 2019) (Figure 3), where at least six of the seven species are present, with varying degrees of species diversity and cover over time and space (Maxwell *et al*., 2019). Seagrass communities in the western and southern embayments are less diverse. *Z. muelleri* is the dominant species in these western and southern areas, with *H. ovalis* and *H. spinulosa* also occurring (Maxwell *et al*., 2019).

These meadows are an important habitat for numerous organisms and are recognised globally for their biodiversity and as critical nursery habitats for commercially important fish and invertebrate species (Leigh *et al.,* 2013; Maxwell *et al*., 2019). They also play important roles in coastal protection, and as carbon stocks.

However, the diversity of species within seagrass meadows decreases in areas with poorer water quality, particularly in the southern and western embayments of the Bay (Maxwell *et al*., 2019).

5.2.3 Population status

The Healthy Land and Water report card (Healthy Land & Water, 2023) describes the status of seagrass in Moreton Bay as 'Fair' for the central bay, western bay and southern bay, but 'Excellent' for the eastern bay. Depth ranges for seagrasses have declined for most regions and are described as 'very poor' for the southern bay (Healthy Land & Water, 2023). Overall, the extent of seagrass within Moreton Bay remains 'Fair' (Healthy Land & Water, 2023).

Sensitive seagrass species, such as *Halophila*, have been lost in some subtidal areas, although large areas of seagrass have persisted despite the 2022 floods (Healthy Land & Water, 2023). The 2022 floods led to seagrass meadows retreating to shallower areas in some Bay regions (Healthy Land & Water, 2023). Over the long term, substantial recovery of seagrass has been observed in Deception Bay and Bramble Bay (Healthy Land & Water, 2023).

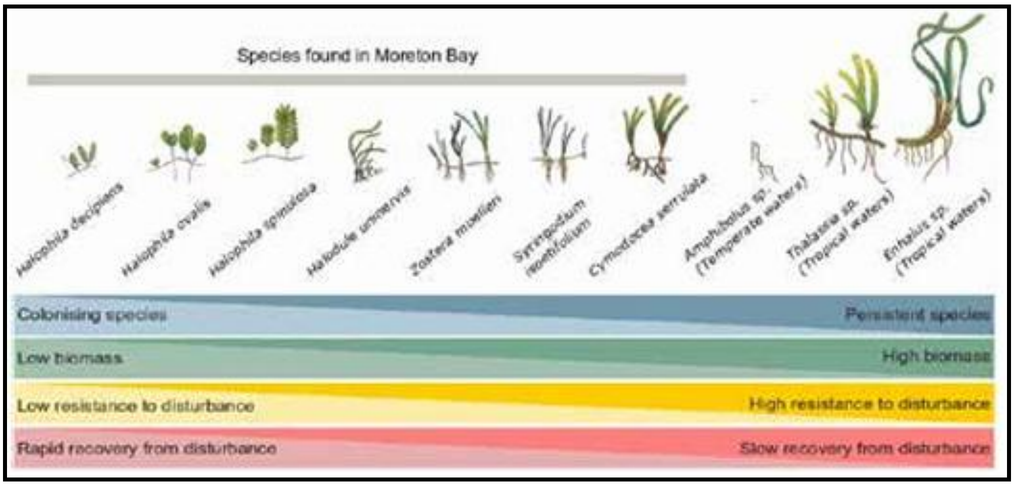


Figure 2. Seagrass species found in Moreton Bay. Extract from Maxwell et al. (2019).

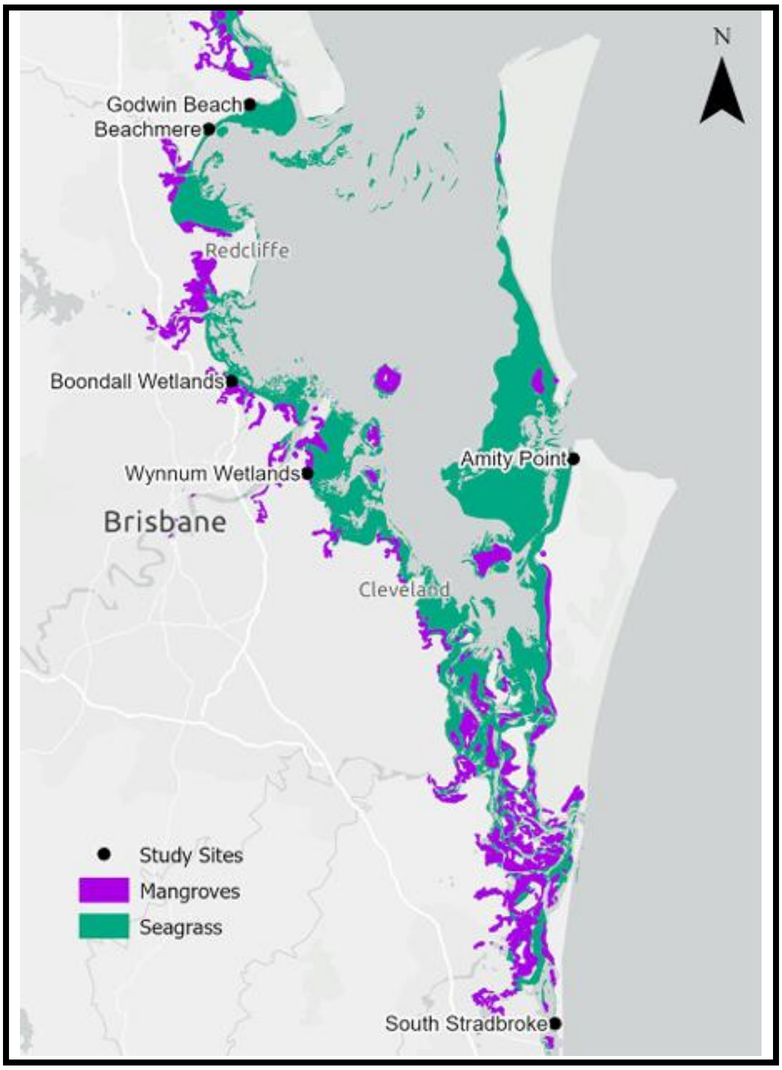


Figure 3. Distribution of Seagrass beds and Mangroves. Extract from Twomey et al. (2023).

5.2.4 Value

Ecological value

1. Habitat provision

Seagrass meadows serve as dominant habitat-forming components in shallow coastal zones globally (Zabarte-Maeztu *et al*., 2021). They provide essential structure for prawn and fish communities, including commercially important fish and invertebrate species (Leigh *et al.,* 2013). They offer shelter, food, and structural habitat both above and below the substrate surface for numerous marine organisms (Zabarte-Maeztu *et al.,* 2021).

2. Food source

Seagrasses serve as a direct food source for a variety of herbivores, including charismatic megafauna such as green turtles (*Chelonia mydas*) and dugongs (*Dugong dugon*) (McKenzie *et al.,* 2021). In Moreton Bay, dugongs selectively feed on high-nutrient, low-fibre seagrass species like *H. ovalis*, and have been shown to prevent the spread of the more fibrous *Z. muelleri* by grazing, effectively cultivating areas for their preferred food (Maxwell *et al*., 2019). Seagrasses also provide food for detrital and filter feeders (McKenzie *et al.,* 2021). Herbivorous fish, particularly rabbit fishes (*Siganidae*), consume seagrass in Moreton Bay, with juveniles preferring *Z. muelleri* (Maxwell *et al*., 2019). Small gastropods like *Smaragia souverbiana* also target seagrass leaves, specifically preferring *Z. muelleri*, possibly due to lower phenol content (Maxwell *et al*., 2019).

3. Biodiversity support

Seagrass ecosystems support high biodiversity (McKenzie *et al.,* 2021) and are globally recognised as hotspots for biodiversity (Maxwell *et al*., 2019). The presence of seagrass significantly influences the abundance and types of species that use these areas (Maxwell *et al*., 2019). The diversity effect also increases with the size of seagrass meadows and their proximity to other habitats (Maxwell *et al*., 2019). Even during disturbances such as algal blooms, seagrass meadows continue to function as a nursery habitat for a diverse assemblage of fish and prawns (Maxwell *et al*., 2019).

Connectivity between seagrass meadows and adjacent habitats, such as mangroves, is a vital factor influencing the abundance and types of species present, sometimes having a greater impact than the structural complexity of the meadow itself (Maxwell *et al*., 2019). Sites in estuaries closer to seagrass patches consistently support a greater number of species and individuals than those further away (Maxwell *et al*., 2019).

4. Ecosystem Engineering and Environmental Regulation

Seagrasses are described as 'ecosystem engineers' due to their ability to modify their environment (Zabarte-Maeztu *et al*., 2021). For example:

- Seagrasses trap, accumulate and stabilise fine and suspended sediments - a major ecosystem service that supports coastal and marine systems (Maxwell *et al*., 2019; Zabarte-Maeztu *et al*., 2021).

- Seagrasses slow water movement and reduce near-bed currents, lessening physical stress on plants (Maxwell *et al*., 2019). This includes stabilising coastal areas by dampening waves, which reduces storm damage and promotes natural hazard regulation (Maxwell *et al*., 2019).
- Below-ground roots and rhizomes of seagrasses bind sediments, limiting resuspension and improving water clarity (Zabarte-Maeztu *et al*., 2021). This creates a positive feedback loop, enhances conditions for seagrass growth and extends their depth range (Maxwell *et al*., 2019). Following the 2011 flood in Moreton Bay, light quantity was significantly higher in areas with seagrass than in adjacent unvegetated sites (Maxwell *et al*., 2019).
- Seagrasses play a role in disease regulation by reducing harmful bacteria (McKenzie *et al*., 2021).
- Seagrass leaves provide grazing opportunities for other animals, helping to regulate broader ecosystem function and structure. Small fish and invertebrates graze on epiphytic growth on seagrass leaves, improving light conditions for photosynthesis and globally regulating ecosystem structure and function (Maxwell *et al*., 2019). In Moreton Bay, this grazing enhances seagrass persistence, particularly in areas with high nutrient loads (McKenzie *et al*., 2021).
- Seagrasses oxygenate the rhizosphere, the area surrounding their roots, modifying substrate chemistry and influencing the surrounding sediment environment (Zabarte-Maeztu *et al*., 2021).

<u>5. Biogeochemical Cycling/Carbon Sequestration</u>
Seagrasses contribute substantially to nutrient recycling (Maxwell *et al*., 2019). They are globally recognised as significant carbon stocks. Recent findings have highlighted high rates of carbon sequestration in sediments within seagrass meadows (Maxwell *et al*., 2019). They also play a role in regulating ocean acidification to increase calcification of reefs (McKenzie *et al.,* 2021).

Cultural value

Seagrasses in Moreton Bay provide substantial support for cultural values, including:

<u>1. Support for traditional and contemporary fisheries and livelihoods</u>
Seagrass meadows provide critical nursery habitats, food and shelter for marine communities that are the basis for valuable recreational and commercial fisheries for Aboriginal and non-Aboriginal residents (Ross *et al*., 2019a). Indigenous fishers have harvested seagrass-dependent seafood like finfish, crustaceans, shellfish, turtles, and dugongs for thousands of years, and these resources remain an important part of their culture today (Thurstan *et al.,* 2019). Some Quandamooka people continue to catch fish and shellfish, with mullet being culturally and economically significant (Thurstan *et al*., 2019).

2. Support for culturally significant species

Seagrass meadows serve as a food source for Green Turtles and Dugongs (Leigh *et al*., 2013), both of which are iconic coastal species in Moreton Bay and feature prominently in the Dreamtime stories of the Quandamooka people (Delaney, 2013). Traditional Custodians also link enhancing knowledge of local ecosystems to improving their care (Ross *et al*., 2019a).

3. Aesthetic appreciation
Aesthetic value is placed on waterways, and for Traditional Custodians, this appreciation is shaped by their ancestral connections, dreaming stories and a rich social memory (Ross *et al*., 2019a). They associate the aesthetic qualities of seagrass and their saltwater habitats with ecosystem health (Pinner *et al*., 2019) and feel despondent about the beauty that has been lost over time due to degradation (Ross *et al*., 2019a).

Economic value

Moreton Bay provides crucial ecosystem services to over two million people, including recreational and commercial fisheries, tourism, and aquaculture operations (Pascoe *et al*., 2025; Lockington *et al*., 2017). Seagrasses in Moreton Bay contribute significantly to various economic values, primarily through their role in supporting commercial and recreationally important species and activities (see 5.15. Moreton Bay Fisheries:
Sedimentation Impact Statement).

1. Support for commercial fisheries
Moreton Bay supports a significant commercial fishing fleet that provides fresh seafood, including prawns, crabs, and fish, many of which depend on seagrass for their survival (Pascoe *et al*., 2025). Maintaining the linkages between estuarine seagrass habitats and the larger meadows in the Bay is essential for supporting these commercial fisheries (Maxwell *et al*., 2019).

2. Support for recreational fisheries
Seagrass meadows are also the basis for valuable recreational fisheries in Moreton Bay (Leigh *et al.,* 2013). The region attracts large numbers of recreational anglers each year, many of whom prize fish species found in habitats supported by seagrasses (Pascoe *et al*., 2025). The importance of seagrass connections to other habitats is also noted for supporting recreational fisheries (Maxwell *et al.,* 2019).

3. Broader Economic Activities
The role of seagrasses in maintaining overall ecosystem health and supporting key species contributes to the appeal and functionality of the Bay. Seagrasses are also included in areas declared as RAMSAR sites and no-take zones within the Moreton Bay Marine Park, highlighting their recognised importance for protecting iconic coastal species and managing fisheries (Lockington *et al.,* 2017). High rates of carbon sequestration within seagrass sediments are also noted, emphasising the valuable ecosystem services these habitats deliver.

5.2.5 History

Historically, seagrass has been absent or sparse in some western embayments (Kovacs *et al*., 2019). An undocumented total loss in Bramble Bay is believed to have happened before the 1980s (Kovacs *et al*., 2019). Following flood events between 1987 and 1998, a loss of 2,000 hectares was calculated for southern Deception Bay, and an estimated loss of 800 hectares occurred around the southern Bay islands (Kovacs *et al*., 2019). However, since these historical losses, there have been no recorded large-area seagrass losses in the western Bay, even after major flood events in 2011 and 2013 (Kovacs *et al*., 2019).

The overall cover of intertidal seagrass in the western Bay has been reported as stable since 2001, and stable in Pumicestone Passage since the early 1970s (Kovacs *et al*., 2019). Encouraging recovery of meadows has been observed in some degraded areas, such as southern Deception Bay and parts of Bramble Bay (Maxwell *et al*., 2019). Near the Fisherman Islands port development, there has been a trend of slight seagrass expansion into deeper waters. At the same time, areas subject to bait worming have experienced a decrease in seagrass cover (45-54%) (Kovacs *et al*., 2019). Despite monitoring efforts, the exact current extent of seagrasses and how they vary temporally is difficult to quantify (Maxwell *et al*., 2019).

5.2.6 Impacts of sedimentation

The impacts of sedimentation on seagrass communities in Moreton Bay are broadly described in the conceptual model (Figure 4). Seagrasses in Moreton Bay are subject to threats that have been steadily increasing since the 1990s (Maxwell *et al*., 2019). The major drivers of seagrass decline include increased sediment and nutrient inputs from rainfall events via their catchment sources (Leigh *et al*., 2013). For example, in areas like Deception Bay, Bramble Bay and around Mud Island, fine sediments from the Brisbane River are regularly resuspended and contribute to poor water clarity (Adams *et al*., 2016). Port development and maintenance are another significant contributor to sediment loads that are introduced into the coastal benthic systems of Moreton Bay.

Such inputs of fine sediments from rivers, combined with wave action, contributes to significant sediment deposition and resuspension and makes seagrass survival and recolonization difficult. Consequently, these rainfall events have led to sediment accretion in the central basin increasing three to nine times over the past 100 years and have historically caused substantial seagrass loss (Maxwell *et al*., 2019).

The increased sedimentation into the Bay stems from both anthropogenic activities and natural processes (Kovacs *et al*., 2019), with climate change and land-use change considered to be major threats (Maxwell *et al*., 2019). Modelling indicates that increasing sediment loads, as predicted under future climate and management scenarios, are expected to cause a non-linear decrease in habitat suitable for seagrass (Maxwell *et al*., 2019; Saunders *et al*., 2019). With the population of South-East Queensland projected to increase significantly, pressures on seagrass ecosystems are expected to rise (Maxwell *et al*., 2019).

Declining water quality, associated with increased sediment, as well as toxins and nutrients, also contributes to the decline of seagrass and estuarine ecosystems and can manifest as increased phytoplankton blooms (Leigh *et al*., 2013; Kemp *et al*., 2019). Other impacting factors include changes in salinity, epiphyte cover, disease, pollution, large-scale blooms of the toxic filamentous cyanobacteria *Lyngbya majuscula* and other human impacts such as port development and bait worming (Kovacs *et al*., 2019; Maxwell *et al*., 2019).

The primary processes by which sedimentation impacts seagrasses include:

1. Reduction in light availability

Increased suspended sediment loads in coastal waters cause reduced light penetration to the seabed (Adams *et al*., 2016; Zabarte-Maeztu *et al*., 2020). Seagrasses, being primary producers, require sufficient sunlight for photosynthesis and growth. This reduction in light reduces seagrass productivity and growth (Saeck *et al.,* 2019b) and is considered a major cause of seagrass loss globally (Adams *et al*., 2016; O'Brien *et* al., 2018; Zabarte-Maeztu *et al*., 2020, 2021).

Light availability is the single most important driver of seagrass distribution in the Bay and is primarily controlled by water clarity, which is influenced by catchment-derived sediment (Maxwell *et al*. 2019). Settled fine sediment can also continue to shade seagrasses after deposition (Zabarte-Maeztu *et al*., 2020). Wave action can then resuspend sediment, which reduces light availability, lowers the depth limit of seagrass, and reduces sediment nutrient processing (O'Brien *et al.,* 2011; Adams *et al*., 2016). These impacts can lead to a regime shift from a clear to a turbid environment (O'Brien *et al.,* 2011). While studies frequently investigate light reduction as a single impact mode, it often occurs alongside other sediment effects (Zabarte-Maeztu *et al*., 2021),

2. Smothering and burial

Fine sediment can settle on seagrass leaves, leading to smothering, which inhibits photosynthesis by shading, increases oxygen demand, and restricts the exchange of metabolites (Zabarte-Maeztu *et al*., 2021). While excessive burial is detrimental, some degree of fine sediment accumulation and stabilisation is a natural process that can be advantageous for ecosystem functions, such as carbon sequestration (Zabarte-Maeztu *et al*., 2021).

In more severe cases, complete burial of the plant can occur, initiating these damaging mechanisms (Zabarte-Maeztu *et al*., 2021). The tolerance of seagrasses to burial varies by species (Cabaco *et al*., 2008), with smaller seagrass species generally being more vulnerable to the effects of fine sedimentation, such as burial (Zabarte-Maeztu *et al*., 2021). Burial thresholds (levels causing 50% or 100% shoot mortality) have been estimated for different species, ranging from 2 cm for *H. ovalis* to 19.5 cm for *Posidonia australis* in experimental settings (Cabaco *et al.,* 2008). *Posidonia sinuosa* is a large, slow-growing persistent species and was unaffected by burial depths of 1 and 4 cm for up to eight weeks, however, burial depths of 8 cm and 16 cm led to significant negative impacts on ramet photophysiology and growth (Webster *et al*., 2025).

High concentrations of fine sediments or high sediment mud concentrations can also hinder the presence of seagrass. The estimated threshold for seagrass presence is a sediment mud concentration less than 50% (Adams *et al*., 2016).

3. Degradation of rhizosphere physico-chemistry

When fine sediments and associated organic matter settle, they can intrude into the substrate pore space (Zabarte-Maeztu *et al*., 2021). This intrusion reduces substrate porosity and permeability, which can exacerbate hypoxia (Zabarte-Maeztu *et al*., 2020). Mud with high organic content is considered particularly problematic in this regard and can hinder seagrass growth and prevent recovery (Zabarte-Maeztu *et al*., 2020). Webster *et al*., (2025) noted that at burial depths of 8 cm and 16 cm, sediment redox damaged seagrass health, reflecting conditions consistent with impaired plant physiology and anoxic sediment in the root zone. Furthermore, sulphide intrusion was identified as a key driver of negative impacts on seagrass from burial, especially at depths where plants were still photosynthesising, but growth declined (e.g. 8 cm) (Webster *et al*., 2025).

These three processes by which sedimentation impacts seagrasses (see above) often operate simultaneously and can also interact, potentially accelerating seagrass loss (Zabarte-Maeztu *et al*., 2021). Fine sediment frequently interacts with nutrient enrichment, which can lead to increased organic matter. This interaction can cause additional shading by phytoplankton and epiphytes and impose extra oxygen demand, further complicating the seagrass response (Zabarte-Maeztu *et al*., 2020).

5.2.7 Recommendations

1. Tailor management efforts to specific regions within Moreton Bay, as the environmental factors limiting seagrass presence can differ significantly between adjacent areas (Adams *et al*., 2016). Species distribution models (SDMs) can be used to identify these local limiting factors and assess management options.
2. Prioritise water quality improvement:
   - Reduce the delivery of sediments and nutrients through catchment management (Adams *et al*., 2016).
   - Improve the implementation of silt curtains to manage sediment (Saeck *et al*., 2019b).
   - Continue efforts to reduce point-source nutrient loads, such as upgrades to sewage treatment plants (Maxwell *et al*., 2019).
3. Mitigate direct physical effects:
   - Address high wave action, which can physically remove seagrass and resuspend sediment, through methods like break walls or gabions (Adams *et al*., 2016). These actions should be prioritised in regions where wave action is the primary hindrance.

- Stabilise sediment in areas prone to resuspension. This can be achieved through the deployment of hessian bags or shell armour (Adams *et al.*, 2016). These methods can protect seagrass due to wave action and temporarily create a positive feedback loop for sediment stabilisation until meadows establish naturally (Adams *et al.*, 2016).

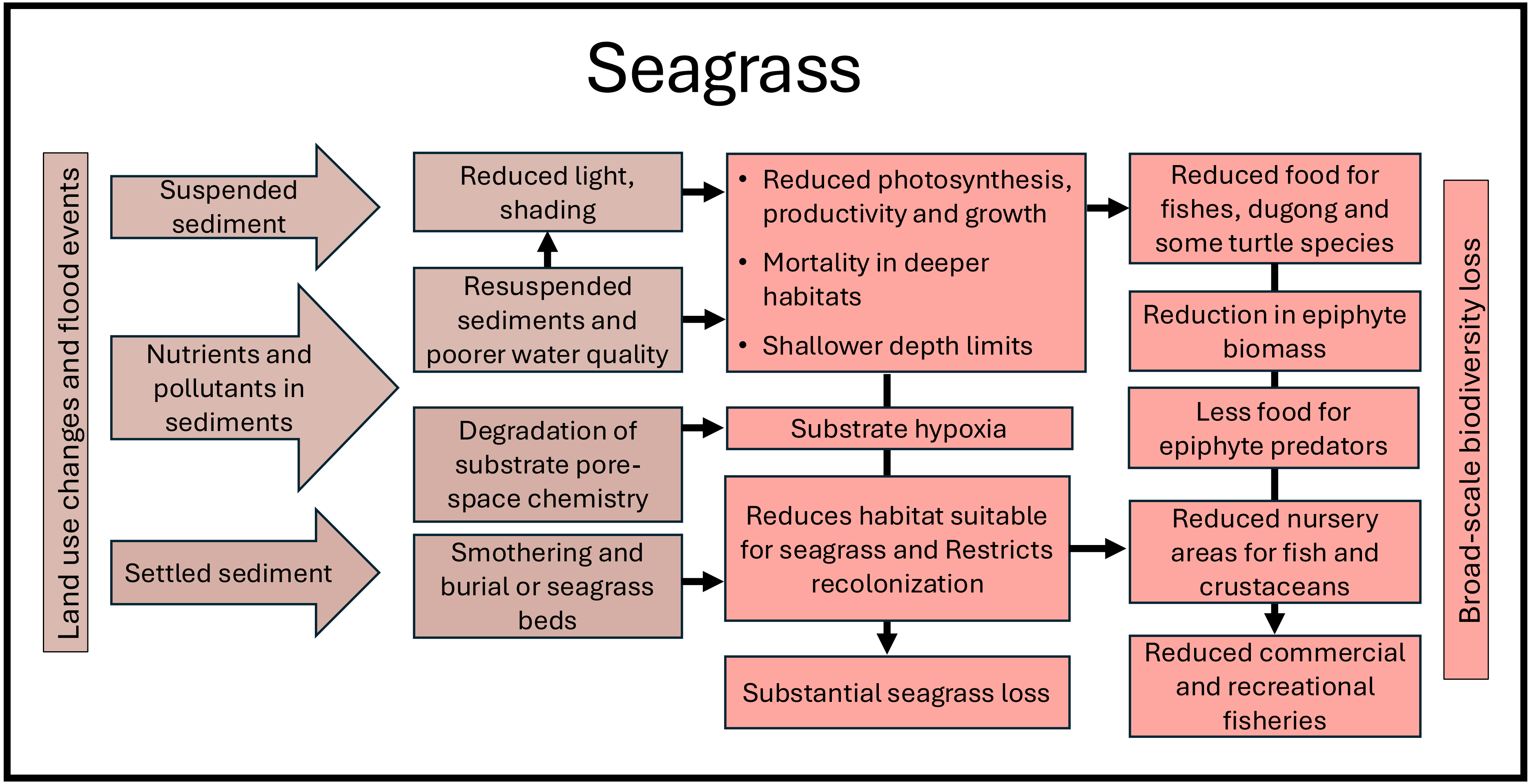
4. Enhance ecological feedback processes and resilience:
   - Focus on enhancing the biomass of existing seagrass meadows, especially in bistable areas (Maxwell *et al.*, 2015).
   - Implement actions that enhance natural feedback processes that promote resistance to impact and break down feedback processes that prevent recovery (Maxwell *et al.*, 2015, 2019). For example, managing to enhance grazing rates (e.g. through protecting herbivores or designating no-take fishing areas) can limit algal loads and improve seagrass growth and abundance (Maxwell *et al.*, 2015).
5. Support ongoing research and monitoring:
   - Develop and validate models (like SDMs and Bayesian Networks) to identify areas at risk of seagrass loss and to prioritise conservation and restoration efforts (Maxwell *et al.*, 2015; O'Brien *et al.*, 2011). These models can integrate disparate data types and provide high-spatial-resolution risk maps (Maxwell *et al.*, 2015).
   - Maintain long-term water quality monitoring programs that couple water quality indicators with ecosystem indicators (e.g. phytoplankton and benthic microalgae community composition and nutrient response) to track and respond to eutrophication pressures (Saeck *et al.*, 2019b).
   - Further investigate the complex relationships between multiple stressors (e.g. light, sediment, nutrients, wave action) and their impacts on seagrass, particularly how they affect light thresholds and the mechanisms of mud damage (Maxwell *et al.*, 2019; Zabarte-Maeztu *et al.*, 2021).
   - Address knowledge gaps, such as the full extent of seagrasses, their temporal variation, and their economic, social, and ecological value (Maxwell *et al.*, 2019).
   - Support socio-economic and cultural valuation of seagrass ecosystems (McKenzie *et al.*, 2021).
   - Build scientific literacy and awareness to foster local stewardship for seagrass conservation (McKenzie *et al.*, 2021).

5.2.8 Expert review

Dr Paul Maxwell (General Manager, EcoFutures Consulting) kindly provided an expert review of the Seagrass: Sedimentation Impact Statement.

5.2.9 Conceptual model - impacts of sedimentation on seagrass

Figure 4. Conceptual model that qualitatively describes the major impacts of sedimentation on seagrass communities in Moreton Bay. Brown boxes signify sedimentation-related processes; red boxes signify adverse impacts/outcomes.



5.3 Mangroves: Sedimentation Impact Statement

Mangroves in Moreton Bay
Photo credit: V. Bennion

5.3.1 Status and trend summary

Table 11 provides a qualitative summary assessment of the mangrove communities in Moreton Bay, highlighting key aspects of their current condition, future trajectory and the impacts of sedimentation. Between 1955 and 2021 mangrove area in the Bay had a net gain of 10.9% due to sea level rise and sediment accretion. But there have also been losses due to subsiding soils and dieback. Most gains in mangrove area have been due to landward encroachment into saltmarsh and supratidal forest communities. The overall current condition of mangroves in the Bay is rated as 'Good, with 'High' confidence.

The condition trend for mangroves is noted as 'Stable' and with 'Medium' confidence. This reflects a combination of the moderate increases in mangrove area happening in the Bay, along with the limited scope for future mangrove encroachment over time due to 'coastal squeeze', where future landward mangrove migration is blocked by permanent urban and industrial development on the coastline. Other factors affecting mangroves include a range of anthropogenic inputs into the Bay, such as pollutants, the impacts of which are poorly understood. Given that sedimentation from Moreton Bay catchments is not decreasing and sea level rise may promote increased sediment deposition, the contribution of sedimentation to the condition trend for mangroves is considered 'Moderate' with 'Medium' confidence.

Table 11. Qualitative assessment of the overall status and trend in condition, and the likely severity and direction of sedimentation-specific impacts, on mangroves in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Good	High
Contribution of sedimentation to the current condition	Moderate	Medium
Condition trend	Stable	Medium
Contribution of sedimentation to trend	Moderate	Medium

5.3.2 Overview

Moreton Bay's mangrove communities are significant subtropical wetlands in Southeast Queensland, covering 15,469 hectares in 2021 (Figure 5) (Queensland Government, 2024). They are dominated by salt-tolerant vegetation found within the intertidal zone, ranging from approximately mean sea level up to the highest neap tides (Lovelock *et al.*, 2019). Their distribution ranges from upstream river systems and tidal creeks to low-energy fringing parts of the Bay, including smaller Bay islands (Lovelock *et al.*, 2019) Figure 6). They are regularly inundated by seawater in the intertidal zone (Choi *et al.*, 2022) and are often distributed as parallel zones representative of an elevation gradient and tidal flushing frequency (Adame *et al.,* 2010).

Moreton Bay's mangroves support a moderate diversity of seven tree species, which is typical for subtropical Australian coastlines (Lovelock *et al*., 2019). Fringe mangroves occupy the lowest elevations and are diurnally flooded by neap and spring tides (Adame *et al.,* 2010). Scrub mangroves occupy mid-elevations, flooded only during spring tides. Saltmarshes and supratidal forest communities containing *Casuarina glauca* (Swamp she-oak) and *Melaleuca quinquenervia* (Broad-leaved paperbark) are found at the highest elevations, flooded during spring tides, and occupy higher elevations landward of mangrove stands (Adame *et al.,* 2010; New South Wales Government, 2008a) (see 5.4 Saltmarshes: Sedimentation Impact Statement).

Avicennia marina (Grey mangrove) is the most widely distributed species and the dominant species in most communities, particularly on the western side of Moreton Bay (Lovelock *et al*., 2019). *Rhizophora stylosa* (Red mangrove) is abundant on soft unconsolidated marine clays or sandy soils, particularly on the eastern islands and southern shores of the Bay (Lovelock *et al.,* 2014, 2019; Hill *et* al., 2021; Bennion *et al.,* 2024a). *Bruguiera gymnorhiza* (Orange mangrove) and *Ceriops australis* (Yellow mangrove) are found within the high intertidal zone, and *Aegiceras corniculatum* (River mangrove) is commonly found within riverine conditions (Lovelock *et al*., 2019).

Mangroves filter out and capture nutrients and sediments from the water column, depositing and storing carbon within their soils, forming significant ‘blue carbon’ repositories (Adame *et al.,* 2010; Lovelock *et al.,* 2014*,* 2022; Woodroffe *et al.,* 2016). Blue carbon sinks include the accumulation of organic matter, particularly root matter, in combinations with accumulated sediments. Their above-ground root systems and stems enhance sediment deposition, promoting mangrove growth and expansion (Adame *et al.,* 2010; Bennion *et al.,* 2024a). Higher sediment deposition occurs within the fringing zone of mangrove forests, with riverine mangroves showing more homogeneous sediment distribution (Adame *et al.,* 2010).

Sediment trapping efficiency varies among species due to differences in root structure, stem densities and forest structure (Bennion *et al.,* 2024a). For instance, *Rhizophora* species' prop roots have been associated with higher surface accretion rates compared to *Avicennia* pneumatophores (Bennion *et al.,* 2024a). The fringe (or lowest elevation) zone accounts for up to 72% of total sedimentation, largely due to greater vegetation cover, more extensive root systems, and a well-developed epiphytic algal community that enhances friction (Adame *et al.,* 2010).

Mangrove forests can adjust to rising sea levels by building substrate rapidly enough to keep pace with local rates of sea-level rise (Woodroffe *et al.,* 2016). A global synthesis of studies identified that mangroves should be able to withstand and maintain their elevation with maximum sea level increases of 7 mm year^{-1} (Saintilan *et al.,* 2020).

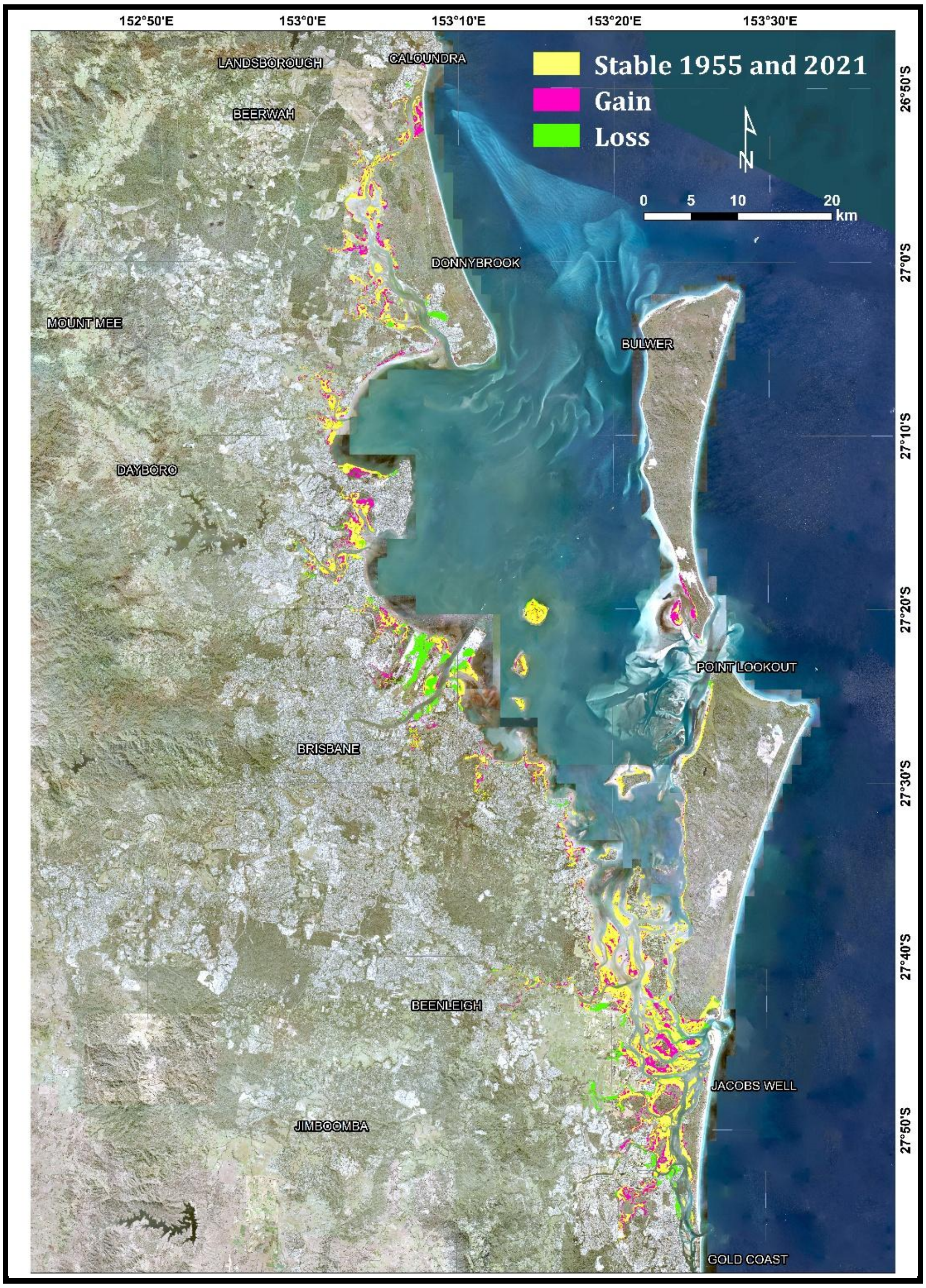


Figure 5. Changes in mangrove extent between 1955 and 2021 within Moreton Bay. Taken from Accad et al. (2023).

5.3.3 Population status

Moreton Bay's mangroves have shown a net gain of 1,519 hectares (10.9%) between 1955 and 2021 (Queensland Government, 2024), primarily through encroachment into adjacent saltmarsh areas communities (Lovelock *et al*., 2019; Queensland Government, 2024). Saltmarshes and supratidal forests have been reduced by 70.4% and 20.5%, respectively (Queensland Government, 2024). A total of 4,560 ha of mangrove has been gained by encroachment into other communities, while 3,041 ha were lost, either by transitioning to another community type or due to anthropogenic causes (Queensland Government, 2024). Despite the net gain, Moreton Bay has experienced significant mangrove dieback, primarily due to subsiding soils creating ponds (Twomey *et al.,* 2023) and extreme weather events (Bennion *et al.,* 2024b). Dieback events accounted for 12% of mangrove losses from 1955–2012 (Accad *et al*. 2016; Lovelock *et al*., 2019) (Figure 5).

The dominant species is *A. marina* (Lovelock *et al*., 2019), but *R. stylosa* is also abundant, particularly on the eastern and southern shores (including the sand islands of the Bay), and its increasing presence may enhance resilience to sea-level rise (Hill *et al*., 2021; Bennion *et al.,* 2024a).

An ongoing program to monitor the mangroves and associated communities within Moreton Bay was established in 2011 (Queensland Government, 2024).

Figure 6. Mangroves in Moreton Bay. Photo credit: V. Bennion.

5.3.4 Value

Ecological value

Mangroves play a crucial role in the region's coastal ecosystems (Adame *et al.,* 2010; Kovacs *et al.*, 2019). They serve as important habitats for a wide range of fauna, including species vital for commercial and recreational fisheries, and act as nursery habitats for many marine species, including fish and prawns (Lovelock *et al.*, 2019; Henderson *et al.*, 2021). They also support a diverse array of crustaceans, worms, and molluscs, which serve as prey for wading birds (Kovacs *et al.,* 2019). Crabs within mangroves process decomposing leaf litter, linking mangrove productivity to fisheries production (Lovelock *et al.*, 2019).

Mangroves act as natural barriers that filter pollutants, nutrients and sediment, and provide protection against extreme weather events, waves and storm surges (Barbier *et al.,* 2011; Lovelock *et al.*, 2019, Beeston *et al.*, 2023). Their roots enhance sediment deposition, which in turn promotes their growth and expansion, thereby protecting adjacent seagrass and coral reef ecosystems from excess sedimentation (Bennion *et al.,* 2024a).

Mangroves are effective at trapping sediments (Adame *et al.,* 2010) and play a crucial role in nutrient retention and cycling. Moreton Bay mangroves can retain significant percentages of nitrates (28%), soluble phosphorus (51%), and ammonium (83%) during tidal cycles, thereby enhancing water quality (Lovelock *et al.*, 2019; Choi *et al.*, 2022).

Cultural value

Moreton Bay's mangroves hold significant cultural value, particularly for the Quandamooka People, the Traditional Custodians of the region, who have nurtured the Bay's lands and seas for over 25,000 years (Dean *et al.*, 2019; Fischer *et al.*, 2019). This cultural importance is rooted in a deep, multi-millennial connection to the land and sea, fostering a custodial ethic where environmental management is a customary responsibility (Fischer *et al.*, 2019; Nasplezes *et al.*, 2019).

Mangroves are integral to cultural identity, heritage and well-being. Places hold symbolic meanings, often reflected in Aboriginal place names or archaeological sites, such as middens and fish traps, which are tangible expressions of their connection to Country (Pinner *et al.*, 2019; Lovelock *et al.*, 2019; Beeston *et al.*, 2023).

Overall, mangroves provide important cultural benefits and contribute to the well-being of coastal people, extending beyond their commercial utility (Saeck *et al.*, 2019a; Lovelock *et al.*, 2019; Beeston *et al.*, 2023).

Economic value

Mangroves are crucial habitats and nursery grounds for commercially and recreationally important fish and crustacean species, with commercial catches correlated to mangrove area (Leigh *et al.*, 2013; Lovelock *et al.*, 2019; Henderson *et al.*, 2021). As part of the Bay's natural assets, mangroves contribute to nature-based tourism and various recreational activities (Lovelock *et al.,* 2019; Ross *et al.,* 2019a, b).

Mangroves act as natural barriers, reducing coastal erosion, waves and storm surges, thereby protecting land and infrastructure (Kovacs *et al.,* 2019; Lovelock *et al*., 2019; Bennion *et al*., 2024a). They also store substantial amounts of organic carbon (4.1 to 5.2 million Mg in Moreton Bay), contributing to climate change mitigation (Lovelock *et al*., 2014, 2019; Woodroffe *et al*., 2016; Choi *et al*., 2022; Bennion *et al*., 2024a) and offering potential for income through carbon markets (Lovelock *et al.,* 2019; Beeston *et al*., 2023). They filter pollutants, nutrients, and sediments, benefiting the overall health of the Bay and supporting other valuable ecosystems (Kovacs *et al.,* 2019; Lovelock *et al.,* 2019; Beeston *et al*., 2023).

5.3.5 History

The history of mangroves in Moreton Bay shows a dynamic landscape significantly influenced by both natural processes and human activities since European settlement. Since European colonisation, these habitats have been highly modified by land-use changes and urban development (Lovelock *et al.,* 2019).

Moreton Bay had extensive mangrove areas, covering around 14,273 hectares in 1955 (Accad *et al*., 2023). Between 1955 and 2012 there was a net 10.9% increase in mangrove communities (see Population status section above) (Accad *et al*., 2023; Lovelock *et al.,* 2019).

Extreme weather events, such as the major floods in 1974, 2011, and 2022, also increased mud deposition and fine particle suspension in the Bay, which impacted these habitats (see the Impacts of Sedimentation section below) (Kovacs *et al.,* 2019; Lockington *et al.,* 2017).

Mangroves are protected from development and destruction under Australian law (*Environment Protection and Biodiversity Conservation Act 1999*), state laws (*Fisheries Act 1994*) and international agreements (RAMSAR convention) (Lovelock *et al*., 2019). They are vulnerable to anthropogenic impacts from adjacent onshore developments, as well as to siltation, runoff and climate change-induced effects (such as more severe droughts and sea level rise).

Despite ongoing protective legislation and international agreements, mangroves and saltmarshes continue to face pressures, highlighting the dynamic and contested nature of these valuable coastal ecosystems (Lovelock *et al.,* 2019).

5.3.6 Impacts of sedimentation

Human activities, like urban development, land clearing, freshwater extraction and the alteration of waterways with dams, have drastically increased fluxes of sediments, nutrient loads and contaminants in Moreton Bay and have led to a dramatic increase in mud distribution across the bay (Douglas *et al*., 2003; Grinham *et al*., 2024). Sediment loads are estimated to be 30 to 100 times greater than pre-European settlement rates (Leigh *et al*., 2013). Muddy sediments now cover over 860 km^2 of Moreton Bay, more than doubling since 1970 and becoming the dominant sediment type (Lockington *et al.,* 2017; Saeck *et al*., 2019a; Grinham *et al*., 2024). This increased load of muddy sediments has compromised Moreton Bay's ecosystems by reducing water clarity and smothering other sensitive ecosystems (Kovacs *et al.,* 2019; Saeck *et al.,* 2019a; Grinham *et al*., 2024).

However, sedimentation in Moreton Bay has both positive and negative impacts on its mangrove ecosystems (Adame *et al.,* 2010; Lovelock *et al.,* 2019; Bennion *et al.,* 2024a). See Figure 7 for a conceptual model of sedimentation impacts on mangroves.

Positive Impacts

Mangrove forests rely on sediment accretion and organic matter accumulation (from root growth) to maintain their soil surface elevation and adapt to rising sea levels (Lovelock *et al.,* 2015; Woodroffe *et al.,* 2016; Bennion *et al.,* 2024a). Studies in Moreton Bay have shown that soil surface elevation increases with mean sea level and turbidity in areas with abundant fine sediment (Lovelock *et al.,* 2015). Mangrove structures, such as stems and above-ground roots, play a crucial role in reducing tidal flow velocity and enhancing the retention of sediment and organic material within the wetlands (Lovelock *et al.,* 2015; Bennion *et al.,* 2024a).

The increased sediment supply following European settlement in Moreton Bay has likely contributed to an expansion of mangrove areas and their encroachment into saltmarsh habitats (Kovacs *et al.,* 2019; Lovelock *et al.,* 2019). This aligns with the 10.9% net expansion of mangrove habitats observed in Moreton Bay between 1955 and 2012 (Accad *et al*., 2023; Lovelock *et al.,* 2019).

Mangroves are effective at trapping sediments and retaining nutrients, such as nitrates, soluble phosphorus, and ammonium, thereby contributing to the Bay's water quality (Lovelock *et al.,* 2019).

Negative impacts

High sediment loads, particularly fine muds, can alter mangrove species composition and ecosystem functioning, leading to a shift from predominantly sandy habitats to more mud-dominated ones, especially in the western Bay (Lovelock *et al.,* 2019; Saeck *et al*., 2019a). The shift in sediments creates a corresponding change in benthic species which are essential food organisms for shorebirds, fish and other groups. These fine sediments are easily resuspended by wind and tidal currents, leading to increased turbidity and reduced water clarity (Lockington *et al.,* 2017; Saeck *et al*., 2019a). This negatively impacts light-dependent benthic communities and the higher trophic groups that feed on them.

Mangrove encroachment, partly driven by sedimentation, poses a significant threat to saltmarsh and supratidal forest communities (see Positive impacts section above) (Kovacs *et al.,* 2019; Lovelock *et al.,* 2019; Queensland Government, 2024). The encroachment into saltmarshes also reduces critical feeding and roosting sites for migratory shorebirds (Lovelock *et al.,* 2019; Fuller *et al*., 2021), threatening over two-thirds of assessed roosting sites, although some species do roost within dense mangroves (Fuller *et al*., 2021).

5.3.7 Recommendations

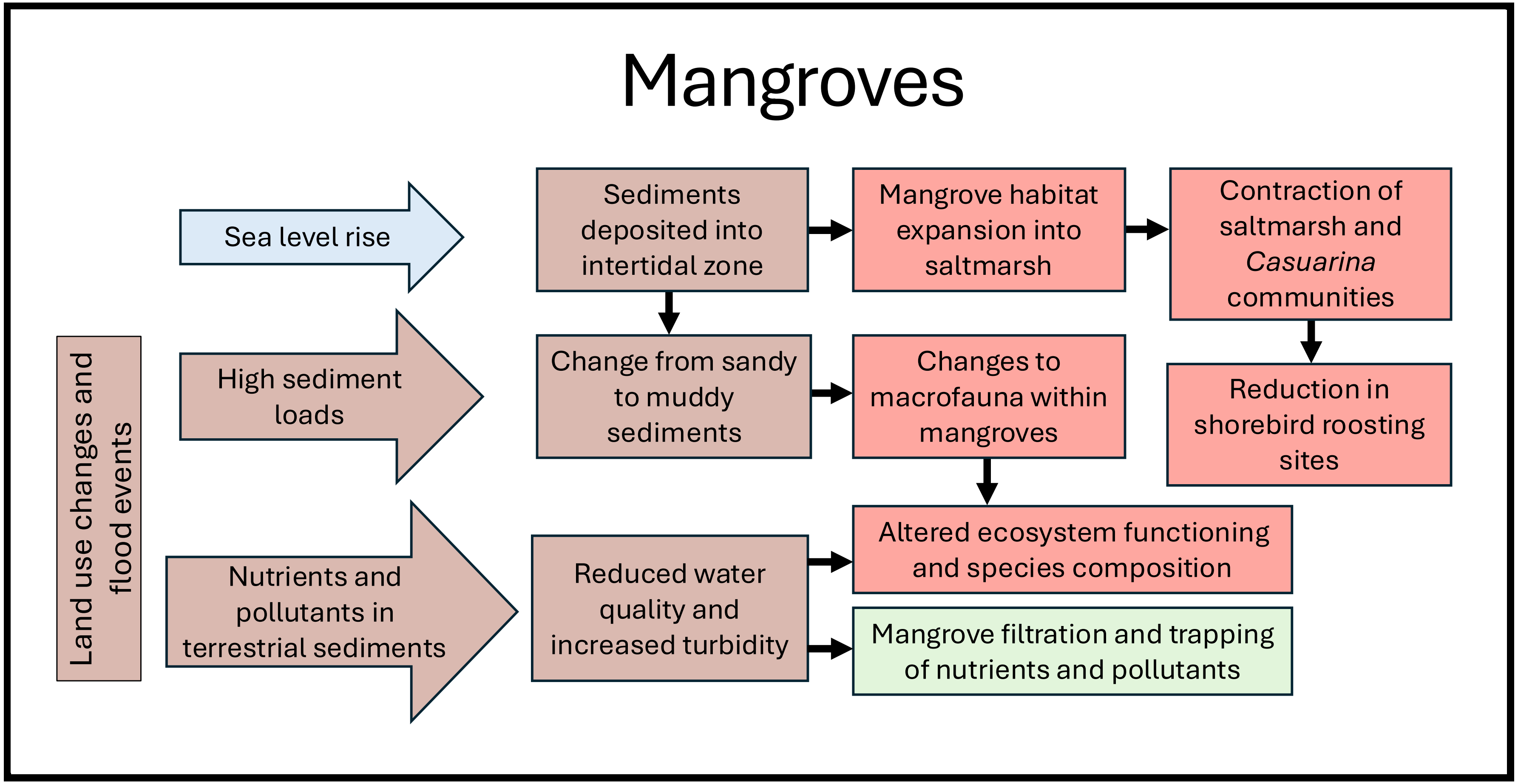
1. Implement active sediment management, which can include manually removing excess sediment where loads are too high, or trapping and adding sediment where rates are too low (Beeston *et al.,* 2023). Permeable structures can be constructed to enhance sediment trapping and reduce wave energy (Beeston *et al.,* 2023).
2. When planting, select native mangrove species that are more tolerant of specific sedimentation rates (Beeston *et al.,* 2023).
3. Address the root causes of erosion, such as unsustainable aquaculture practices, to promote natural mangrove regeneration (Beeston *et al.,* 2023).
4. Prioritise the conservation of the seaward fringe mangrove zone as it plays a crucial role in sediment retention and aim to preserve the entire coastal wetland for sustained sediment retention (Adame *et al.,* 2010).
5. In areas where mangroves encroach on saltmarsh, focus on mitigating the underlying causes or planning for the landward migration of saltmarsh habitats (New South Wales Government, 2008a).
6. Maintain heterogeneous estuarine seascapes that include a mosaic of natural habitats like seagrass meadows and instream rock, alongside mangroves, to support diverse ecosystems (Henderson *et al.,* 2021).

5.3.8 Expert review

Vicki Bennion (School of the Environment, University of Queensland) kindly provided expert review of the Mangroves: Sedimentation Impact Statement.

5.3.9 Conceptual model - impacts of sedimentation on mangroves

Figure 7. Conceptual model that qualitatively describes the major impacts of sedimentation on mangrove communities in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes; green boxes indicate likely positive or neutral impacts/outcomes.



5.4 Saltmarshes: Sedimentation Impact Statement

Saltmarsh in Moreton Bay
Photo credit: V. Bennion

5.4.1 Status and trend summary

Table 12 provides a qualitative assessment of the saltmarsh communities in Moreton Bay, highlighting key aspects of their current condition, future trajectory and the impact of sedimentation. Saltmarshes are important habitats that support a wide range of vertebrate and invertebrate species, including migratory birds, crabs, and molluscs. They also provide crucial ecosystem services like coastal protection. However, since European colonisation saltmarshes in Moreton Bay have been highly modified directly by conversion to other uses, and indirectly by catchment land-use changes, sea level rise and resultant sedimentation into the intertidal zone. Between 1955 and 2021, the total saltmarsh area in Moreton Bay experienced a net loss of 70.4% (6,670 ha). Their current condition is rated as ‘Poor’, with ‘High’ confidence. The contribution of sediment to this condition is ‘Moderate’, which is assigned with ‘High’ confidence.

Land-use changes have continued to release significant volumes of sediment into the Bay. Increased sedimentation and rising sea levels have supported mangrove expansion into the higher tidal zones, including encroachment into the saltmarshes and supratidal forests. Excessive sediment loads have directly impacted some saltmarsh communities through smothering and reduced water clarity, affecting a range of benthic groups in these habitats. These reductions in saltmarsh communities have significant negative impacts on migratory birds, fish and invertebrates that are important for ecosystem and biodiversity maintenance as well as fishery production.

The trend for saltmarsh condition in Moreton Bay is rated as ‘Declining’ with ‘High’ confidence. The contribution of sedimentation to the condition trend is considered ‘Major’ and is assigned ‘High’ confidence given the strong available evidence for this decline due to the combination of high sediment loads, sea level rise and mangrove encroachment, in particular.

Table 12. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, on saltmarshes in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Poor	High
Contribution of sedimentation to the current condition	Moderate	High
Condition trend	Declining	High
Contribution of sedimentation to trend	Major	High

5.4.2 Overview

Saltmarshes in Moreton Bay are found in the high intertidal zone, specifically landward of mangrove communities, on low-gradient marine and estuarine plains (New South

Wales Government, 2008a, b) (Figure 8). They are typically intermittently inundated by king or spring tides rather than daily tidal cycles (New South Wales Government, 2008a). They occupy elevations between the mean high tide and the highest astronomical tides (Lovelock *et al*., 2019).

Saltmarshes are primarily treeless floral communities, consisting of low succulent herbs, salt-tolerant grasses, rushes, and sedges (New South Wales Government, 2008a, b). They may also include bare or sparsely vegetated hypersaline flats where cyanobacteria are dominant (Saintilan and Rogers, 2013). Moreton Bay's saltmarsh plant community exhibits a higher species richness than its mangroves, with approximately 20 species, which accounts for 20% of Australia's total saltmarsh species (Lovelock *et al*., 2019).

Hypersaline areas, common in the western bay (e.g. Tinchi Tamba Wetlands, Geoff Skinner Reserve, Point Halloran Reserve), are dominated by highly salt-tolerant herbs such as *Sarcocornia quinqueflora* (Beaded glasswort or samphire), *Suaeda australis* (Austral seablite), and *Sporobolus virginicus* (Marine couch). Brackish communities, where groundwater reduces soil salinity (e.g. eastern Bay Islands), support saltmarsh communities with a range of reeds and herbs, notably *Juncus kraussii* (a grass-like rush), and tend to have low diversity (New South Wales Government, 2008a, b; Lovelock *et al*., 2019; Bennion *et al*., 2024a).

Saltmarshes in Moreton Bay typically butt against a supratidal forest at their landward edge in natural settings; often consisting of *Casuarina glauca* (Swamp she-oak) and *Melaleuca quinquenervia* (Broad-leaved paperbark).

5.4.3 Population status

The saltmarsh communities of Moreton Bay were officially listed as a Vulnerable ecological community under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in 2013 due to losses in recent decades (New South Wales Government 2008a, b; Lovelock *et al*., 2019). The importance of the Bay's wetlands, including saltmarshes, for migratory waterbirds has also led to listing Moreton Bay as a Ramsar site (Lovelock *et al.,* 2019).

Overall, saltmarsh areas in Moreton Bay are in decline. Human activities and natural processes like mangrove encroachment, potentially exacerbated by climate change and sea-level rise, pose ongoing challenges to their extent and health (Lovelock *et al*., 2019). Saltmarshes have experienced substantial loss, with an estimated 70.4% decline in area from 1955 to 2021, a 6,670 ha overall net loss (Queensland Government, 2024) (Figure 9).

Mangrove expansion into saltmarsh communities is consistent with rising sea levels and increased sediment loads, as increased inundation and sedimentation favours mangrove growth (Lovelock *et al*., 2019). Mangrove expansion is responsible for approximately half of the saltmarsh area loss since 1955 (Queensland Government, 2024; Lovelock *et al*., 2019). Anthropogenic activities such as permanent urban development create coastal squeeze on saltmarsh communities as they block expansion above the high-water mark. Urban development and infilling, as well as agricultural grazing, are responsible for the other half of the saltmarsh area loss since 1955 (Queensland Government, 2024; Laegdsgaard, 2006; New South Wales Government, 2008a, b; Lovelock *et al.*, 2019). Altered tidal flows from artificial structures like seawalls and stormwater discharge also pose threats to saltmarsh communities by changing hydrological flows, salinity regimes and increasing nutrient levels (New South Wales Government, 2008a).

5.4.4 Value

Ecological value

Despite the threats, saltmarshes remain important habitats that support a wide range of vertebrate and invertebrate species, including migratory birds, crabs, and molluscs (Saintilan and Rogers, 2013; Lovelock *et al.*, 2019). They support crab larvae in abundance and a diverse macrofauna and meiofauna, which serve as a trophic base for transient nektonic predators (fish and prawns) during high tide (Lovelock *et al.*, 2019).

Conspicuous invertebrates like crustaceans and molluscs (e.g. the gastropod, *Phallomedusa solida, previously Salinator Phallomedusa*) dominate the epibenthic macrofauna in saltmarshes (Laegdsgaard, 2006). These invertebrates and meiofauna (nematodes, harpacticoid copepods) form a crucial resource for the foraging species that visit during high tide (Lovelock *et al.*, 2019).

Saltmarshes also provide unique feeding and habitat opportunities for several threatened or vulnerable species of mammals and birds, including microbats, the Water mouse (*Xeromys myoides*) and migratory shorebirds. The Water mouse and migratory shorebirds use saltmarshes as important nesting habitats (Saintilan and Rogers, 2013; Traill *et al.,* 2011) and are particularly vulnerable to saltmarsh loss.

Saltmarshes also enhance water quality by acting as filters for pollutants, nutrients, and sediments (Lovelock *et al.*, 2019). They are important sites for nitrogen retention in soils and plant biomass and for denitrification, where nitrogen in water and soil is converted to nitrogen gas (Lovelock *et al.*, 2019). They also show the capacity to retain a significant percentage of nitrates, soluble phosphorus, and ammonium from tidal water (Lovelock *et al.*, 2019).

Figure 8. Saltmarsh communities in Moreton Bay. Photo credit. V. Bennion.

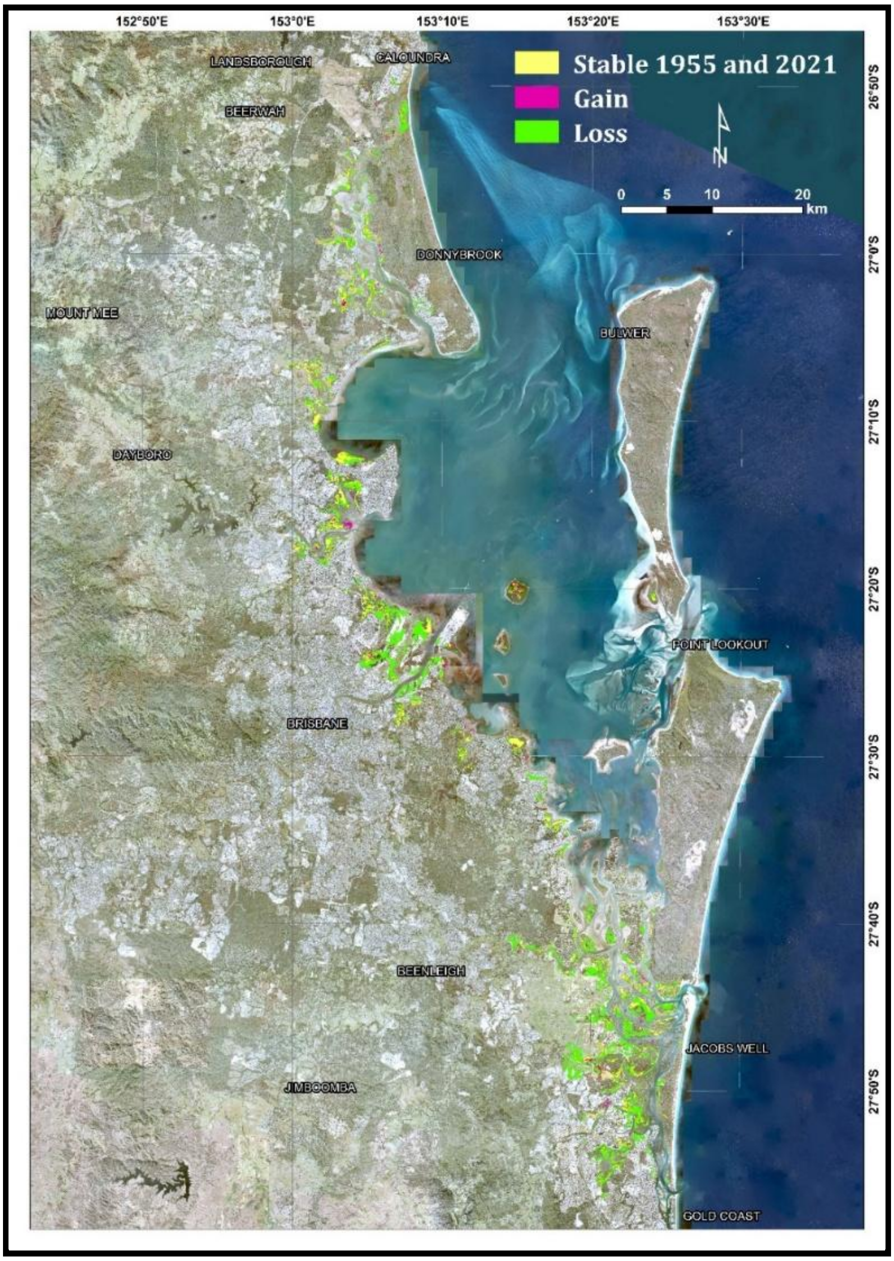


Figure 9. Changes in saltmarsh extend between 1955 and 2021 within Moreton Bay. Taken from Accad et al. (2023).

Cultural value

Overall, Moreton Bay's saltmarshes provide important cultural benefits and contribute to the well-being of coastal inhabitants. They hold significant cultural value, particularly for the Quandamooka People, the Traditional Custodians of the region, who have nurtured these lands and seas for over 50,000 years (Dean *et al.*, 2019; Fischer *et al.*, 2019; Adams *et al.*, 2024). This cultural importance is rooted in a deep, multi-millennial connection to the land and sea, fostering a custodial ethic where environmental management is a customary responsibility (Fischer *et al.*, 2019; Nasplezes *et al.*, 2019).

Saltmarshes are integral to cultural identity, heritage, and well-being, with places holding symbolic meanings, often reflected in Aboriginal place names or archaeological sites like middens and fish traps, which are tangible expressions of their connection to Country (Pinner *et al*., 2019; Lovelock *et al*., 2019; Beeston *et al*., 2023).

Economic value

As noted above (see Ecological value section), saltmarshes support a wide range of vertebrate and invertebrate species that are important food sources for fish and invertebrates, including commercially valuable species like whiting and mullet, and the Giant mud crab (*Scylla serrata*) (Saintilan and Rogers, 2013; Kovacs *et al*., 2019; Lovelock *et al*., 2019).

These wetlands are also important for carbon sequestration, with average rates of 9 g C m^{-2} $year^{-1}$ for *Sarcocornia quinqueflora*-dominated marshes and notably higher rates of 207 g C m^{-2} $year^{-1}$ for *Juncus kraussii* marshes, comparable to some of the highest global rates (Lovelock *et al*., 2014, 2019).

Saltmarshes contribute to coastal protection against flooding and erosion by buffering storm waves and stabilising sediments (Lovelock *et al*., 2019; Pannozzo *et al*., 2023). Like mangroves, they also contribute to climate change mitigation and offer potential for income through carbon markets (Lovelock *et al.,* 2019; Beeston *et al*., 2023).

5.4.5 History

Saltmarsh communities in Moreton Bay have undergone significant historical changes, primarily characterised by substantial decline since European settlement.

In the latter Holocene (last 2000 years), saltmarshes in Australia increased in extent relative to mangroves (Saintilan and Rogers, 2013). Paleoenvironmental studies indicate that in northern Australian macrotidal estuaries, the process of estuarine infilling led to the replacement of mangroves by saltmarsh and salt flats (Woodroffe *et al*., 2016).

Since European colonisation, mangroves and saltmarshes in Moreton Bay have been highly modified indirectly by land-use changes in the catchment and conversion to other uses, reversing the earlier trend of saltmarsh expansion (Saintilan and Rogers, 2013; Lovelock *et al.,* 2019). Increased sediment supply from land-use changes has driven a major transition in the Bay, primarily from sandy habitats to more mud-dominated ones, particularly in the western Bay (Grinham *et al*., 2024), which can alter species composition and ecosystem functioning (Lovelock *et al.,* 2019) (see Impacts of Sedimentation section below). As noted previously, between 1955 and 2021, the total saltmarsh area in Moreton Bay experienced a net loss of 70.4%, with only 2,345 hectares remaining stable (Queensland Government, 2024).

Mangrove encroachment enhanced by high sedimentation rates accounted for almost half of this saltmarsh loss (see Population status section above). This encroachment is consistent with rising sea levels, which increase the frequency of inundation in the high intertidal zone, favouring mangrove establishment and growth (see Impacts of sedimentation section below) (Lovelock *et al.,* 2019).

Anthropogenic activities were also responsible for almost half of saltmarsh losses, largely due to urban development and grazing (Kovacs *et al.*, 2019; Lovelock *et al.,* 2019). Historical reclamation for agricultural, industrial, port, and residential purposes led to significant losses in saltmarsh area (Lovelock *et al.,* 2019).

Any observed small gains in saltmarsh area typically resulted from mangrove dieback or saltmarsh colonising *Melaleuca* or *Eucalyptus* patches where inundation patterns had changed (Queensland Government, 2024; Kovacs *et al.,* 2019).

Despite protection measures, saltmarshes continue to be lost, and large-scale restoration efforts have been limited (Lovelock *et al.,* 2019). The expansion of landward development also restricts opportunities for saltmarshes to migrate inland in response to sea-level rise (Lovelock *et al.,* 2019).

5.4.6 Impacts of sedimentation

Saltmarshes are important habitats that support a wide range of vertebrate and invertebrate species, including migratory birds, crabs, and molluscs (see Ecological value section above). They also provide crucial ecosystem services, such as coastal protection (Lovelock *et al*., 2019). Of considerable concern is that saltmarsh losses can diminish feeding and roosting sites for migratory shorebirds, some of which are critically endangered (Lovelock *et al*., 2019). Figure 10 provides a conceptual model of the key impacts of sedimentation on saltmarshes in Moreton Bay.

Saltmarshes rely on sediment supply for vertical accretion and lateral expansion, which is crucial for them to keep pace with rising sea levels and prevent drowning (Bennion *et al.,* 2024a; Pannozzo *et al*., 2023). A high density of saltmarsh plant material enhances the trapping and binding of mineral sediments delivered by tidal water. This process supports the accumulation of plant material that increases surface elevation (Bennion *et al*., 2024a).

However, since European settlement, Moreton Bay's saltmarshes have experienced dramatic increases in sediment loads, largely due to land clearing in the catchment (Kemp *et al.,* 2019; Lovelock *et al.,* 2019; Saeck *et al.,* 2019b). An increased supply of sediment to the coast has led to higher rates of sediment accretion in intertidal habitats (Lovelock *et al.,* 2019). For example, in the western Bay, Bennion *et al*., (2024a) describe an increase in sedimentation in saltmarsh from 1 mm y^{-1} in 2008 to 1.7 mm y^{-1} in 2024.

Mangroves are known for their ability to enhance sediment deposition through their above-ground root systems and stems, which in turn promotes their growth and expansion (Adame *et al*., 2010). This process provides new substrata suitable for mangrove establishment (Kelleway and Williams, 2008). As mangroves expand, they colonise areas previously occupied by saltmarsh, leading to a direct displacement of these communities (see Population status section above) (Kovacs *et al*., 2019).

This encroachment is also consistent with the expected impacts of rising sea levels, where increased inundation frequency in the high intertidal zone aids the movement of mangrove propagules and creates more favourable conditions for mangrove growth in these higher areas (Lovelock *et al.,* 2019).

Excessive sediment deposition can directly smother saltmarsh plants, leading to minimal or slow recovery (McAtee *et al*., 2020). It also negatively impacts invertebrate communities, reducing their abundance and diversity. Infaunal invertebrates may shift from saltmarsh-associated groups to more terrestrial and mobile species (Ellis *et al*., 2004; McAtee *et al*., 2020).

High mud content from increased fine sediment can lead to reduced water clarity and light availability in the water column, limiting benthic productivity and potentially shifting it towards pelagic productivity (Lockington *et al.,* 2017; Saeck *et al.,* 2019b).

5.4.7 Recommendations

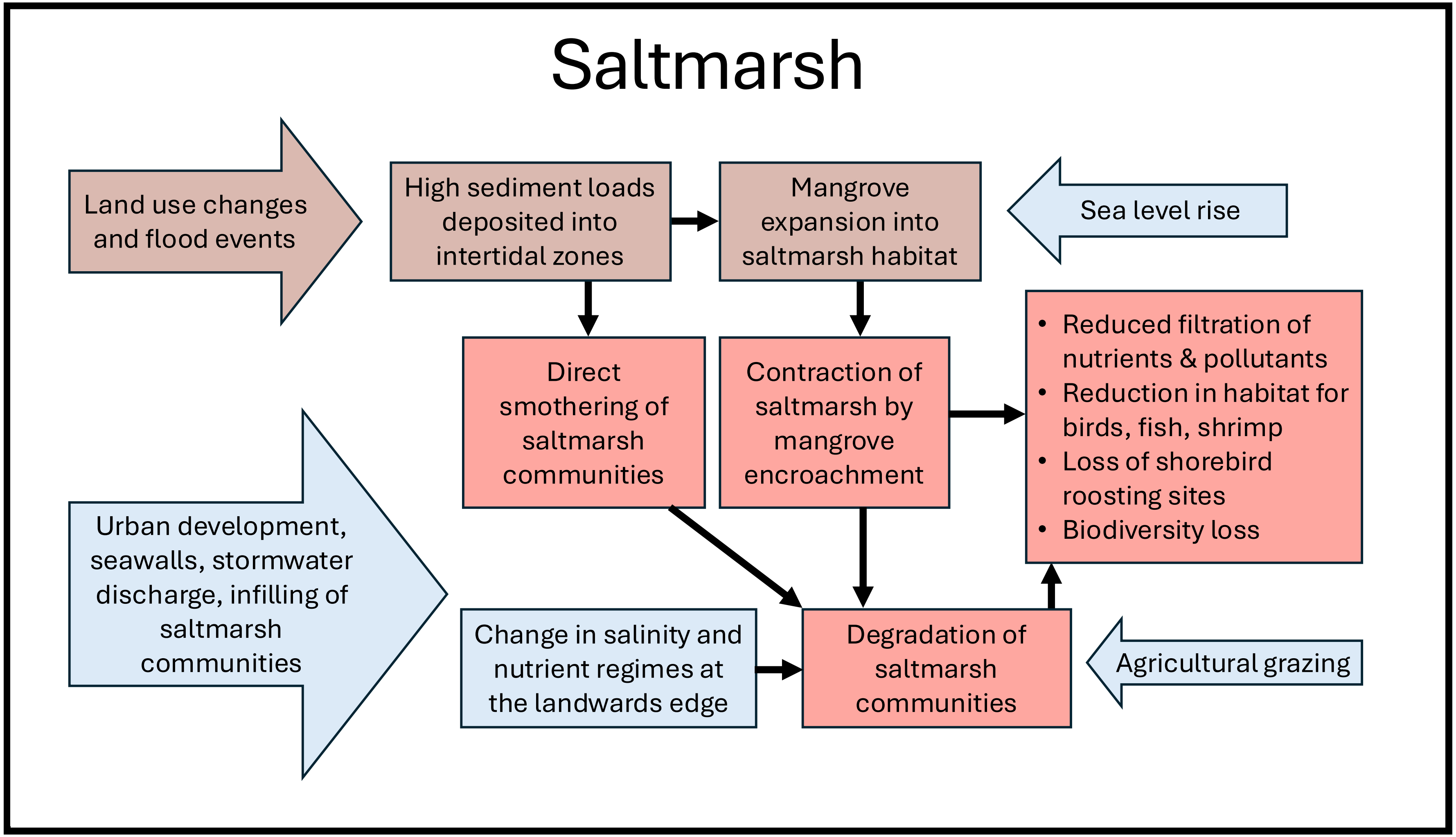
1. Control sediment sources to reduce sediment loads from catchments, through actions like restoring regional stream channel networks and revegetating riparian zones (Leigh *et al*., 2013; Grinham *et al*., 2024). Managing stormwater discharge is also important to limit the introduction of silt and nutrients (New South Wales Government 2008a, b).
2. Restore natural hydrological patterns to improve water flow and tidal exchange and promote a more balanced sediment movement within the ecosystem (Beeston *et al*., 2023). Maintaining appropriate tidal flushing is also vital, though continuous inundation can cause dieback and potentially encourage mangrove encroachment (New South Wales Government 2008a; Laegdsgaard, 2006).
3. Implement strong legislative habitat protection and planning measures to allow for the landward migration of saltmarshes. This includes establishing buffer zones and preventing development that blocks their movement (Kelleway and Williams, 2008; Saintilan and Rogers, 2013; Lovelock *et al*., 2019; Jinks *et al*., 2020). Maintaining or increasing saltmarsh plant cover can also enhance sediment trapping (Bennion *et al*., 2024a).
4. Minimise disturbance by controlling human access to prevent physical damage like trampling and wheel ruts. These impacts alter the topography and lead to issues such as mangrove incursion (New South Wales Government, 2008a, b; Kelleway and Williams, 2008).
5. Implement continuous monitoring and adaptive management of restoration projects, as impacts can vary based on the depth and composition of applied sediment (New South Wales Government, 2008a; McAtee *et al*., 2020).

5.4.8 Expert review

Vicki Bennion (School of the Environment, University of Queensland) kindly provided an expert review of the Saltmarsh: Sedimentation Impact Statement.

5.4.9 Conceptual model - Impacts of sedimentation on saltmarshes

Figure 10. Conceptual model that qualitatively describes the major impacts of sedimentation on saltmarsh communities in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes.



5.5 Phytoplankton: Sedimentation Impact Statement

Phytoplankton species Skeletonema costatum Photo credit: E. Saeck

5.5.1 Status and trend summary

The Bay's phytoplankton community appears resilient, reflecting a system that has improved due to management interventions aimed at reducing nutrient inputs. However, nutrient loads, particularly nitrogen, have remained unchanged in the Bay since approximately 2000. Table 13 provides a qualitative assessment of the phytoplankton communities in Moreton Bay, highlighting their current condition, future trajectory and the impacts of sedimentation.

Persistent, chronic pressure from catchment-derived sediment and nutrients has posed an ongoing threat, including recent increases in the relative abundance of bloom-forming marine diatoms, cyanobacteria and dinoflagellates. The current condition of the Bay's phytoplankton is rated as 'Fair' with 'Moderate' confidence.

The trend in phytoplankton condition in the Bay is assessed as 'Stable', with 'Medium' confidence, despite some observed resilience of the phytoplankton community to past nutrient management interventions. The rating is based on the lack of recent progress in nutrient load management, a similar lack of progress in land clearing and catchment erosion, the ongoing expansion of muddy sediments, and continued human population growth in the Moreton Bay catchment.

The impact of sedimentation on both the current condition and trend of phytoplankton in Moreton Bay is considered 'Moderate' with 'Medium' confidence.

Table 13. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for phytoplankton populations in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Fair	Medium
Contribution of sedimentation to the current condition	Moderate	Medium
Condition trend	Stable	Medium
Contribution of sedimentation to trend	Moderate	Medium

5.5.2 Overview

Phytoplankton are critical for primary productivity, water quality, habitat condition and biodiversity in Moreton Bay (Saeck *et al.*, 2019a), contributing an estimated 74% of the Bay's total primary productivity (Saeck *et al.*, 2019b).

The Moreton Bay phytoplankton community is generally typical of a temperate shallow coastal water (neritic) assemblage, dominated by chain-forming diatoms. It also contains a low proportion of nano- and picoplankton (Saeck *et al.*, 2019b). Spatial variation exists in the Bay phytoplankton, with a relatively higher abundance of oceanic and dinoflagellate species in the northern regions compared to the south (Saeck *et al.*, 2019b).

Moreton Bay has overall low areal phytoplankton productivity due to light and nitrogen limitation during summer and temperature limitation during winter (O'Mara *et al.*, 2019). The Bay is oligotrophic (low nutrients, low productivity) for most of the year with acute nutrient pulses delivered by high rainfall events that stimulate productivity peaks (Saeck *et al.*, 2019b). These nutrient pulses drive phytoplankton growth and shifts in species composition (Saeck *et al.*, 2019b).

A west to east gradient of phytoplankton standing stocks across the Bay reflects the influence of river discharges (Saeck *et al.*, 2019b), with higher chlorophyll *a* concentrations found in the western and southern regions of the Bay (2.20 ± 0.7 μg L^{-1} and 2.36 ± 0.8 μg L^{-1}, respectively), where riverine influence is significant (Saeck *et al.*, 2019b). The eastern Bay exhibits lower chlorophyll *a* levels (0.87 ± 0.28 μg L^{-1}) due to minimal river discharge influence and stronger oceanic flushing (Saeck *et al.*, 2019b).

5.5.3 Population status

Overall, the Bay's phytoplankton community appears resilient and reflects a relatively healthy system that has improved due to management interventions (Saeck *et al.*, 2019b). However, persistent, chronic pressure from catchment-derived sediment and nutrients poses an ongoing threat, continuing to fuel algal growth, as observed following the 2022 floods (Saeck *et al.*, 2019b). Such conditions cause unnaturally high productivity of phytoplankton which can often manifest as algal blooms and shifts in community composition (Lockington *et al.*, 2017; Huang *et al.*, 2024).

While some areas show improved water quality and algae indicators, others have experienced declines (Healthy Land & Water, 2023). Between 2022 and 2023 chlorophyll *a* declined from 'Excellent' to 'Very good' condition in the Bay overall (Healthy Land & Water, 2023). However, in the eastern Bay, the decline was more severe, from 'Excellent' to 'Poor' condition (Healthy Land & Water, 2023).

The increased delivery of nitrogen, fine sediments, and pollutants from land-use changes continues to occur in the bay. This has impacted the photosynthetic community, leading to persistent phytoplankton blooms and shifts in phytoplankton community composition (Coates-Marnane *et al.*, 2020). In extreme cases, this leads to an increase in bloom-forming marine diatoms (including harmful algal blooms), hypoxic dead zones and a decline in dominant benthic diatoms (Saeck *et al.*, 2019b; Coates-Marnane *et al.*, 2020).

5.5.4 Value

Ecological value

Phytoplankton are critical to Moreton Bay's ecosystem productivity, and as primary producers, they form the base of the Bay's food web, converting available nutrients into the fundamental energy source for the entire aquatic community, supporting most higher trophic levels (Saeck *et al.*, 2019b; Huang *et al.*, 2024). This process is also vital for maintaining good water quality for Bay ecosystems (Saeck *et al.*, 2019b).

Phytoplankton produce around 50% of the world's oxygen through photosynthesis and hence play a vital role in regulating climate by influencing oceanic and atmospheric processes; a process which also contributes significantly to carbon cycling by absorbing carbon dioxide (Saeck *et al.*, 2019b). The dissolved oxygen produced by phytoplankton is also critical for other trophic levels in the Bay ecosystems (J. Lu, pers. comm.)

Cultural value

The Quandamooka people do not have the same overt cultural connections with phytoplankton as they do for many marine species which are often named, for example, in the context of Aboriginal place names and symbolic associations (Pinner *et al.*, 2019). The cultural significance of phytoplankton should be viewed with an emphasis on a holistic view of culture and the indivisibility of people and country, and encompassing interests in ecosystem health, biodiversity, resources, and ancestral connections (Pinner *et al.,* 2019).

This value can be seen, for example, through phytoplankton's role as the base of the marine food web (Huang *et al.*, 2024), supporting larger consumers such as fish, marine mammals, jellyfish, and sea turtles; many of which do have highly significant cultural connection with the Quandamooka people. Phytoplankton are also fundamental to the Bay's water quality and habitat condition, contributing to the overall health that sustains life and traditional resources like fish and oysters. This same importance can be inferred for the other critical roles that phytoplankton play in supporting the marine ecosystem, including in nutrient cycling, supporting secondary production and in transferring energy and nutrients between the seafloor and the water column.

Economic value

Phytoplankton in Moreton Bay are crucial to the region's economy due to their foundational role in the marine food web (Saeck *et al.*, 2019b). They provide the essential food source for higher trophic levels, including fish, crabs, and oysters, which are used for both commercial purposes and recreational enjoyment (Jones *et al.*, 2011). Moreton Bay's commercial fisheries are valued at approximately $24 million per annum, while the recreational fishing sector generates around $194 million per (Thurstan *et al.*, 2019), most of which are also underpinned by phytoplankton.

The overall health and productivity of the Moreton Bay ecosystem, which is critically supported by phytoplankton, also underpins other crucial economic activities like tourism and aquaculture operations (Lockington *et al*., 2017).

5.5.5 History

Historically, sewage discharges were a significant driver of phytoplankton growth, leading to elevated nitrogen and chlorophyll *a* in western Moreton Bay, particularly Bramble Bay, before 2000 (Saeck *et al*., 2019b). Investment in sewage treatment plant upgrades successfully reduced chronic nitrogen loads and subsequently lowered mean monthly chlorophyll *a* concentrations (Saeck *et al*., 2019b).

In the late 20th century (prior to 2000) the western region of Moreton Bay, particularly Bramble Bay, experienced elevated nitrogen concentrations and high phytoplankton biomass due to sewage discharge, indicating symptoms of eutrophication (Coates-Marnane *et al*., 2020). Major investments in the early 2000s to reduce nitrogen loads from sewage treatment plants by approximately 70% led to observed declines in annual mean phytoplankton biomass (Saeck *et al*., 2019b; Coates-Marnane *et al*., 2020). This reduction in chronic nutrient loads appears to have improved the Bay's resilience to large, episodic nutrient loading events from floods, with phytoplankton blooms following the 2011 floods being much shorter-lived than those in 1996 (Saeck *et al*., 2019b).

Despite these improvements, nitrogen concentrations have not decreased substantially across the Bay since the early 2000s, and may even be increasing in some areas, potentially due to substantial nitrogen recycling processes within the Bay and nutrients released from previously-deposited catchment sediments (Saeck *et al*., 2019a).

Moreton Bay's phytoplankton community appears resilient to both long-term and short-term changes in nutrient inputs, with no evidence of permanent state shifts observed to date (Saeck *et al*., 2019b). Shifts in community composition in response to acute nutrient inputs from large episodic rainfall events are typically temporary, with communities returning to baseline conditions within approximately two weeks (Saeck *et al*., 2019b).

5.5.6 Impacts of sedimentation

The impacts of sedimentation on phytoplankton communities in Moreton Bay are broadly described in the conceptual model (see Figure 11). Sedimentation acts as a double-edged sword for phytoplankton. While sedimentation can reduce access to sunlight for photosynthesis and energy production, it also provides nutrients for consumption and a rich diet. This leads to a complex and often problematic overabundance of these microscopic organisms that can impact the broader ecosystem health of Moreton Bay (Leigh *et* al., 2013; Lockington *et al*., 2017; Coates-Marnane *et al*., 2020; Saeck *et al*., 2019b). These phytoplankton blooms can occur almost immediately (within days or weeks) of a flood event (O'Mara *et al*., 2019; Saeck *et al*., 2019b; Huang *et al*., 2024).

Fine sediments and mud entering the Bay significantly increase water turbidity and reduce water clarity (Coates-Marnane *et al.*, 2020). The resuspension of these sediments directly affects light availability, which can limit phytoplankton productivity (Lockington *et al.*, 2017; Saeck *et al.*, 2019b; Grinham *et al.*, 2024).

Despite the turbidity, deposited sediments (particularly those from floods) also act as a significant source of bioavailable nutrients, especially nitrogen and ammonium (Huang *et al.*, 2024). Organic compounds from soil erosion are particularly bioavailable to microbes, which then release more nutrients. In marine waters, salinity can rapidly enhance the release of adsorbed nutrients, further fueling algal growth (Huang *et al.*, 2024; Lu *et al.*, 2025). These nutrients have also led to an increase in bloom-forming marine diatoms and a decline in the dominance of other diatoms since the mid-20th century (Coates-Marnane *et al.*, 2020). In some cases, the enhanced nutrient availability from resuspension can lead to increased phytoplankton biomass despite the elevated turbidity (Jin *et al.*, 2022).

The decomposition by microbes of the increased organic matter from the sediment and stimulated algal growth consumes dissolved oxygen, leading to deoxygenation, which harms the broader aquatic ecosystem (Lu *et al.*, 2025).

The combined effect of reduced light and smothering of the benthos by fine sediments can also cause a shift from benthic to pelagic (water column/phytoplankton) dominance in primary production, with increased water column nutrient flux perpetuating these conditions (Lockington *et al.*, 2017; Saeck *et al.*, 2019b).

The impacts of sedimentation on phytoplankton in Moreton Bay appear to be increasing and posing a greater threat to the ecosystem's health, despite some observed resilience of the phytoplankton community to past nutrient management interventions (Saeck *et al.*, 2019b). This is based on:

- the dramatic increase in sediment export from its catchments since European settlement, with current rates estimated to be approximately 100 times greater than pre-settlement levels due to land clearing and erosion (Saeck *et al.*, 2019a)
- muddy sediments more than doubled their coverage since 1970 (Lockington *et al.*, 2017) and have continued to expand since 1998 (Healthy Land & Water, 2023)
- nitrogen concentrations have not decreased substantially across the Bay since the early 2000s, and may even be increasing in some areas (Saeck *et al.*, 2019a)
- the limited success in reducing the sediment load entering Moreton Bay (Saeck *et al.*, 2019a).

Continued population growth and urban expansion are predicted to place Moreton Bay under more pressure from sediment and nutrient additions (Saeck *et al.*, 2019a). As catchments remain degraded, nutrient loads and sediment infilling will continue to increase, which will progressively impact biogeochemical processes and primary producers in the Bay (Saeck *et al.*, 2019b).

5.5.7 Recommendations

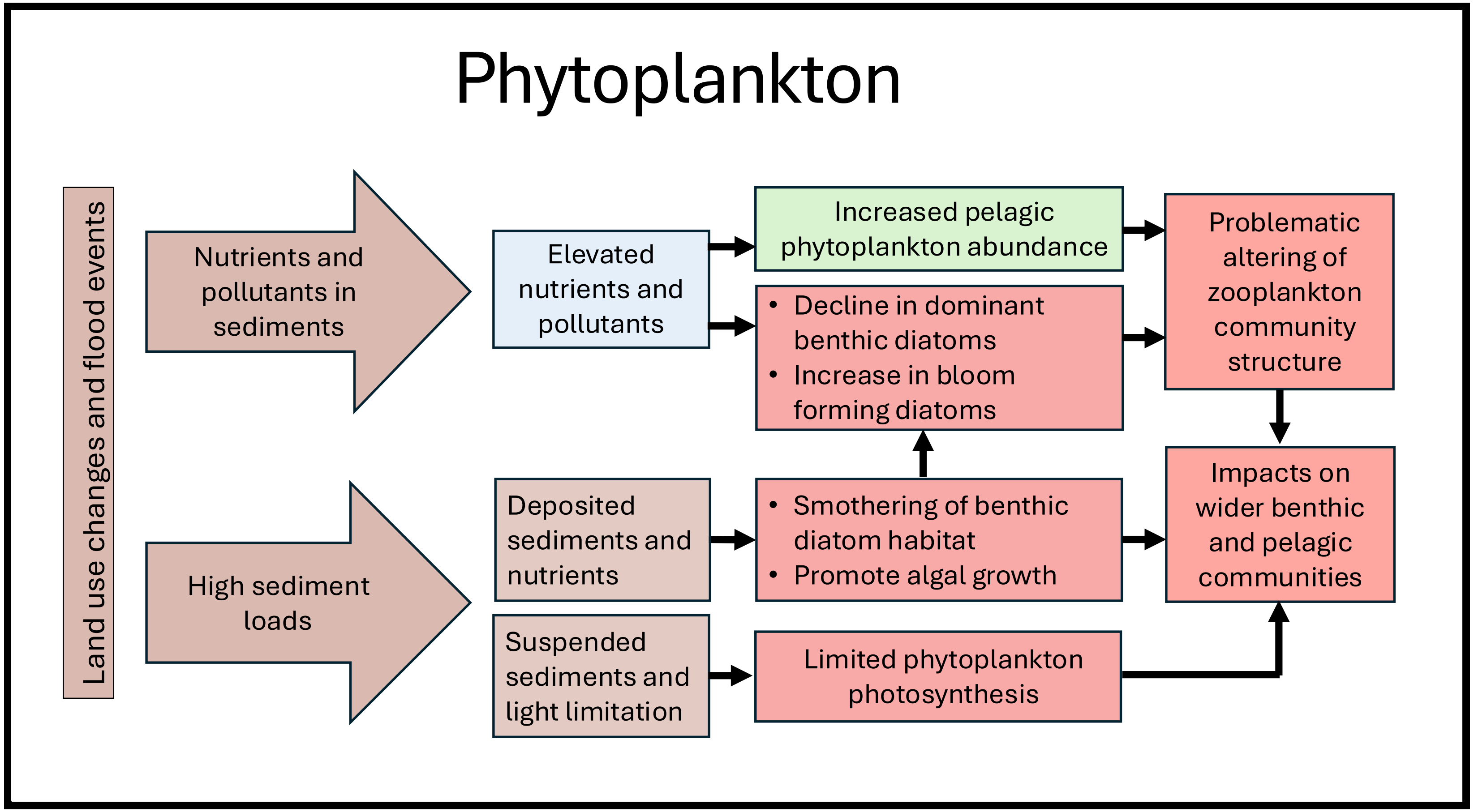
1. Urgently reduce the overall diffuse sediment loads entering Moreton Bay from its catchments (Leigh *et al*., 2013; Saeck *et al*., 2019a,b).
2. Invest in catchment conservation and restoration, including:
    - Rehabilitate degraded stream networks and upper catchments (Leigh *et al*., 2013; Saeck *et al*., 2019a,b; Grinham *et al*., 2024; Lu *et al*., 2024)
    - Protect and enhance streambank (riparian) vegetation (Leigh *et al*., 2013; Saeck *et al*., 2019a; Lu *et al*., 2024)
    - Address channel and gully erosion, which are major sediment loading pathways (Leigh *et al*., 2013; Lockington *et al*., 2017)
    - Support sustainable and regenerative agricultural practices to improve soil health and reduce pollutant runoff (Healthy Land & Water, 2023)
    - Protect and enhance wetlands and floodplain ecosystems, as they provide vital services such as sediment and nutrient retention (Healthy Land & Water, 2023).
3. Implement improved erosion and sediment controls, particularly for land development activities. This includes focusing on engagement and compliance within industries with high soil disturbance, such as agriculture and development (Healthy Land & Water, 2023).
4. Implement innovative stormwater management practices in new developments to reduce sediment and nutrient runoff (Healthy Land & Water, 2023; Saeck *et al*., 2019a).
5. Enhance nitrogen management. While sedimentation is often a physical process affecting light, the sediment itself carries and releases nutrients, particularly nitrogen, that fuel phytoplankton growth in Moreton Bay (Grinham *et al*., 2024; Saeck *et al*., 2019a; Huang *et al*., 2024).
6. Improve monitoring for a broader suite of parameters, including organic forms of nutrients and carbon, to understand their impact on algal growth responses and refine water quality models (Lu *et al*., 2024).

5.5.8 Expert review

Dr Jing Lu (Research Fellow, Australian Rivers Institute, Griffith University) kindly provided an expert review of the Phytoplankton: Sedimentation Impact Statement.

5.5.9 Conceptual model - impacts of sedimentation on phytoplankton

Figure 11. Conceptual model that qualitatively describes the impacts of sedimentation on phytoplankton communities in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes; green boxes indicate likely positive or neutral impacts/outcomes.



5.6 Zooplankton: Sedimentation Impact Statement

Moreton Bay zooplankton
Photo credit: J. Uribe-Palomino

5.6.1 Status and trend summary

Table 14 provides a qualitative assessment of the zooplankton communities in Moreton Bay, highlighting their current condition, future trajectory and the impacts of sedimentation. The overall current condition of zooplankton in the Bay is rated as 'Variable', with 'Low' confidence. This reflects a lack of information for the status of zooplankton populations, combined with the more variable nature of their population dynamics. In the Bay, observations of lower copepod biomass despite higher abundances are typical of high nutrient (eutrophic) conditions.

Increased suspended sediment loads into the Bay bring chronic light limitation for photosynthetic phytoplankton (a major food source for many zooplankton) and carry highly available nutrients from catchment soils. Nutrient loads, particularly nitrogen, have not improved in the Bay since about 2000. Zooplankton are impacted indirectly by suspended sediment and nutrient loads due to their complex impacts on phytoplankton populations.

The increase in mud content in the Bay also has important ramifications for zooplankton. Mud deposition on the sea floor can smother habitats, affecting the emergence of some species of zooplankton from substrates, particularly demersal zooplankton that associate with the seafloor during the day. This smothering can also adversely impact primary producers, including benthic microalgae, which serve as another food source for zooplankton.

The trend in zooplankton condition in the Bay is assessed as 'Declining', with 'Medium' confidence. The impact of sedimentation on both the current condition and trend of zooplankton in Moreton Bay is considered 'Moderate' with 'Medium' confidence.

Table 14. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for zooplankton in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Variable	Low
Contribution of sedimentation to the current condition	Moderate	Medium
Condition trend	Declining	Medium
Contribution of sedimentation to trend	Moderate	Medium

5.6.2 Overview

Zooplankton are floating, or weakly swimming, aquatic animals that drift with water currents and range from microscopic organisms to large species, such as jellyfish. They are mainly heterotrophic and usually consume phytoplankton and/or other zooplankton. Zooplankton are important nutrient cyclers and a critical link between primary producers and higher trophic levels in marine and coastal ecosystems (Pausina *et al.,* 2019). Arguably, the most important role of zooplankton is as the major grazer in food webs, providing the principal pathway for energy from primary producers (the phytoplankton) to larger consumers such as fish, marine mammals, jellyfish and sea turtles (Jacoby and Greenwood, 1989; Pausina *et al.,* 2019).

Copepods, a group of small crustaceans generally around 1 to 2 mm in length, dominate the zooplankton fauna in Moreton Bay, accounting for 74% of the permanent members (Pausina *et al.,* 2019). The copepod community is consistently dominated by calanoids, averaging 76% of total copepods (Greenwood, 1980; Pausina *et al.,* 2019). Other numerous holoplanktonic groups (or organisms that spend their entire life cycle in the water column) include appendicularians (larvaceans), cladocerans, chaetognaths (arrow worms), and cnidarians (Greenwood, 1980; Pausina *et al.,* 2019). The dominant large zooplankton species is the jellyfish, *Catostylus mosaicus,* that swarms periodically, and its large biomass at times contributes significantly to nutrient cycling (Gershwin *et al*., 2010; Pausina *et al*., 2019). This species is one of numerous other species of Scyphozoa (jellyfish) recorded in the Bay (*Gershwin et al*., 2010).

5.6.3 Population status

Moreton Bay is a shallow, subtropical embayment, and its zooplankton populations exhibit specific characteristics and dynamics influenced by both natural processes and anthropogenic impacts (Jacoby and Greenwood, 1989; Pausina *et al*., 2019).

Assessing the population status of zooplankton is not straightforward due to their high variability in space and time and the lack of direct monitoring compared to larger species groups and species of higher interest to stakeholder groups. One exception is the Blue blubber jellyfish, *C. mosaicus,* which has been shown to have seasonal and long-term cycles of abundance (Pitt *et al*., in prep.). These include blooms of abundance that have been recorded for at least 150 years. Impacts have included disrupting shipping in the 1800s and clogging power station water intakes in the 1930s (K. Pitt, pers. comm.).

Copepods are typical of a range of smaller zooplankton in the Bay and are generally smaller than copepods found in oceanic waters, which contributes to a lower biomass despite higher abundances in the Bay (Pausina *et al*., 2019). This is typical for zooplankton in coastal waters at lower latitudes (Pausina *et al*., 2019). However, high-nutrient (eutrophic) bays also commonly feature smaller zooplankton (Uye, 1994; Park and Marshal, 2000), suggesting that their populations may be impacted by human development and land-use changes (Saeck *et al*., 2019b).

The broader zooplankton community, which represents a wide range of species, is likely to have been impacted in different ways by a range of conditions. However, there is a recognised lack of reliable zooplankton population and biomass estimates and minimal validation for zooplankton components in water quality models, both generally and in the Bay (Pausina *et al*., 2019).

In summary, it appears as though zooplankton populations are impacted by factors such as high nutrient and sediment loads. However, their current status is difficult to ascertain without targeted monitoring programs.

5.6.4 Value

Ecological value

Zooplankton in Moreton Bay are critical to the ecosystem functioning of estuarine and coastal food webs (see Overview section above) (Pausina *et al*., 2019). Many larger consumers, such as fish, marine mammals, jellyfish, and sea turtles, are highly dependent on healthy zooplankton populations (Jacoby and Greenwood, 1989; Pausina *et al.,* 2019).

Zooplankton are also major grazers within the aquatic ecosystem, exerting selective pressure on phytoplankton community dynamics and influencing the fate of algal blooms (Stone and Steinberg, 2018; Pausina *et al*., 2019).

Zooplankton feeding, secretions, and excretions play a crucial role in nutrient cycling, supporting the production of microbes and phytoplankton (Condon *et al*., 2010; Pausina *et al*., 2019). This includes the assimilation of carbon and nutrients, and the release of nitrogenous wastes and dissolved organic carbon (Condon *et al*., 2010; Pausina *et al*., 2019). Demersal zooplankton, which dwell on or near the seafloor during the day and emerge into the water column at night, are important in transferring energy and nutrients between the seafloor and water column (Bishop and Greenwood 1994; Pausina *et al*. 2019).

Jellyfish, a significant component of Moreton Bay's zooplankton, host various organisms, including fish and copepods, thereby supporting pelagic biodiversity within the Bay (Carr and Pitt, 2008; Pausina *et al*., 2019). Periodic jellyfish swarms can play a major role in nutrient recycling through high predation levels on other zooplankton (Gershwin *et al*., 2010; Pausina *et al*., 2019).

Zooplankton can also serve as indicators of environmental changes such as sediment deposition, turbidity and nutrient enrichment (Pausina *et al*., 2019).

Cultural value

The Quandamooka people have cultural connections with zooplankton as demonstrated by their naming of jellyfish, for example, Birin (Yugumbeh), or Birihn (Bunjulung) (K. Pitt, pers. comm.). The cultural significance of zooplankton should also be viewed with an emphasis on a holistic view of culture and the indivisibility of people and country, encompassing interests in ecosystem health, biodiversity, resources, and ancestral connections (Pinner *et al.,* 2019).

This value can be seen, for example, through zooplankton's role as a critical link in marine food webs supporting larger consumers (see Ecological value section above) - many of which do have highly significant cultural connection with the Quandamooka people. This same importance can be inferred for the other critical roles that zooplankton play in supporting the marine ecosystem, including nutrient cycling, supporting microbial and phytoplankton production, and transferring energy and nutrients between the seafloor and the water column.

Economic value

Zooplankton in Moreton Bay are crucial to the region's economy due to their foundational role in the marine food web (see Ecological value section above) (Pausina *et al*., 2019). These food webs also support Moreton Bay's commercial fisheries, valued at approximately $24 million per annum and targeting species such as prawns, crabs, and various finfish, which rely on the food web underpinned by zooplankton (Thurstan *et al*., 2019). Similarly, the recreational fishing sector in Moreton Bay is generates around $194 million per annum in direct expenditure, with anglers targeting species like mud crabs, sand whiting, snapper, tailor, and bream (Thurstan *et al*., 2019); most of which are also underpinned by zooplankton.

Large zooplankton, such as the Blue blubber jellyfish (*Catostylus mosaicus*), can also have direct socio-economic effects, for instance, by causing disruptions to shipping activities when they form dense swarms (Pausina *et al*., 2019).

Ultimately, safeguarding zooplankton dynamics is crucial for protecting the broader ecological and economic resources of coastal areas, such as Moreton Bay (Pausina *et al*., 2019).

5.6.5 History

In the late 20th century (before 2000), the western region of Moreton Bay, particularly Bramble Bay, experienced elevated nitrogen concentrations and high phytoplankton biomass due to sewage discharge, indicating symptoms of eutrophication (Coates-Marnane *et al*., 2020). The repercussions for zooplankton included altering their community structure, abundance, and food quality, with cascading effects throughout the ecosystem (Pausina *et al*., 2019). Major investments in the early 2000s to reduce nitrogen loads from sewage treatment plants by approximately 70% led to observed declines in annual, mean phytoplankton biomass (Saeck *et al*., 2019b). This change impacted zooplankton populations, primarily by altering their food environment and community structure (Coates-Marnane *et al*., 2020).

This reduction in chronic nutrient loads appears to have improved the Bay's resilience to large, episodic nutrient loading events from floods, with phytoplankton blooms following the 2011 floods being much shorter-lived than those in 1996 (Saeck *et al*., 2019b). This reduction in overall phytoplankton biomass and the improved resilience to prolonged blooms likely led to an improvement in food quality for zooplankton and would likely create a shift in zooplankton community structure (Duggan *et al*., 2002; Özkundakci *et al*., 2020). However, the water quality model for Moreton Bay which predicts biomass changes in plankton has also had limited zooplankton validation (Herzfeld *et al.*, 2014; Pausina *et al.*, 2019).

Despite the historic improvements, nitrogen concentrations have not decreased substantially across the Bay since the early 2000s. They may even be increasing in some areas, potentially due to substantial nitrogen recycling processes within the Bay and the release of nutrients from previously deposited catchment sediments (Saeck *et al.*, 2019b).

5.6.6 Impacts of sedimentation

The impacts of sedimentation on zooplankton in Moreton Bay are broadly described in the conceptual model (see Figure 12, Figure 4). Land-use changes and floods in the catchment have dramatically increased sediment export into Moreton Bay (Coates-Marnane *et al.*, 2020; Grinham *et al.*, 2024). The increase in mud content has important, direct ramifications for zooplankton, particularly demersal zooplankton that associate with the seafloor during the day (Jacoby and Greenwood, 1989; Pausina *et al.*, 2019). Their emergence patterns are significantly influenced by the type of substratum, with higher emergence observed from structurally complex habitats, such as seagrass beds and coral reefs, compared to muddy habitats (Jacoby and Greenwood, 1989; Pausina *et al.*, 2019), which are increasing in the Bay (Grinham *et al.*, 2024).

However, the indirect impacts of high sediment loads also have major consequences for Moreton Bay ecosystems. Floods bring increased suspended sediment loads which lead to chronic light limitation, impacting phytoplankton photosynthesis. The sediments also act as a significant source of bioavailable nutrients, especially nitrogen and ammonium (Huang *et al.*, 2024; Lu *et al.*, 2025), which provides phytoplankton with a nutrient-rich diet. The combination of light limitation and high nutrients leads to a complex and often problematic alteration of the photosynthetic community, including a selective over-abundance of phytoplankton that can impact zooplankton and hence, broader ecosystem health (Leigh *et al.*, 2013; Lockington *et al.*, 2017; Saeck *et al.*, 2019b; Coates-Marnane *et al.*, 2020).

Increased sediment loads impact benthic microalgae, which are also a food source for zooplankton (Saeck *et al.*, 2019b). This has led to an increase in bloom-forming marine diatoms (a type of phytoplankton) and a decline in dominant benthic diatoms since the mid-20th century (Coates-Marnane *et al.*, 2020). These changes in phytoplankton community structure are likely to impact zooplankton populations that have evolved to depend on specific suites of phytoplankton for survival.

In addition to chronic catchment-based sedimentation, dredging operations in the Brisbane River estuary have also been found to lead to a significant decline in zooplankton abundances, although these may not have a substantial impact on their community composition or distribution (Greenwood *et al.*, 2002; Pausina *et al.*, 2019).

5.6.7 Recommendations

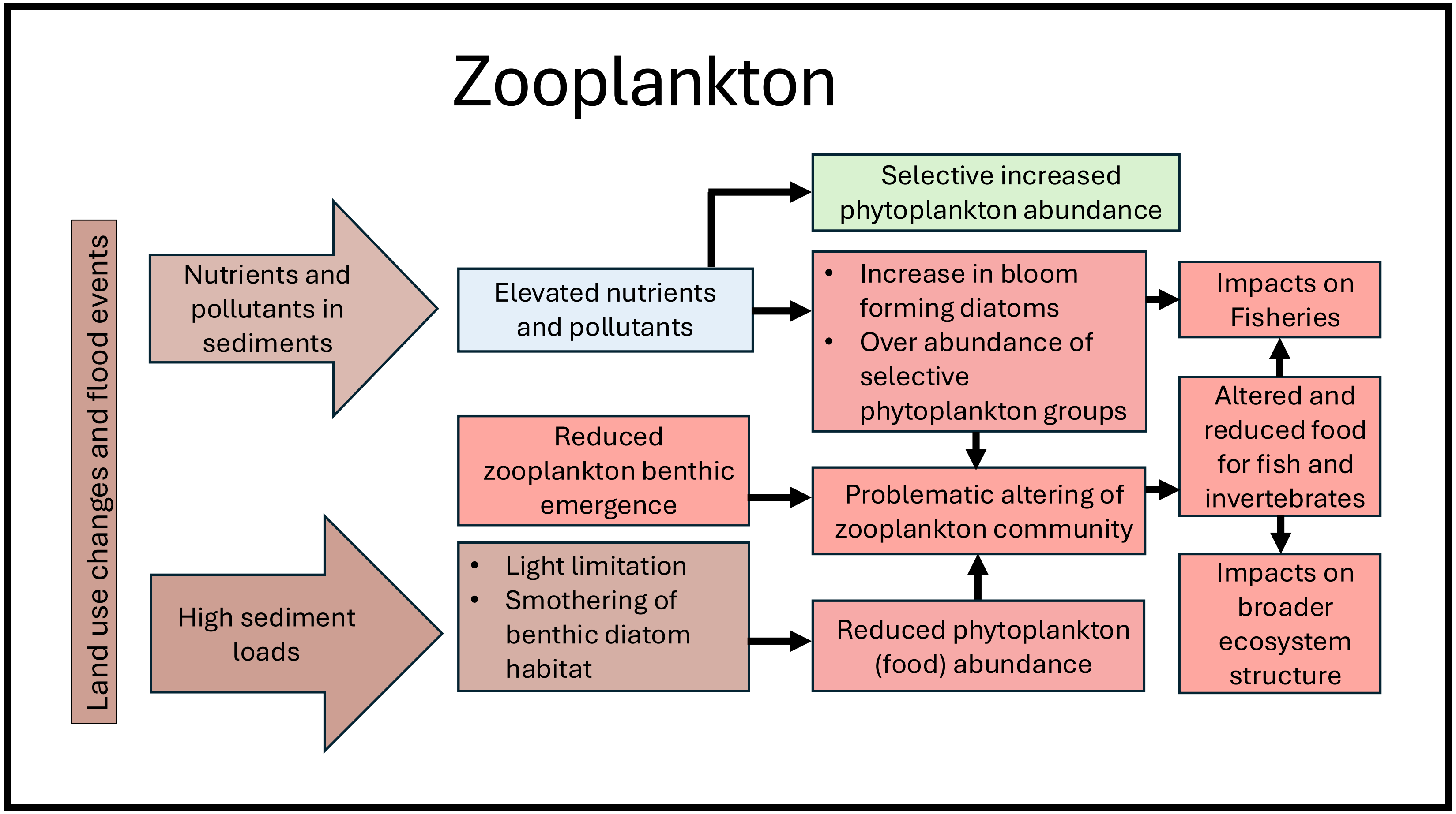
1. Increase research on the seasonality of zooplankton in relation to wet season freshwater inputs and nutrient loads, as current models suggest higher biomass during spring/summer, but this hasn't been field-tested after flood events (Pausina *et al*., 2019).
2. Sample smaller zooplankton, particularly microzooplankton, more thoroughly, as historical studies have likely underestimated their abundance and impact on phytoplankton (Pausina *et al*., 2019).
3. Consider using zooplankton as ideal ecosystem indicators for environmental change, eutrophication, pollution, and climate change. They are not currently included in monitoring programs, which tend to focus on physico-chemical parameters and phytoplankton biomass (Pausina *et al*., 2019).
4. Validate the zooplankton components in water quality models, like the Receiving Water Quality Model (RWQM). This is crucial to better understand Bay-wide zooplankton dynamics (Pausina *et al*., 2019).

5.6.8 Expert review

Professor Kylie Pitt (School of Environment and Science, Coastal and Marine Research Centre, Griffith University) kindly provided an expert review of the Zooplankton: Sedimentation Impact Statement.

5.6.9 Conceptual model - impacts of sedimentation on zooplankton

Figure 12. Conceptual model that qualitatively describes the major impacts of sedimentation on zooplankton communities in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes; green boxes indicate likely positive or neutral impacts/outcomes.



5.7 Benthic Macrofauna: Sedimentation Impact Statement

Seastar (Pentaceraster regulus) in Halophila spinulosa in Moreton Bay
Photo credit: C. Roelfsema

5.7.1 Status and trend summary

Table 15 provides a qualitative assessment of the subtidal benthic macrofaunal communities in Moreton Bay. The population status of these communities in Moreton Bay is complex and exhibits significant spatial and temporal variation, strongly influenced by habitat type and sediment characteristics. However, the Bay's highly diverse and species-rich benthic macrofaunal communities (referred to as macrofauna) have undergone significant changes, largely driven by trawling and sedimentation from the rapid growth of Greater Brisbane. In some areas, the cessation of trawling activities has led to increases in species richness and overall abundance. However, overall, the macrofaunal communities' current condition is rated as 'Poor' with 'Medium' confidence. The confidence rating is limited by a lack of monitoring and scientific knowledge.

The smothering of macrofaunal species during flood events and the subsequent resuspension of sediments are profoundly impacting large areas of their habitats, leading to lower diversity and abundance. Consequently, many of the Bay's macrofaunal communities are in decline and being replaced by more homogeneous, infaunal-dominated states, with reduced species richness. The main exceptions are the 'closed areas' of the marine park, where trawling was previously a key impacting process. These areas now show an increase in species richness and overall abundance. Many macrofaunal species in Moreton Bay are opportunistic and capable of rapid recolonisation after physical disturbances, such as dredging. However, the decreasing capacity of the Bay to effectively store fine sediment, and the relatively high frequency of recent flood events, suggest that future floods and sediment inputs will likely lead to increasingly turbid waters and persistent impacts to macrofaunal communities. Hence, the condition trend is considered 'Declining' with 'High' confidence. The contribution of sedimentation to the current condition and the condition trend is rated as 'Major'. This rating is also assigned a 'Medium' confidence for the same reason as above, namely, lack of monitoring and scientific data.

Table 15. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for subtidal macrofaunal communities in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Poor	Medium
Contribution of sedimentation to the current condition	Major	Medium
Condition trend	Declining	High
Contribution of sedimentation to trend	Major	Medium

5.7.2 Overview

The benthic macrofauna of Moreton Bay generally exhibits high species diversity and richness, including a large number of singleton or rare species (Stevens and Connolly 2005; Richardson *et al*., 2015). The high diversity is due to the Bay's position as a meeting point for faunal assemblages that reflect its subtropical location, supporting both tropical and subtropical taxa (Davie and Hooper, 1998; Stevens & Connolly, 2005; Fautin *et al*., 2008). However, declines in species richness have been consistently observed in epibenthic communities across much of Moreton Bay between 2002 and 2015 (Jackson, 2015; T. Stevens, pers. comm.).

A comprehensive survey of Moreton Bay's epibenthos (species living on the surface of the seafloor) for conservation planning purposes identified 114 morphospecies and categorised four bioturbation (sediment mixing) indicators (Stevens and Connolly, 2005). While many taxa were rare, five common taxa constituted over 61% of total standardised abundance (Stevens and Connolly, 2005) (Figure 13). Key groups and their distribution include bivalves (350 species within 155 genera and 55 families) (Healy and Potter, 2010), sea anemones (19 species) (Fautin *et al*., 2008), sessile invertebrates (e.g., cnidarians, sponges, bryozoans, tunicates) (Davie and Hooper, 1998), and infaunal and mobile epibenthic species (e.g., crustaceans, annelids, echinoderms) (Davie and Hooper, 1998).

The distribution of macrofaunal communities is strongly influenced by habitat type and sediment characteristics (Davie and Hooper, 1998; Ellis *et al*., 2017). Stevens and Connolly (2005) defined nine distinct benthic habitat types that have been classified based on their dominant faunal characteristics. 'Bioturbated mud' habitats are dominated by various bioturbators, with mostly small and (to a lesser extent) medium burrows (Stevens and Connolly, 2005). 'Bioturbated sparse' habitats are also dominated by bioturbators but distinguished by the presence of *Halophila ovalis* and high-density patches of cerianthid sand anemones (Stevens and Connolly, 2005).

'Rubble and sand' habitats feature low densities of mobile macroinvertebrates, such as echinoids, crinoids, bivalves, and occasionally sponges and soft corals, attached to rubbly substrates (Stevens and Connolly, 2005). 'High-density patches of cerianthid anemones uniquely characterise diverse sandy' areas and include seagrasses and echinoderms (Stevens and Connolly, 2005).

'Seagrass-dominated' areas are characterised by species such as *H. ovalis*, *H. spinulosa*, and *Zostera capricorni* (Stevens & Connolly, 2005). Seagrass communities are described separately in this report. 'Inshore algae and sponge' habitats are very diverse, dominated by algae and sponges, with significant contributions from solitary ascidians, anemones, and seagrass (Stevens & Connolly, 2005).

'Reefal habitats' are dominated by encrusting algae, soft corals, and sponges and include deep-water algal and soft coral reefs (Stevens & Connolly, 2005). Hard coral habitats are described separately in this report.

Generally, more taxa and individuals are found at deeper depths in the northern parts of Moreton Bay, possibly due to the greater stability of the substratum or finer sediment characteristics in those areas (Richardson *et al.*, 2015). The high-energy hydrodynamic conditions, including strong tidal currents and wave action, characterise northern Moreton Bay, selecting for species with adaptations for rapid locomotion and migration to deal with regular disturbance (Richardson *et al.*, 2015).

Periodic flood events, storms and cyclones (large-scale), along with tidally-induced sediment movement, are key natural physical drivers of community structure (Richardson *et al.*, 2015). Coastal development, reclamation, commercial fishing operations (especially trawling), and sand/gravel extraction activities are also significant human drivers of change to benthic habitats (Richardson *et al.*, 2015).

However, orders of magnitude higher sediment loads have been delivered into Moreton Bay in recent decades, estimated to be approximately 100 times greater than what would have occurred from natural catchments (Lockington *et al.*, 2017; Saeck *et al.*, 2019a). This is due to the combination of high sediment exposure from land clearing in the catchment, in conjunction with several very large flood events in 2011, 2013, and 2022 (Grinham *et al.*, 2024). The impacts of these sediment loads have changed the Bay and have substantially impacted benthic communities (Lockington *et al.*, 2017; Saeck *et al.*, 2019a; Grinham *et al.*, 2024) as summarised below (see Population status section).

Figure 13. Images of different benthic communities in Moreton Bay. Photo credit: T. Stevens.

5.7.3 Population status

The population status of subtidal macrofaunal communities in Moreton Bay is complex and exhibits significant spatial and temporal variation, strongly influenced by habitat type and sediment characteristics (Dunn *et al.*, 2013). The Bay's macrofaunal communities have undergone significant changes, primarily driven by anthropogenic pressures, including increasing environmental pressure with the rapid growth of Greater Brisbane (Davie and Hooper, 1998). As noted in Section 4, 'Sedimentation – Sources and Issues', the combination of land clearing and large flood events has greatly increased sediment loads into the bay and impacted benthic populations (Lockington *et al.*, 2017; Saeck *et al.*, 2019a; Grinham *et al.*, 2024).

Overall, many of the Bay's wetland and benthic habitats, including those supporting macrofauna, are in decline, with human activity leading to marked decreases in their areal extent (Kovacs *et al.*, 2019).

However, the cessation of trawling activities has led to strong increases in species richness and overall abundance in some sandy substrates, indicating a positive 'reserve effect' (Stevens *et al.*, 2014).

5.7.4 Value

Ecological value

Macrofaunal communities are integral to the functioning of Moreton Bay's ecosystem. Bivalve molluscs play a key role in filtering and cleansing water by removing particulate organic and inorganic material through their gills (Healy & Potter, 2010). Macrofaunal activities, including bioturbation (e.g., burrowing), influence sediment biogeochemistry, nutrient fluxes, and the oxygenation of surface sediments, which in turn control the release of nitrogen and phosphorus to the overlying water column (Ellis *et al.*, 2004). Hence, their abundance is critical to maintaining water quality (Healy and Potter, 2010).

Macrofaunal communities serve as primary food sources for many predatory invertebrates (e.g., gastropods, octopods, crabs) and vertebrates (e.g., fish, wading birds, gulls) within the Bay system (Healy and Potter, 2010), forming an essential link in the coastal food web (Richardson *et al.*, 2015).

Clumping species such as oysters, mussels, and ark shells provide rich settlement opportunities and complex living structures for numerous smaller animals, including other molluscs, sponges, hydroids, and small fish (Healy and Potter, 2010). They also offer valuable refuge and shelter for smaller invertebrates and fish, thereby enhancing overall benthic biodiversity (Healy and Potter, 2010). Even after death, these clumped bivalves contribute to benthic biodiversity and help stabilise soft or moving sediments (Healy and Potter, 2010).

Cultural value

The macrofaunal communities in Moreton Bay possess significant cultural value, primarily articulated through the deep and enduring connection of the Quandamooka People, the Traditional Custodians of the region, who have cared for this Country for over 50,000 years (Fischer *et al.*, 2019; Adams *et al.,* 2024). This value is multi-dimensional and extends beyond mere utilitarian aspects, integrating into identity, ecological understanding, and traditional practices (Pinner *et al.*, 2019).

Macrofaunal species, especially bivalves like rock oysters (*Saccostrea glomerata*), mussels (*Trichomya hirsuta*), ark shells (*Anadara trapezia*) and pearl oysters (*Pinctada* species), have historically been, and continue to be, important elements of the diet of local Aboriginal people, a fact evidenced by the numerous shell middens found throughout the Bay islands and adjacent areas (Healy and Potter, 2010). These resources are also vital for the continuity of cultural lifestyles and Traditional Knowledge, including their use in traditional medicine (Ross *et al.*, 2019a).

For Traditional Custodians, the health and presence of macrofaunal communities, such as oyster banks, mud whelks, and cockles, are seen as integral indicators of healthy waterway conditions (Pinner *et al.*, 2019). They are perceived as part of ‘nature's way to improve the water quality’, demonstrating a profound understanding and value placed on their ecological function as a sign of a thriving environment (Pinner *et al.*, 2019).

Specific macrofaunal species are directly woven into the cultural identity and historical geography of Moreton Bay. For instance, Bribie Island is known as ‘Yurin’, meaning ‘place of mud crabs’, highlighting the significance and abundance of these animals in traditional place names (Pinner *et al.*, 2019).

Economic value

The macrofaunal communities in Moreton Bay hold significant economic value, serving as direct resources for commercial and recreational fisheries (Healy and Potter, 2010). Key harvested species include prawns (e.g., Tiger, Banana, Eastern School, Endeavour and Greasy back prawns), Blue swimmer crabs, Moreton Bay bugs and oysters (e.g., Sydney rock and pearl oysters) (Healy and Potter, 2010; Richardson *et al.*, 2015).

The commercial fishery in Moreton Bay accounts for approximately 10% of Queensland's total trawl catch (e.g. prawn species and Moreton Bay Bugs) and 41% of the Bay's total seafood production by weight (Jackson, 2015; Richardson *et al.*, 2015). Historically, these communities also underpinned oyster farming and other aquaculture (Fischer *et al.*, 2019; Lockington *et al.*, 2017).

Indirectly, macrofaunal communities are vital as nursery grounds for commercially important fish species (Dunn *et al.*, 2013; Kovacs *et al.*, 2019), improving water quality through filter feeding (Healy and Potter, 2010), contributing to the Bay's overall productivity and supporting broader nature-based tourism and regional primary industries (Jackson, 2015; Steven *et al.*, 2014; Lockington *et al.*, 2017).

5.7.5 History

Historically, intensive trawling activities since the 1960s have led to changes in benthic community structure, typically removing or damaging attached and mobile macro-epibenthic organisms, such as sponges, soft corals, and echinoderms, shifting communities towards more homogeneous, infaunal-dominated states, and reducing species richness (Stevens *et al.*, 2014).

Following the cessation of trawling in parts of Moreton Bay Marine Park in 2009, studies have observed signs of recovery (Stevens *et al.*, 2014). In muddy habitats, closed areas showed a significant increase in species richness and overall abundance, with a notable reserve effect for ascidians, sponges, burrows, and macroalgae (Stevens *et al.*, 2014). On sandy substrates, there was a recovery signal, with increases in echinoderms, burrows, and crustaceans (Stevens *et al.*, 2014). Anemone species, ascidians, and echinoderms have begun to recolonise previously impacted sandy areas, even after flood events (Stevens *et al.*, 2014).

Seafloor heterogeneity has increased in areas closed to trawling, becoming less flat and featureless compared to continuously trawled areas where net marks are still visible (Stevens *et al*., 2014). However, recovery is still considered to be in its early phases, and infauna analyses have not yet shown clear positive reserve effects (Stevens *et al*., 2014).

In areas not subject to trawling, macrofaunal communities have been impacted by increasing sedimentation from the Moreton Bay catchment (Lockington *et al*., 2017; Grinham *et al*., 2024). These impacts are described below.

5.7.6 Impacts of sedimentation

Fine sediment deposition has impacted over 98% of Moreton Bay's benthic zone (Grinham *et al*., 2024). Muddy bottom habitats in the Bay increased dramatically from approximately 30% in 1998 to 70% in 2011 (Saeck *et al.,* 2019a). Mud is easily resuspended, increasing turbidity and chronically reducing light availability (Lockington *et al*., 2017; Saeck *et al.,* 2019a; Grinham *et al*., 2024). This directly smothers organisms (Ellis *et al*., 2004; Lockington *et al*., 2017) and inhibits primary productivity in both pelagic and benthic microalgae, which are critical to the Bay's productivity and nutrient cycling (Saeck *et al.,* 2019b) (see conceptual model in Figure 14). The loss of large-bodied, suspension-feeding, and freely motile taxa (such as bivalves and amphipods, respectively) also significantly impacts essential ecosystem functions like bioturbation and benthic-pelagic coupling (Ellis *et al*., 2017; Richardson *et al*., 2015) and can limit benthic productivity (Lockington *et al*., 2017).

The distribution, composition, density and biomass of macrofauna are profoundly affected by the type of habitat and sediment (Dunn *et al*., 2013). Areas with increased mud content and sedimentation rates often experience lower diversity and abundance (Ellis *et al*., 2004), and a shift towards infaunal-dominated assemblages (Jackson, 2015). In Moreton Bay, areas that previously had stable sandy substrates, such as the northern and eastern regions, became entirely dominated by infaunal assemblages by 2015, suggesting a shift to mud-dominated substrates (Jackson, 2015). Communities shift to being dominated by opportunistic deposit-feeding species, such as polychaetes and oligochaetes, and an expansion of infaunal assemblages occurs, while suspension feeders, including bivalves, decline (Ellis *et al*., 2004, 2017; Jackson, 2015). Filter-feeding species, such as ascidians, sponges and cerianthid anemones, are also susceptible to increased turbidity (Stevens *et al*., 2014).

This shift from sandy to muddy habitats is exacerbated by flood events and reduced capacity of the Bay's deeper channels to store sediments, leading to a loss of vertical accommodation space (Coates-Marnane *et al*., 2016b; Saeck *et al.,* 2019a; Grinham *et al*., 2024). For example, areas that support trawl fisheries have high suspended sediment concentrations and are usually characterised by declines in species richness (Stevens *et al*., 2014). Similarly, high sedimentation rates in estuaries are associated with lower benthic macrofaunal diversity and abundance (Ellis *et al*., 2004).

While many macrofaunal species in Moreton Bay are opportunistic and capable of rapid recolonisation after physical disturbances, such as dredging (Richardson *et al*., 2015), large-scale or catastrophic sedimentation events, particularly those caused by floods, can lead to slower recovery rates and longer-term changes in community structure (Ellis *et al*., 2004). The decreasing capacity of the Bay to effectively store fine sediment suggests that future inputs will likely lead to increasingly turbid water columns and persistent impacts (Leigh *et al*., 2013; Coates-Marnane *et al*., 2016b; Saeck *et al.,* 2019a).

5.7.7 Recommendations

To manage the impacts of sedimentation on benthic macrofaunal communities in Moreton Bay, the primary recommendations focus on reducing the influx of fine sediments from catchments and adopting informed management practices (Coates-Marnane *et al*., 2016; Saeck *et al.,* 2019a, b; Grinham *et al*., 2024). They include:

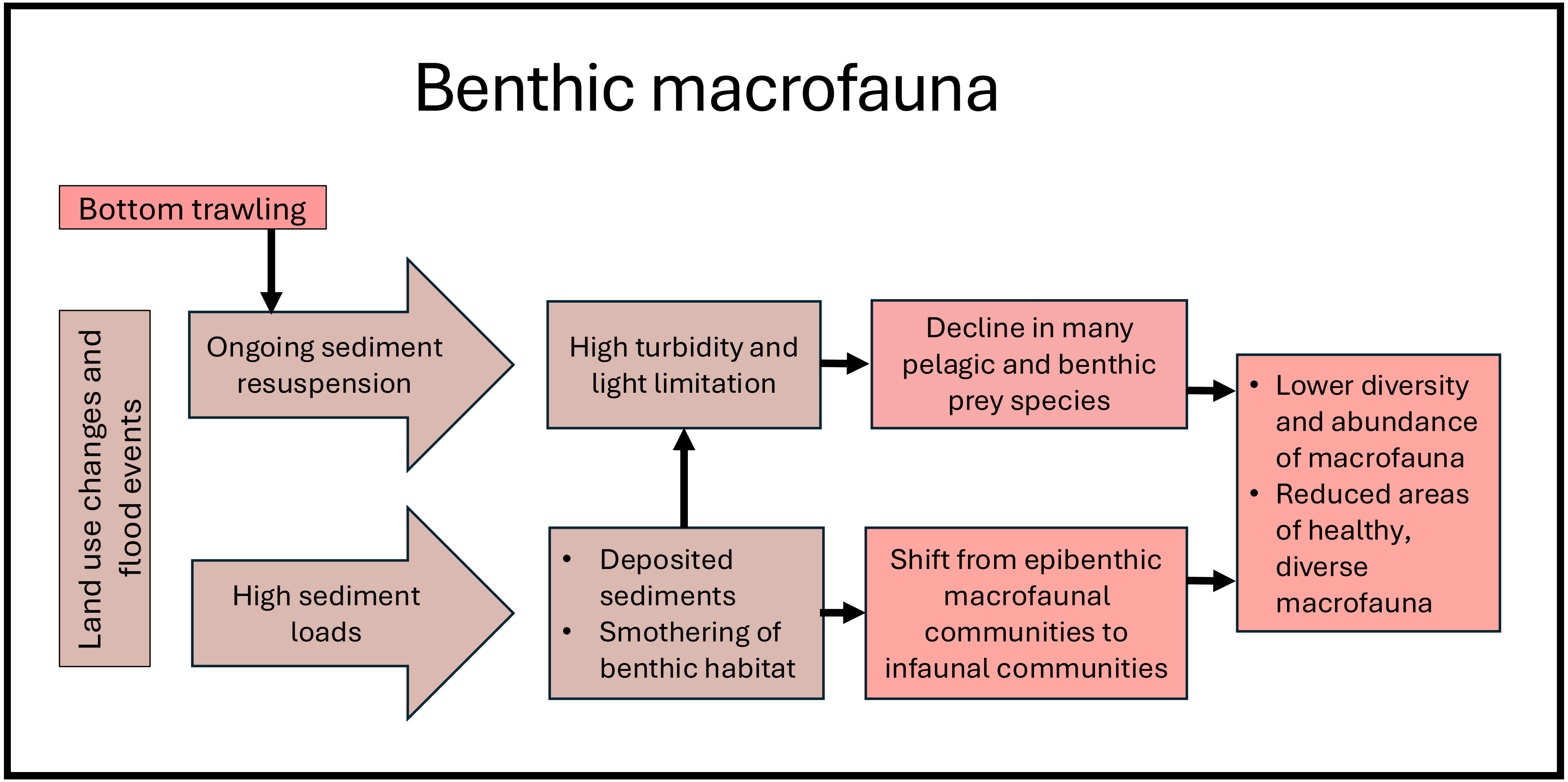
1. Reduce diffuse sediment pollution by (i) implementing targeted rehabilitation of channel networks, (ii) establishing buffers in agricultural lands, and (iii) revegetating riparian zones and catchments to decrease sediment and nutrient loads (Leigh *et al*., 2013; Saeck *et al.,* 2019b).
2. Recognise that even moderate levels of sedimentation can reduce the positive effects of key species on ecosystem functions like productivity and denitrification, even if the species persist (Jones *et al*., 2011).
3. Set ecologically relevant limits for sedimentation, moving beyond current sediment quality guidelines, which may not adequately protect coastal ecosystems from adverse effects (Ellis *et al*., 2017).
4. Implement persistent monitoring and continually adapt management strategies (Jackson *et al*., 2015; Stevens *et al*., 2014) to understand long-term shifts in benthic assemblages and build resilience against future disturbances (Gibbs and Hewitt, 2004; Stevens *et al*., 2014).

5.7.8 Expert review

Dr Timothy Stevens (Adjunct Senior Lecturer, Griffith University) kindly provided an expert review of the Benthic Macrofauna: Sedimentation Impact Statement.

5.7.9 Conceptual model - impacts of sedimentation on benthic macrofauna

Figure 14. Conceptual model that qualitatively describes the major impacts of sedimentation on macrobenthic communities in Moreton Bay. Brown boxes signify sedimentation-related processes; red boxes signify adverse impacts/outcomes.



5.8 Hard Corals: Sedimentation Impact Statement

Fringing reef corals in Moreton Bay
Photo credit: C. Roelfsema

5.8.1 Status and trend summary

Table 16 provides a qualitative assessment of the coral communities in Moreton Bay, highlighting key aspects of their current condition, future trajectory and the impact of sedimentation. The current condition of these coral populations is rated as 'Fair,' with 'High' confidence. This reflects the current and historical impacts of human activities, including coastal development, historical dredging, and coral extraction, as well as the compounded effects of climate change. Sedimentation, stemming from increased runoff, is a significant factor contributing to this condition, indicative of the sediment and nutrient influx that has degraded habitat quality and altered species composition.

The condition trend is noted as 'Declining,' also with 'High' confidence. This downward trajectory underscores the ongoing pressures exacerbated by climate variability and the increasing frequency of disturbance events, such as floods and severe storms, which heighten sedimentation effects, and increased water temperatures that cause bleaching. However, there is also some evidence that corals can recover from impacts in the medium to long term.

Sedimentation's contribution to this trend is assessed as 'Moderate', with 'Medium' confidence, indicating its considerable role in hindering coral resilience and recovery. Such impacts lead to shifts from more diverse communities dominated by *Acropora* sp. to those dominated by sediment-resistant species like massive corals, which reduce overall biodiversity, habitat functioning and coral cover.

Addressing these challenges requires targeted sediment management strategies, restoration efforts and further research on coral communities to understand and mitigate sedimentation impacts, thereby stabilising and potentially reversing the declining trends observed in Moreton Bay's coral ecosystems (Table 16).

Table 16. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for hard coral populations in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Fair	High
Contribution of sedimentation to the current condition	Moderate	Medium
Condition trend	Declining	High
Contribution of sedimentation to trend	Moderate	Medium

5.8.2 Overview

Corals are colonial marine invertebrates. They typically form colonies of many identical individual animals or polyps, often with hard skeletons made of calcium carbonate, which they secrete to build coral reefs. Corals are vital to marine ecosystems, often referred to as the 'rainforests of the sea,' as they provide habitats for a diverse range of marine life and contribute to the biodiversity of ocean environments. Lybolt and Pandolfi (2019) define Moreton Bay's reefal habitats as marginal reefs (Johnson and Neil, 1998a, b; Wallace *et al*., 2009). These habitats are unique for their high-latitude location and are considered key ecological values in Moreton Bay (as described below). They are predominantly found in shallow water (above 3 m Lowest Astronomical Tide) (Roelfsema *et al*., 2017), which could be a result of light limitation at greater depths due to turbidity, consistent with the general observations by Fabricius (2005).

Live coral cover varies across the Bay, showing an inshore to offshore gradient, with Myora Reef (near-oceanic site and furthest from the Brisbane River) still largely dominated by *Acropora* (34.9 ± 11.7% live coral cover) (Hammerman *et al*. 2022). However, near-river and intermediate sites like Wellington Point and Peel Island are dominated by stress-tolerant species, with lower live coral cover (1.8 ± 0.8% and 13.5 ± 8.3% respectively). These reefal communities include dead mainland fringing reefs (e.g. at Wellington Point and Cleveland Point) and live fringing reefs (e.g. around King, Green, St Helena, Mud, Peel, Goat, Coochiemudlo, and Macleay Islands) (Figure 15) which support coral assemblages historically dominated by *Acropora* and more recently by massive and sub-massive species, such as *Dipsastraea* (Lybolt and Pandolfi, 2019). *Porites* and *Montipora* species are generally absent from the Bay, but are present on reefs outside of the Bay, such as Flinders Reef, Flat Rock and Shag Rock (N. Hammerman, pers. comm.).

Over 60 species of Scleractinian hard corals from 21 genera have been recorded in Moreton Bay (Fellegara and Harrison, 2008). In 2015/2016, a total of 1,627.5 ha of area containing hard coral (and 192.5 ha of area containing soft coral) were mapped (Kovacs *et al*., 2019). Mean live coral cover was highest at Myora Reef (in the eastern Bay) at 34.9% (in 2019) (Hammerman *et al*., 2022), and this is the only site of modern coral assemblages within Moreton Bay that is dominated by *Acropora* corals (Hammerman *et al*., 2022). Coral cover at most other sites is currently dominated by massive corals, particularly corals from the Families Faviidae and Dendrophylliidae (Fellegara and Harrison, 2008; N. Browne, pers. comm.) (Figure 16).

5.8.3 Population status

Corals in Moreton Bay recently experienced mass mortality due to the 2022 floods (Healthy Land & Water, 2023). The floods delivered a significant amount of sediment to the Bay, leading to an expansion of mud and associated nutrients that fueled algal growth, negatively impacting coral communities (see Impacts of sedimentation section below) (Healthy Land & Water, 2023). Furthermore, in 2024, corals in the Bay experienced relatively large temperature ranges from 14°C to 28°C, and although some bleaching occurred in summer it did not result in a mortality event (N. Browne, pers. comm.).

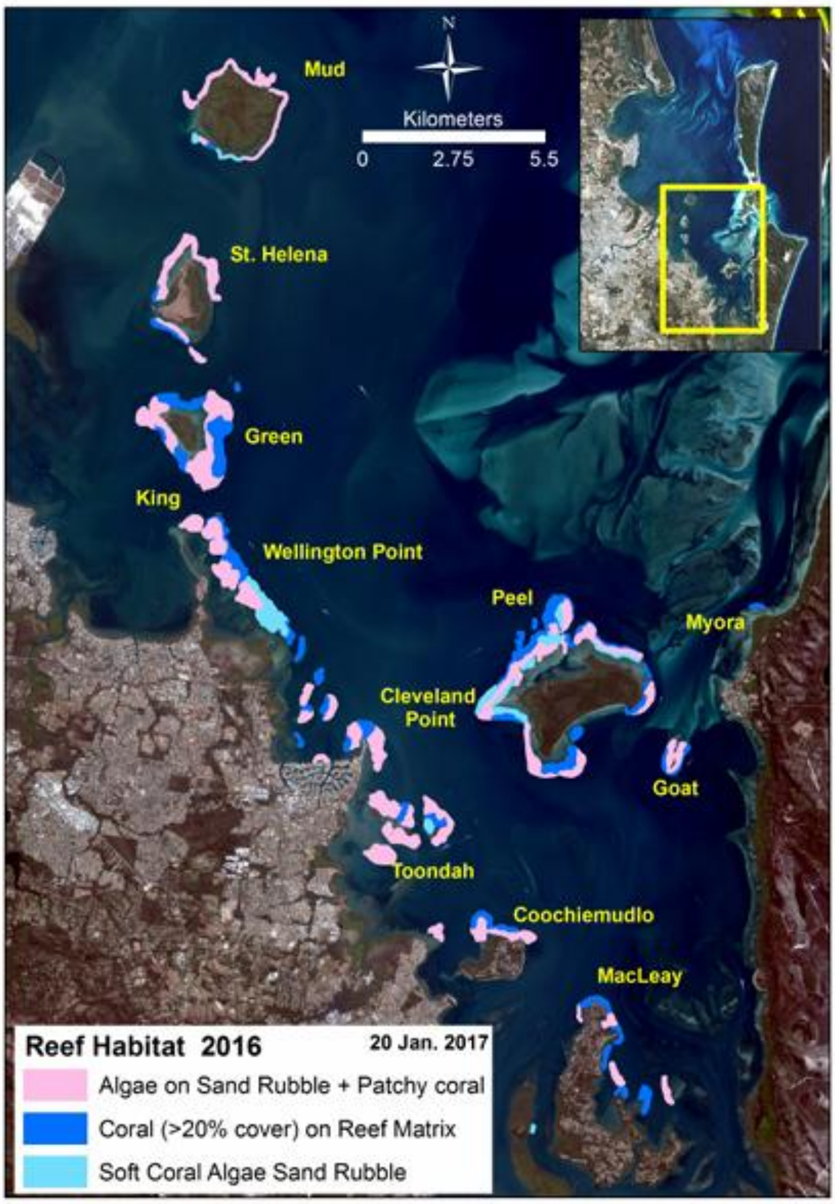


Figure 5: Inshore Moreton Bay reefal areas, derived through manual digitsation guided by 2014 ZY-3 satellite image (5 m x 5 m pixel) as a backdrop overlayed with spot-check field data collected in 2015 and 2016, for interpretation. Polygons are in this figure overlayed on a 2014 Landsat L8 (30 m x 30 m pixel) satellite imagery.

Figure 15. Map of the inshore Moreton Bay reefal areas. Figure presented with its original caption from Roelfsema et al. (2017).

As described in the History section below, there has been a long-term shift from branching *Acropora* corals to more stress-tolerant massive coral species in some areas of the Bay. For example, Goat Island had high coral cover of ~30%, dominated by plating Acropora's prior to the 2022 floods. These were mostly killed in the 2022 floods (reduced to 10% coral cover) but show signs of recovery (Golding, 2022). Of four sites investigated (Peel Island, Goat Island, Myora reef and Flinders reef), only Goat Island was substantially impacted (Golding, 2022). The corals along the north-eastern edge of Peel Island had 15-20% coral cover, of which <25% was Acropora in 2024.

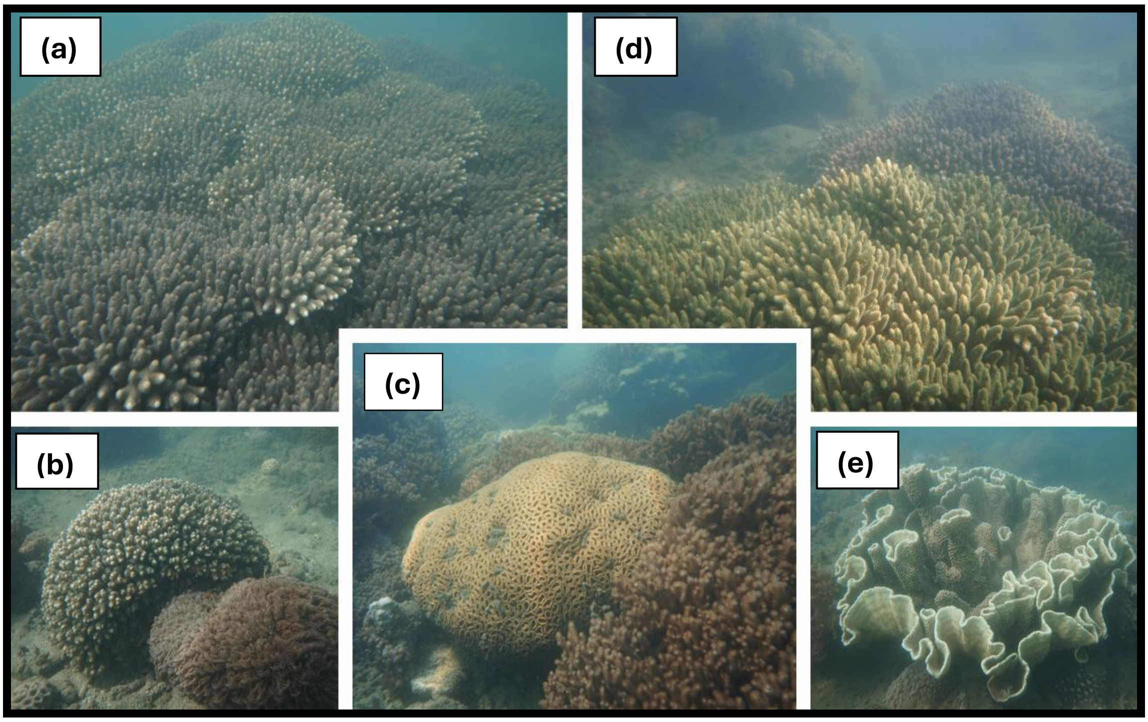


Figure 16. Recent photos showing examples of coral colonies from Moreton Bay: (a) - Acropora colonies from Myora Reef, lower left (b) - Pocillopora colony from Myora Reef, middle image (c) - mixed hard and soft coral community from Goat Island, upper right (d) - Acropora colonies from Peel Island, and lower right (e) - Turbinaria colony from Green Island. Photo credit: Nicholas M. Hammerman.

The partial recovery of some corals in the Bay following previous flood and bleaching events (summarised in the History section below) has led to the assertion that they are self-sustaining systems and may be relatively tolerant of environmental change (N. Hammerman, N. Browne, pers. comms.).

However, the increasing frequency of major flood events, strong storms (see Section 4, 'Sedimentation - Sources and Issues') and the associated diminishing water quality, along with increasing temperatures, will continue to reduce the opportunity for re-establishment of coral reef communities in Moreton Bay (Grothe *et al*., 2019; IPCC, 2022; NOAA, 2023; Hammerman *et al*., 2022). The dynamic between flood frequency and sediment clearing rates (described further in Section 4, 'Sedimentation - Sources and Issues'), along with increasing frequency of elevated water temperatures, bleaching and coral recovery rates, suggests that corals in the Bay may be at substantial risk of an ongoing decline.

5.8.4 Value

Ecological value

<u>1. Habitat and structural protection</u>
While the building of significant reef structures is generally limited in this marginal environment, the region still hosts notable coral communities, including fringing reefs around islands in the inshore bay, such as Peel, Mud, Goat, Saint Helena, and Green Islands. As well as providing important habitats for many other species groups, these reef structures also shield adjacent shorelines from erosion.

2. Support for unique biodiversity

The coral communities of Moreton Bay support a highly diverse range of ecologically and economically important species. At least 64 species of scleractinian corals, including 59 reef-building species, have been recorded in the inner Bay (Veron 2000; Wallace *et al.*, 2009). The reefal habitats sustain a large array of species that find refuge and food within coral reef ecosystems. These include a wide variety of smaller fish species known for their colour and high diversity, such as angelfish (Pomacanthidae), butterflyfish (Chaetodontidae), clownfish (Pomacentridae), damselfish (Pomacentridae), eels (Muraenidae), gobies (Gobiidae), lionfish (Scorpaenidae), surgeonfish (Acanthuridae), and triggerfish (Balistidae). Economically valuable finfish species are discussed in the Economic value section below.

Cultural value

The Quandamooka have a deep connection that extends to all aspects of Sea Country, including coral reef habitats (Ross *et al.*, 2019b). Coral reefs are included within the scope of Traditional Knowledge and contemporary management efforts, with Quandamooka Rangers being actively involved in managing and monitoring Sea Country. This includes undertaking coral reef monitoring (Fischer *et al.*, 2019), demonstrating the practical application of their custodial responsibility and desire to enhance knowledge of marine ecosystems, including coral reefs, in order to care for them better (Fischer *et al.*, 2019).

Economic value

Coral reefs have historically provided economic value through resource extraction, which supplied calcium carbonate for a range of large concrete legacy constructions in South East Queensland (such as the *Sir Leo Hielscher Bridges* or 'Gateway Bridge') (Butcher, 2022). However, that dredging activity also had economic impacts on other users, such as the livelihood of commercial tunnel net fishermen who fished periodically for a range of species at Mud Island, before coral dredging (J. Page, pers. comm.; see 5.15. Moreton Bay Fisheries: Sedimentation Impact Statement).

Ongoing economic value includes habitat support for highly diverse marine communities (see Ecological value section above), which attract tourists, students, etc, all are important contributors to many small businesses based within Moreton Bay. The coral reefs of Moreton Bay also support many species groups noted for their 'immense cultural, social and economic value' to a broad range of people, including Indigenous, recreational and commercial fishers (Olds *et al.*, 2019). These species groups include Emperors (Lethrinidae), Rabbitfish (Siganidae), Groupers/Cod (Serranidae), Tropical Snappers (Lutjanidae), Sea breams/Snapper/Squire (Sparidae), Parrotfish (Scaridae), Tuskfish and Wrasses (Labridae). Recreational fishing in Moreton Bay, of which coral reefs are the major habitat, attracts a direct expenditure of about $194 million per annum (Thurstan *et al.,* 2019) and brings significant economic benefits to the local area, with industries like boating, bait, and fishing tackle outlets benefiting from the ecological integrity of Moreton Bay coral habitats.

5.8.5 History

Moreton Bay's coral communities are considered marginal, heavily impacted by freshwater, sediment, nutrients, and turbidity from river discharge and human activities like land clearing, urbanisation and coral dredging (Fellegara and Harrison, 2008).

The dredging for coral/limestone to make cement saw the removal of a large biomass (>30 million tonnes) of hard coral around Mud and St Helena islands as well as off Wellington Point and Cleveland (Butcher, 2022). For example, by 1981, 48% of the Mud Island reef flat had been removed, and the surrounding islands' reefs are now almost entirely gone, replaced by a deep, muddy seabed (Butcher, 2022). This dredging ceased in November 1997, after approximately six decades of exploitation (Butcher, 2022). There is little prospect of corals re-establishing themselves in the dredged areas because they cannot attach themselves to the muddy bottom that remains, and because the combination of greater turbidity and water depth—a legacy of the dredging—also precludes effective coral establishment (Butcher, 2022).

There are several large river systems which feed into the Bay (i.e. Brisbane, Logan, Caboolture and Pine Rivers) (Figure 1). These rivers discharge freshwater, sediment, nutrients, trace metals and turbidity into the Bay, but their levels of discharge have varied substantially between flood events. In recent history, Moreton Bay has experienced several notable flooding events, including those in 1974, 1996, 2011, and most recently in 2022 (N. Hammerman, pers. comm.). The 1974 floods killed many hard corals in the western bay (Butcher 2022; Fellegara and Harrison, 2008), while the eastern Bay sites experienced between 0-20% coral mortality (N. Hammerman, pers. comm.). The 1996 and 2011 floods caused lower and less widespread impacts on coral cover in the Bay (N. Hammerman, pers. comm.). The 2022 flood event delivered heavier rainfall and higher impacts in the Bay's lower catchment than in 2011 (N. Hammerman, pers. comm.). The impacts of 2022 on corals are yet to be fully investigated, but observations and some research results are described above in the Population status section.

Due to the types of historical impacts described above, modern coral assemblages are considerably different from historical fossil assemblages. The impact of increased sediment and nutrient input since European settlement is evident in the shift of the dominant coral community structure in Moreton Bay (Lybolt *et al*., 2011; Hammerman *et al*., 2022). The Bay was previously dominated by *Acropora* species, but now most coral communities in the Bay are dominated by massive corals (see Impacts of sedimentation section below) (Lybolt *et al*., 2011; Hammerman *et al*., 2022).

5.8.6 Impacts of sedimentation

Sedimentation is a major factor causing the severe degradation of coastal reefs globally (Fabricius, 2005). It adversely affects the structure and function of coral reef ecosystems by altering both physical and biological processes (Rogers, 1990). Sediment affects light availability, reef growth and ultimately coral community composition (Lybolt and Pandolfi, 2019).

Grinham *et al*., (2024) describe the increase in sedimentation in the Bay in recent decades and note that:

- During major flood events, surface water nutrient and turbidity levels are elevated to 10 times above background.
- Fine sediment deposition has now impacted 98% of Moreton Bay.
- Porewater ammonium concentration can be elevated to 1000 times higher than surface waters.
- Annual sediment ammonium flux can be elevated to 180 times larger than the region's point source inputs.
- The 'clean sand' sediment class has been reduced in Moreton Bay from 442 km^2 to 30 km^2 in 50 years

The impact of increased sediment and nutrient input since European settlement is evident in the shift of the dominant coral community structure in Moreton Bay (Lybolt *et al*., 2011; Hammerman *et al*., 2022). The whole Bay was previously dominated by *Acropora* species, but now most coral communities in the Bay are dominated by massive corals such as *Cyphastraea*, *Dipsastraea*, and *Goniopora* species (Lybolt *et al*., 2011; Hammerman *et al*., 2022). This aligns with the general understanding that massive corals are often more resistant to sedimentation compared to branching *Acropora* (see below) (Zweifler *et al*., 2024).

Due to coastal modification and urbanisation, Moreton Bay generally follows a west-to-east gradient in coral condition and associated water quality. The western 'riverine' influenced side of the Bay typically has lower coral cover, a dominance of domed coral species and the near absence of branching *Acropora* species. The more 'oceanic' influenced eastern margin still supports branching corals and a comparatively higher coral cover (Lybolt *et al*., 2011; Hammerman *et al*., 2022). This gradient in coral cover and water quality is also evident in Hervey Bay, a similar embayment just north of Moreton Bay (Butler *et al*. 2013).

'In the past 200 years, reefs have changed significantly, and for the first time in 7,000 years reefs of Moreton Bay persist in a degraded state caused by increased sediment and nutrient runoff from anthropogenic land use changes. Reversal of this degraded state will require reduced sediment and nutrient loads onto the reefs' (Lybolt and Pandolfi, 2019).

The primary processes by which sedimentation impacts corals include:

1. Smothering

Sediment particles can smother reef organisms. Fabricius (2005) noted that high sedimentation rates (accumulating to >100 mg cm^{-2} d^{-1} or suspended >10 mg l^{-1}) can easily smother benthic communities. Even short exposure to sediments (a few days) can have long-term effects by removing young coral cohorts and delaying reef recovery (Fabricius, 2005).

Encrusting and massive corals can suffer sedimentation stress due to sediments settling on flatter coral surfaces and smothering/blocking corallites, the cup-like skeleton deposited by a coral polyp (Fabricius, 2005; Zweifler *et al.,* 2024).

Branching corals are less vulnerable to settling sediment due to their more vertical and complex structure (Rogers, 1990; Zweifler *et al.,* 2024).

Some corals have mechanisms to help cope with sediments, such as using tentacles, cilia, stomodeal distension, and entangling particles in their mucus, which may then be sloughed off (Rogers, 1990).

2. Reduced light penetration

Sediment particles, particularly resuspended sediments (turbidity), reduce the light available for photosynthesis for the symbiotic algae (zooxanthellae) within coral tissues (Rogers, 1990). This can lead to:

- reduced photosynthesis, which is critical for coral's energy budget and overall metabolism (Rogers, 1990)
- reduced calcification and slower growth rates (Browne *et al.,* 2021)
- a shallower, lower depth limit for reef growth (Rogers, 1990).

Turbid water corals may have a higher capacity for feeding, promoting their survival during turbidity and bleaching events (Fox *et al*., 2018). Examples of these turbid water corals include *Turbinaria* species (Sofonia and Anthony 2008; Ross *et al*., 2019a) as well as *Porites* and *Pavona* species (Zweifler *et al.,* 2024).

3. Altered benthic community structure

Sedimentation can lead to profound changes in coral population structures (Fabricius, 2005). Branching *Acropora* corals dominated Moreton Bay assemblages from 7,000 to 200 years ago. However, since that time, assemblages have transitioned to be dominated by massive corals such as *Dipsastraea* (Lybolt and Pandolfi, 2019).

Sedimentation can increase macroalgae, which compete with corals for space (Fabricius, 2005). Sediment settlement onto hard substrates can promote algal turf growth, which:

- inhibits coral larval settlement (Ellis *et al*., 2017; Albert *et al*., 2014, 2017)
- increases post-settlement mortality of corals (Fabricius, 2005)
- leads to reduced recruitment and juvenile density (Fabricius, 2005).

Hard corals also provide habitat for sedentary fishes (see examples in the Ecological value section above) and other reef-associated species (lobsters, crabs, shrimp and many other invertebrates) (Figure 17), which are forced to migrate, if possible, to less degraded habitats. Such changes are likely to result in reduced species richness, including a reduction in recreational fish populations.

4. Increased Bioerosion

Bioeroding communities are anticipated to undergo significant changes, which will increase in future years, potentially pushing reefs into net erosional states (N. Browne, pers. comm.). This is primarily due to the widespread loss of corals and increased nutrient pollution, which will elevate the importance of bioeroders in reef accretion (Browne *et al*., 2021). These shifts are influenced by a complex combination of abiotic factors, such as ocean acidification, temperature, nutrients, light, and water flow, alongside biotic factors like recruitment and predation, as well as characteristics of the reef substrate itself. Such changes directly impact the density of the reef framework, sediment production, and the subsequent redistribution of carbonate material. However, accurately modelling these dynamics remains challenging due to the high diversity of bioeroding organisms, varied erosion mechanisms, and considerable spatial and temporal variability (Browne *et al*., 2021).

The overall impacts of sedimentation on hard coral communities in Moreton Bay are broadly described in the conceptual model (Figure 18).

Figure 17. Coral reef-associated species in Moreton Bay, Quandamooka, including (a) the biscuit starfish, Pentagonaster duebeni, photo credit: C. Roelfseama; (b) Blood red featherstar, Heterometra sp., *photo credit: C. van den Berg; and (c) the dorid nudibranch, Chromodoris elisabethina, Photo credit: C. van den Berg.*

5.8.7 Recommendations

1. Mitigate sediment and nutrient runoff**.** It is crucial to reduce and mitigate sediment and nutrient runoff from anthropogenic land-use changes, including land clearing, agriculture, and urbanisation, to improve water quality and related conditions for coral reef growth (Kemp *et al.,* 2019; Lybolt and Pandolfi, 2019; Hammerman *et al.,* 2022).
2. Manage dredging impacts**.** Implement methods to reduce sediment plumes created during dredging operations. Specific suggestions include maintaining wider shallow margins to dissipate wave energy and opening more drainage points around Mud Island (Butcher, 2022).
3. Use marine reserves. Well-designed and managed marine reserves, especially those that are well-connected and located in clearer waters, can enhance ecosystem resilience and support coral recovery from disturbances (Roelfsema *et al.,* 2017; Olds *et al.,* 2019; Ross *et al.,* 2019b).

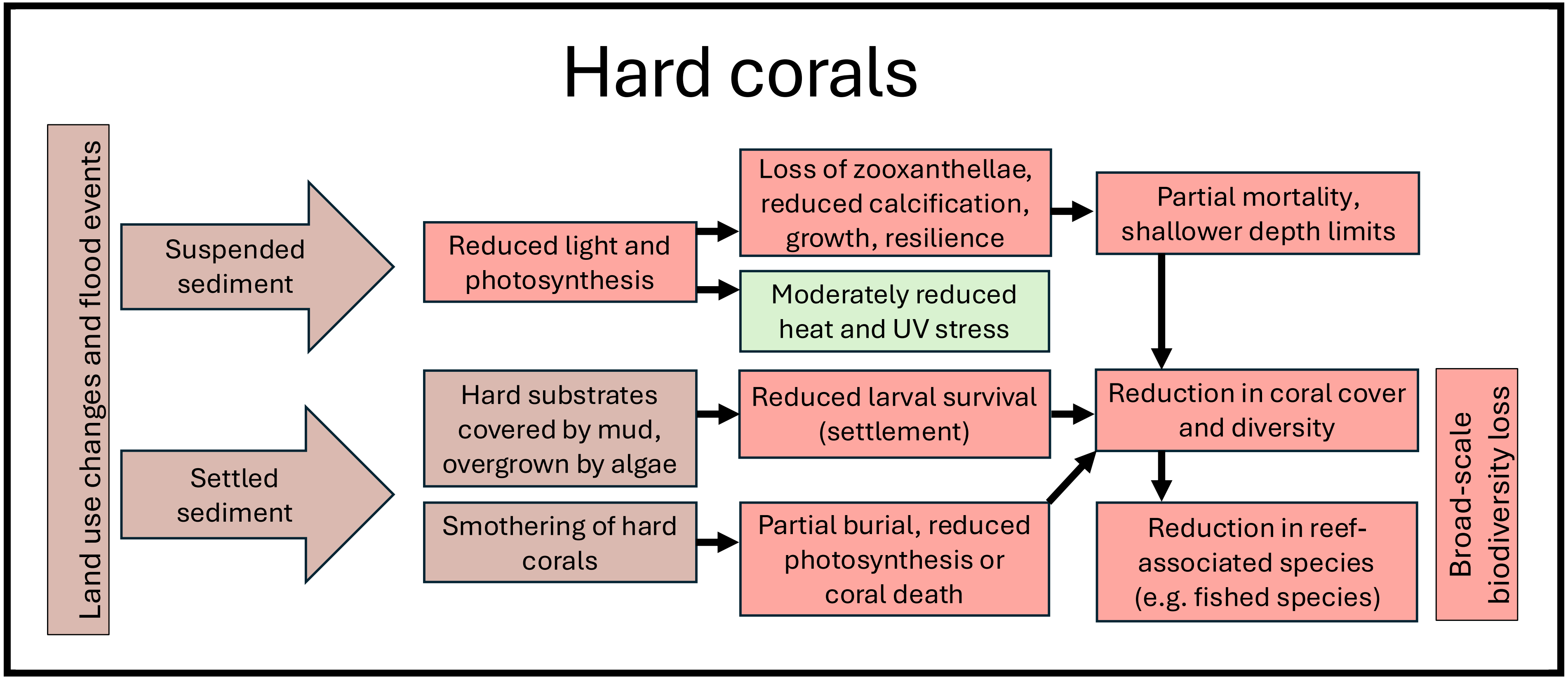
4. Support ecological health. Foster healthy populations of herbivorous fish, which can protect reefs against overgrowth by sediment-trapping macroalgae (Fabricius, 2005).
5. Implement integrated management and monitoring. Adopt integrated land-to-sea management strategies through collaborative efforts (Ross *et al.,* 2019b). Regular monitoring and assessment of reef conditions are crucial for informing management decisions and raising community awareness (Roelfsema *et al.,* 2017; Haywood *et al.,* 2019). The presence of Acropora corals can serve as an indicator of successful management (Hammerman *et al.,* 2022).
6. Further research into the impacts of sedimentation on corals, including (i) disentangling the impacts on and responses of corals to sediments and nutrients, including different sediment types, (ii) evaluating the role of sediment shading during heatwaves, and (iii) investigating the impacts of microplastics on corals and benthic systems in the Bay.
7. Adopt localised and adaptive strategies. Conservation efforts should be tailored to the unique characteristics and specific stressors of individual reef systems, with management strategies addressing both short-term responses to disturbances and longer-term recovery dynamics (Zweifler *et al.,* 2024).

5.8.8 Expert reviews

Dr Nicholas M. Hammerman (University of Queensland) and Dr Nicole Browne kindly provided an expert review of the Hard corals: Sedimentation Impact Statement.

5.8.9 Conceptual model - impacts of sedimentation on hard corals

Figure 18. Conceptual model that qualitatively describes the major impacts of sedimentation on hard coral communities in Moreton Bay. Brown boxes signify sedimentation-related processes; red boxes signify adverse impacts/outcomes; green boxes indicate likely positive or neutral impacts/outcomes.



5.9 Epibenthic Bivalve Reefs: Sedimentation Impact Statement

Shellfish reef habitat, Moreton Bay
Photo credit: R. Porter

5.9.1 Status and trend summary

Table 17 provides a qualitative assessment of the epibenthic bivalve reefs (or shellfish reefs) in Moreton Bay, highlighting key aspects of their current condition, future trajectory and the impact of sedimentation. The current condition of these bivalve reef populations is rated as 'Poor', with 'High' confidence. This reflects the current and historical impacts of human activities such as coastal development and historical harvesting in the 1800s and early 1900s. Sedimentation, stemming from increased runoff, is a significant factor contributing to this condition, which is indicative of the influx of sediment and nutrients that have degraded habitat quality.

The condition trend is noted as 'Declining,' also with 'High' confidence. Despite prolific recruitment and recovery through the 1900s, high-quality shellfish reef habitats have continued to be impacted through a combination of flood events, poor water quality and diseases. The contribution of sedimentation to this trend is assessed as 'Major' (Table 17). Flood events brought high sedimentation rates and volumes into the Bay, impacting (i) settlement success through loss and covering of hard substrates, (ii) energy intake through increased suspended sediment and reduced phytoplankton activity, (iii) disease impacts through organic enrichment and eutrophication, and (iv) increased runoff of pollutants (especially trace metals). Addressing these challenges requires targeted sediment management strategies and restoration efforts to mitigate the impacts of sedimentation, as climate change is predicted to increase the intensity of flooding and coastal development continues nearby.

Table 17. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for shellfish reef-forming epibenthic bivalve populations in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Poor	High
Contribution of sedimentation to the current condition	Moderate	High
Condition trend	Declining	High
Contribution of sedimentation to trend	Major	High

5.9.2 Overview

Bivalves are part of the large mollusc grouping (or phylum), which comprises soft-bodied invertebrates that are wholly or partly enclosed in a calcium carbonate shell.

Bivalves are characterised by a shell that is divided into two valves, connected via a hinge, and are largely sedentary with a deposit- or suspension-feeding lifestyle.

Bivalves include rock oysters, clams, mussels, scallops and more (Figure 19). Moreton Bay hosts a large and significant bivalve mollusc fauna, with a preliminary checklist recording 350 species belonging to 155 genera and 55 families (Healy and Potter, 2010). Usually only three or four species are able to successfully form biogenic reefs in subtropical Moreton Bay (B. Gilby, pers. comm.). This diversity is attributed to the Bay's unique position within the eastern Australian subtropical-to-temperate transition zone and its strong connections to both oceanic and estuarine influences.

The focus of this impact statement is on shallow (intertidal and shallow sub-tidal), epifaunal (living on the surface) bivalves due to their ecological, cultural and economic value. The predominant epifaunal bivalves in Moreton Bay include:

1. Cemented rock oysters (Ostreidae) (‘rock oysters’ or ‘oysters’ hereafter), typically the rock oysters, *Saccostrea cucullata* and *Saccostrea glomerata*, which have a strongly clumping lifestyle

2. Pearl oysters (Pteriidae) and Mangrove oysters (Isognomonidae), also with a strongly clumping lifestyle

3. Hairy mussels (*Trichomya hirsute),* which form extensive shallow subtidal and intertidal beds throughout the Bay and also have a strongly clumping lifestyle

4. Hammer oysters (*Malleus albus)*, usually solitary or in patchy aggregations, and living on the surface of sandy-mud substrates in intertidal and shallow subtidal areas, often in seagrass (to 5-10 m) (B. Gilby, pers. comm.).

5. Other relatively abundant epifaunal bivalve taxa, including species within the true cockles (Cardiidae), Arcidae (ark shells, Sydney cockle), Chamidae (jewel box clams), Mactridae (duck clams) and Pinnidae (razor clams) (Healy and Potter, 2010).

(a) Cemented Rock Oysters (Ostreidae)

(b) Pearl Oysters /Quampies (Pteriidae)

(c) Cockles (Cardiidae)

(D) Hairy Mussels (Mytilidae)

Figure 19. Photos of four of the main epibenthic bivalves in Moreton Bay.

These bivalve communities are also well known for forming shellfish reefs (Figure 20) due to their clumping lifestyle and abundance (Healy and Potter, 2010; Gilby *et al.,* 2019c, 2021). They are well known for their roles as ecosystem engineers, habitat formers, water quality regulators and nutrient cyclers (Anderson *et al.,* 2019; Gilby *et al.,* 2021). Their value is described in more detail below.

5.9.3 Population status

The devastation of shellfish reefs in Moreton Bay has been ongoing for decades and centuries, with significant losses due to overharvesting, land-use changes, increased siltation, and diseases (Thurston *et al.*, 2020). The current status of shellfish reefs in Moreton Bay is poor, with widespread functional extinction (Beck *et al*., 2011). An estimated 96% of the vertical zonation suitable for oyster habitation has been lost in areas like Pumicestone Passage within Moreton Bay over approximately 120 years (Wills *et al*., 2024). Only isolated, patchy, and degraded remnant intertidal shellfish reefs persist, primarily dominated by the Sydney rock oyster (*Saccostrea glomerata*) (Wills *et al*., 2024).

Current oyster production in the region is less than one-tenth of its historical peak (Thurston *et al.*, 2020), while the remaining oyster populations continue to experience recurring severe QX disease epizootics (Diggles, 2013).

5.9.4 Value

Ecological value

<u>1. Formation of shellfish reef habitats</u>
The clumping habit of epibenthic bivalves, particularly rock oysters, hairy mussels, pearl oysters and ark shells, can form extensive shellfish reefs in shallow subtidal and intertidal areas throughout the Bay (Healy and Potter, 2010) (Figure 20).

These shellfish reefs provide attachment surfaces and settlement opportunities for an extensive range of organisms (e.g. molluscs, sponges, hydroids, bryozoans, tubiculous polychaetes, barnacles and sea squirts) that live on the surface of other organisms (epibionts). The clumping habit also results in valuable refuges for many different invertebrates and some vertebrates (especially small fish) (Ellis *et al*., 2004; Healy and Potter, 2010).

Shellfish reefs can structure entire ecosystems, providing hard subtidal and intertidal reef structures, food, and habitat for invertebrates and fish (Diggles, 2013). They can substantially contribute to the diversity, biomass, and abundance of fish in the area (Gilby *et al*., 2018a).

<u>2. Maintenance of water quality</u>
Shellfish reefs can help maintain water quality and ecosystem health by providing a unique and critical service in water filtration (Healy and Potter, 2010; Anderson *et al.,* 2019). They can filter organic and inorganic particles suspended in the water column within their gill (ctenidial) complex (Healy and Potter, 2010).

Shellfish reefs regulate nutrients by three methods:

(i) using them for growth,

(ii) deposition into anoxic sediments via pseudofaeces, and

(iii) providing beneficial environments for nitrifying and denitrifying bacteria to thrive, driving nitrogen removal to the atmosphere (B. Gilby, pers. comm.).

Shellfish reefs exert 'top-down control' on phytoplankton populations - a primary food source for oysters and other bivalves (Diggles, 2013); the absence of which can lead to a substantial increase in phytoplankton blooms (Jones *et al.,* 2011). The removal of suspended particulate matter by shellfish reefs also improves water clarity, which can have negative impacts on many benthic invertebrates (Diggles, 2013; Wills *et al.,* 2024).

<u>3. Food source</u>
Bivalves are a primary food source for many predators, including stingrays, gastropods, octopods, crabs, fish, rays, wading birds and gulls (Pierce, 2008; Healy and Potter, 2010).

<u>4. Stabilisation of fine or moving sediments</u>
The clumping habit of these bivalves is considered an important factor in the stabilisation of soft or moving sediments (Healy and Potter, 2010; Anderson *et al.,* 2019). This includes facilitating the persistence of proximal seagrass beds (B. Gilby, pers. comm.). This stabilising effect occurs even after the bivalves die (Ellis *et al*., 2004; Healy and Potter, 2010). This means that some of the key functions of these habitats can be relatively easily mimicked or replaced or by artificial shellfish reefs (Duncan *et al.,* 2019; Gilby *et al.,* 2019c, 2021).

Cultural value

There is strong evidence of the long-standing use of epibenthic bivalves as a food source by the Quandamooka people based on their abundance in shellfish middens in Moreton Bay, including rock oysters, hairy mussels, Sydney cockles, and pearl oysters or Quampies (Healy and Potter, 2010; Ross *et al*., 2019b; Thurston *et al*., 2020). Quampies (*Pinctada albina*), for example, continue to be a culturally important food for the Quandamooka people including for ceremonial use (Thurston *et al*., 2019).

However, the Quandamooka people of Moreton Bay have reported concern over the diminishing populations of Quampies (D. Burns, Quandamooka, pers. comm.). Like other important epibenthic bivalves, Quampies require a hard substrate on which to attach. Healy and Potter (2010) also suggest that the Pteriidae (including Quampies) may have a lower tolerance to sedimentation than other bivalves.

Economic value

Rock oysters continue to form the basis of an aquaculture industry in Moreton Bay, (Thurston *et al.*, 2019; West *et al.,* 2019). As of 2015–16, sixty-seven oyster businesses operated 97 approved areas covering 435 ha of the Bay, with an annual production valued at over $500,000 (West *et al.,* 2019).

Natural shellfish reefs provide important structural habitats and support for food species, which in turn support many higher-level food web species (see Ecological value section above). These species are often targets for commercial and recreational fishing which have high commercial value in Moreton Bay (Thurstan *et al.,* 2019). It is also argued that shell reefs should be promoted as nature-based solutions that provide coastal protection and help in climate change mitigation and adaptation (Ysebaert *et al.*, 2019).

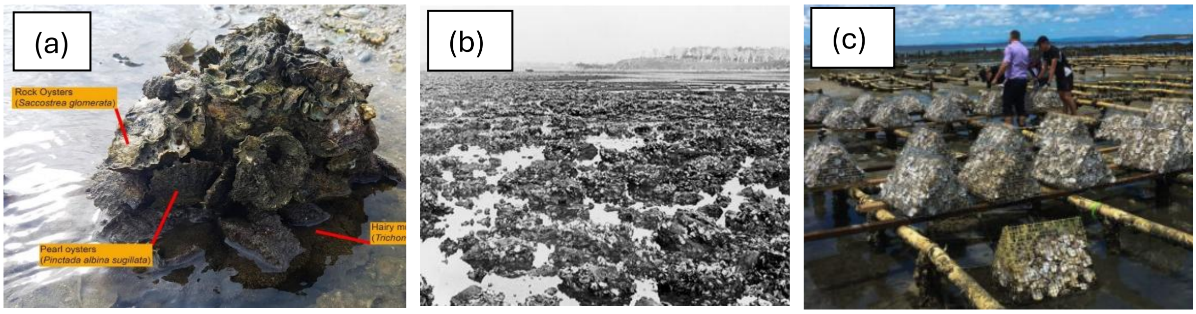


Figure 20. (a) An example of a small shellfish reef clump consisting of three bivalve species and demonstrating their attachment to the hard substrates of other shells. (b) Intertidal oyster bank (or shellfish reef) at Toorbul Point in 1906 (Photo from John Oxley Library). (c) Experimental oyster baskets, or artificial shellfish reefs in Moreton Bay (Photo courtesy of Robbie Porter).

5.9.5 History

Sydney rock oysters (*Saccostrea glomerata*) historically formed extensive oyster banks covering 2,036 ha of Moreton Bay by 1886 (Thurston *et al.*, 2019). These were mined for food and lime, with the production peaking in 1891 (Diggles, 2013), reaching nearly 21,000 sacks (approximately 1890 tonnes) from Moreton Bay.

The decline in oyster landings and presumably reefs began from the 1920s and continued throughout the 20th century (Thurston *et al.*, 2019). By 1920, oyster farmers shifted their focus almost exclusively to cultivation on intertidal banks (Diggles, 2013). Oyster farms still exist in Moreton Bay today, albeit on a significantly reduced scale, covering only 435 hectares in 2008. However, Diggles (2013) notes that while harvesting was significant, it is unlikely to have been the primary cause of the large-scale decline in shellfish reefs, as prolific recruitment was noted to replenish the beds.

The primary drivers for the decline and loss of shellfish reefs from the 1920s onwards have been identified as a combination of flood events, poor water quality and diseases (Diggles, 2013; Thurston *et al.*, 2019). All of these are related to the impacts of sedimentation on these organisms, as described below.

5.9.6 Impacts of sedimentation

The impacts of sedimentation on epibenthic bivalve reefs in Moreton Bay are broadly described in the conceptual model (Figure 21). Given the important ecological, cultural and economic role played by epibenthic bivalves in Moreton Bay, there is particular concern for the impacts of sedimentation on these taxa.

The primary processes by which sedimentation impacts epibenthic bivalves include:

1. Habitat changes

Sediment has transformed large areas of benthic habitat in the Bay from sandy to muddy, with muddy bottom habitats increasing significantly in extent over time (Jones *et al*., 2011; Saeck *et al*., 2019a; Grinham *et al*., 2024). Significant areas of clean sand have been replaced by mud, with muddy sediment habitats increasing by more than 50% between 1970 and 2015, to over 860 km^2, making mud the dominant sediment type in the Bay (Kemp *et al.,* 2019; Grinham *et al*., 2024). Clean sand habitats have declined by 20% (260 km^2) over the 30-year period from 1970 to 2011.

Major floods starting in 1887 introduced large amounts of sediment and nutrients into the Bay. The impacts of these flood events were exacerbated by the increased movement of sediment through the landscape (sediment flux) due to European land-use practices, such as deforestation, which accelerated significantly by 1870. These changes are highly likely to have increased sedimentation in the Bay by a factor of ~10 from the late 1800s onwards (Coates-Marnane *et al*., 2016b). Habitat changes from sandy towards more muddy substrates directly impact bivalve and other groups as follows:

(i) Favours mud-dwelling, deposit feeding species: Muddy substrates favour populations of mud-dwelling, deposit feeding species such as cockles, polychaetes and gastropods (Jones *et al*., 2011; Diggles, 2013; Richardson *et al*., 2015; Ellis *et al*., 2017; Pandolfi *et al*., 2019). However, even deposit-feeding species can be smothered and buried, potentially causing major declines (e.g. 90%) in macrofauna within 10 days (Gibbs and Hewitt, 2004; Anderson *et al.,* 2019).

(ii) Reduces populations of suspension-feeding species: A change from sandy to muddy substrates reduces populations of suspension-feeding species such as oysters and mussels, which prefer firmer and/or sandy substrates (Healy and Potter 2010; Ellis *et al*., 2017).

(iii) Reduces primary productivity: The incursion of muddy habitats directly reduces primary productivity through an increase in suspended sediments and hence, water clarity and light penetration (Jones *et al*., 2011; Lockington *et al*., 2017). Elevated suspended sediments also have significant implications for benthic-pelagic coupling (Jones *et al*., 2011; Ellis *et al*., 2017; Anderson *et al.,* 2019). In this altered state, sediment microbial nutrients become decoupled from benthic productivity and are instead released into the water column (Saeck *et al*., 2019a). The resulting nutrient flux boosts pelagic productivity, further reducing light availability and reinforcing the muddy conditions (Saeck *et al.*, 2019a).

(iv) Reduces the availability of hard substrates: The incursion of muddy habitats promotes algal turf growth, which traps sediment and reduces the availability of hard substrates on which many larger shellfish reef-forming bivalves can settle (as post larval stage) and grow into reproducing adults (Ellis *et al.*, 2004; Diggles 2013; Albert *et al.*, 2021). This has implications for future shellfish reef recovery or the placement of artificial shellfish reefs, in that areas that were once used by bivalves for settlement and growth may no longer be suitable, thereby reducing the potential for future shellfish reefs in the Bay (B. Gilby, pers. comm.).

2. Smothering and burial

Sediment deposition can directly smother and bury benthic animals, including epibenthic bivalves living on and in sediments (Lockington *et al.*, 2017). Smothering was identified as a significant cause of mortality for oysters in subtidal shellfish reefs following flood events in the late 1800s (Diggles, 2013), and it is also likely to impact the remaining shellfish reefs in future floods.

3. Poor water quality

Diggles (2013) suggests that declining water quality in Moreton Bay is considered the 'overriding mechanism' responsible for the decline of oyster reefs over the last 120 years. Historical epidemiology suggests that water quality decline, often associated with sedimentation and organic enrichment, contributes to the loss of shellfish reefs (Diggles, 2013). Sedimentation and sediment resuspension, combined with nutrient loading, can generate sediment-laden algal turfs over hard surfaces, which is sufficient to cause multi-generational recruitment failure for oyster spat in subtidal areas (Diggles, 2013). Ellis *et al*. (2004) also suggest that increases in suspended sediment reduce the energy intake of bivalves due to their ingestion in place of higher energy food sources.

4. Diseases

Increased sedimentation promotes organic enrichment and eutrophication, which can lead to increased abundance of spionid polychaete mudworms (Diggles, 2013). Historically, the decline of subtidal oyster reefs after flood events was associated with infestations by mudworms. Diggles (2013) also suggests that endemic mudworms increased in numbers due to siltation and organic enrichment caused by land clearing and increased water traffic.

The expansion of muddy areas due to increased sedimentation may have also increased the prevalence of the QX disease, caused by the paramyxean pathogen *Marteilia sydneyi*. The intermediate hosts for the pathogen include some of the mud-dwelling polychaetes, whose habitats have expanded due to sedimentation. This has potentially increased the impacts of infection on oysters (Diggles, 2013). These mortalities associated with QX disease emerged in the late 1960s and continue to this day. QX epizootics are particularly severe following flood events in disturbed catchments (Diggles, 2013).

Both of these disease issues are driven by declining water quality from anthropogenic catchment development (Diggles, 2013).

5. Recruitment failure

Diggles (2013) indicates a loss of approximately 96% of the vertical zonation suitable for oyster habitation. They suggest that dying oysters are not being replaced by new spat at lower tidal levels. This recruitment failure is likely caused by the lack of suitable hard surfaces for larvae to settle on, as resuspended sediments, stimulated by eutrophication, lodge in algal biofilms covering these surfaces (see 3. Poor water quality section above).

5.9.7 Recommendations

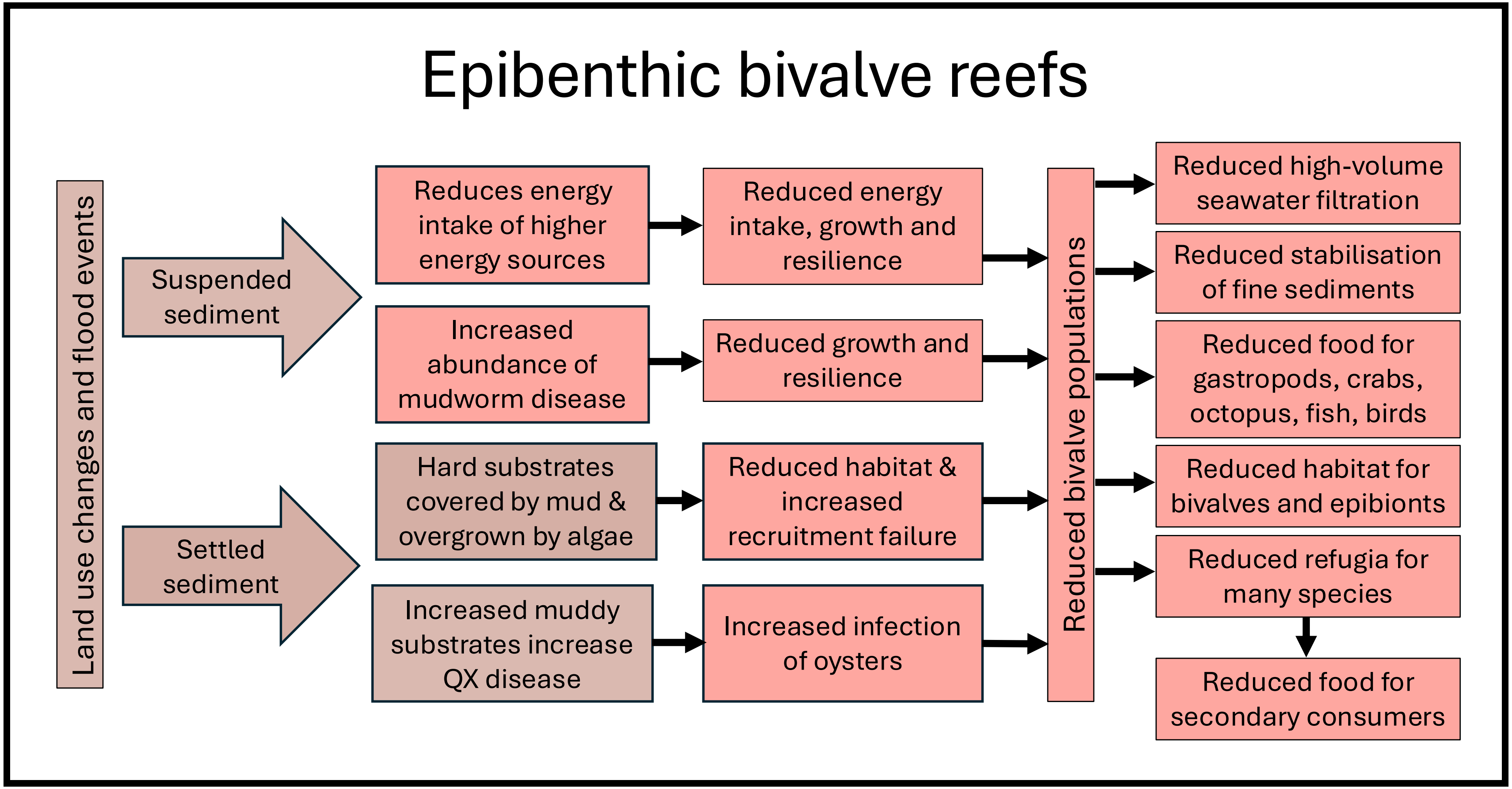
1. View oyster reefs as important habitats for fish and other species and as part of a more expansive, connected seascape (Gilby *et al.*, 2018b).
2. Substantially reduce terrestrial runoff to reduce the impacts of sedimentation, eutrophication and hypoxia on key benthic habitats (Gilby *et al.*, 2018b).
3. Restore shellfish reef habitats using clear, quantifiable goals and adaptive management based on robust, ongoing monitoring (Gilby *et al.*, 2018b).
4. Monitor the physicochemical environment and ecological processes (e.g., scavenging, predation, nutrient cycling) as indicators of ecosystem health (Gilby *et al.*, 2018b).

5.9.8 Expert reviews

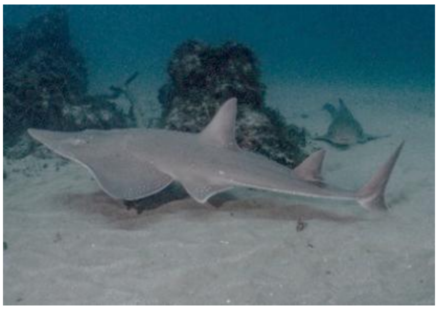
Associate Professor Ben Gilby (Assoc Prof Animal Ecology, University of the Sunshine Coast) and Robbie Porter (Ozfish) kindly provided expert review of the Epibenthic bivalve reefs: Sedimentation Impact Statement.

5.9.9 Conceptual model - impacts of sedimentation on epibenthic bivalve reefs

Figure 21. Conceptual model that qualitatively describes the major impacts of sedimentation on epibenthic bivalve reefs in Moreton Bay. Brown boxes signify sedimentation-related processes; red boxes signify adverse impacts/outcomes.



5.10 Sharks and Rays: Sedimentation Impact Statement



Critically Endangered Bottlenose wedgefish (Rhynchobatus australiae) in Moreton Bay
Photo credit: M. Erdmann

5.10.1 Status and trend summary

Despite historical and ongoing impacts, Moreton Bay still supports a high diversity and abundance of elasmobranchs, including many ray species that are common predators in intertidal zones. Table 18 provides a qualitative assessment of the shark and ray populations in Moreton Bay. The history of sharks and rays in Moreton Bay is largely characterised by long-term degradation, primarily due to human activities, with major declines indicated since pre-human times.

The International Union for Conservation of Nature (IUCN) Red List notes that 68% (30 of 45) shark species, and 67% (20 of 30) ray species that occur in Moreton Bay are Critically Endangered, Endangered, Vulnerable or Near Threatened. The absence of comprehensive baseline and monitoring data for most elasmobranch species makes it difficult to assess the current condition of these populations. However, the availability of status assessments, along with the likely impacts of habitat degradation, fishing, and pollution on these relatively vulnerable species, dictates that the current condition of shark and ray populations in Moreton Bay can be rated as 'Fair' with 'Medium' confidence.

Sedimentation in Moreton Bay, primarily driven by human activities in the catchment and flood events, has significantly altered fish habitats and assemblages, which are crucial for shark populations. Fine, muddy sediments deposited by rivers can modify the persistence of ray feeding pits, and increased turbidity is a crucial factor influencing the distribution of rays, as they are sensitive to changes in water quality, including salinity, temperature, dissolved oxygen, and pH. Hence, a condition trend rating of 'Declining' with 'Medium' confidence is applied. The contribution of sedimentation to the current condition and the condition trend is rated as 'Unknown' due to the broader range of impacts on these species. However, this rating is assigned with 'Low' confidence due to a lack of specifically targeted studies.

Table 18. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts on sharks and rays in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Fair	Medium
Contribution of sedimentation to the current condition	Unknown	Low
Condition trend	Declining	Medium
Contribution of sedimentation to trend	Unknown	Low

5.10.2 Overview

Moreton Bay has a high species diversity of sharks and rays (elasmobranchs) (Pierce, 2008), with 69 elasmobranch species recorded by Johnson (2010). This diversity is attributed to the Bay's geographic location at the interface between temperate and tropical biomes, combined with its diverse range of sheltered habitats (Dudgeon *et al*., 2019).

Johnson (2010) recorded 41 species of sharks in Moreton Bay and adjacent waters. However, a total of 44 species have been identified as occurring in the Bay for this current project, compiled from available literature as of July 2025. This includes species present across various areas, including coastal Moreton Bay, Flinders Reef, Flat Rock, Southport Seaway, and offshore waters (40–200 m depth) (Johnson, 2010).

A total of 29 species of rays have been identified as occurring in the Bay for this current project, which included 21 species of stingrays (suborder Myliobatoidei) and eight species of batoid rays, which include the shovelnose rays (guitarfish), wedgefish, electric rays and sawfish (Johnson, 2010). The Bay supports a relatively high diversity of ray species, particularly those that use the intertidal zone extensively, where they have been identified as the most common large predators in the shallow margins of the Bay (Pierce, 2008).

5.10.3 Population Status

Sharks and rays are highly susceptible to anthropogenic influences due to their life-history characteristics, including low fecundity, slow growth, and late sexual maturity (Kock *et al*., 2013). As Moreton Bay is surrounded by one of the world's fastest-growing urban areas, resident sharks and rays may be at particular risk from anthropogenic processes, such as habitat degradation, pollution and fishing. However, there is little information available (e.g., local monitoring or population assessments) from which to compile estimates of the population status for most species.

At a broader, but indicative level, the susceptibility of shark and ray species is reflected by the high proportion of species that are listed as being at some level of risk on the IUCN Red List (IUCN, 2025). The most recent global analysis, in which experts assessed 1,199 chondrichthyan (shark, ray, and chimaera) species against IUCN Red List criteria and found 391 species (32%) qualified as either Critically Endangered, Endangered, or Vulnerable (Dulvy *et al*., 2021). A recent Fisheries Research and Development Corporation (FRDC) report card for Australia’s 322 chondrichthyan species (Current Shark and Ray Report) noted that in fishery assessment terms, 63 species were either recovering (11), depleting (15), depleted (19) or undefined (18); with 230 species assessed as sustainable (Fisheries Research and Development Corporation, 2023a).

A summary of the IUCN classifications for sharks and rays in the Bay is provided in Table 19. Lists of the shark and ray species that occur in Moreton Bay, along with their relative abundances and IUCN classifications, are presented in Table 20 and Table 21. These status indicators reveal that 68% (n=30) of the 45 shark species, and 67% (20) of the 30 ray species that occur in Moreton Bay (Johnson, 2010) are either Critically Endangered, Endangered, Vulnerable or Near Threatened. The Green sawfish (*Pristis zijsron*), for example, has not been recorded in Moreton Bay since the 1960s (Pierce, 2008). Its disappearance from local records indicates a significant conservation concern due to anthropogenic impacts.

Fishing is one of the main human pressures that impacts shark and ray populations (Pierce, 2008; Gilby *et al*., 2019c; Olds *et al*., 2019). Gilby *et al*. (2019c) note that many sharks and rays can be significantly affected by fishing outside the boundaries of marine reserves. Some shark species are fished commercially in Queensland and have fishery assessments in place (Fisheries Research and Development Corporation, 2023b). However, they are assessed at the broader stock level, which is usually a much larger region than Moreton Bay alone (see Queensland Fisheries).

Pierce (2008) notes that shovelnose rays and the Estuary Stingray (*Hemitrygon fluviorum*) - an Australian endemic species) are threatened coastal species impacted by commercial and recreational fisheries (as well as habitat modification and pollution) (Pierce, 2008). Moreton Bay is considered an important population centre for the Estuary Stingray, due to its suitable habitat, including seagrass meadows and mangroves (Pierce, 2008). However, this species faces various anthropogenic threats, including from habitat degradation, pollution, recreational line-fishing, and coastal commercial fisheries (Pierce, 2008). The Blue-spotted stingray (*Neotrygon australiae*) is a common bycatch in demersal prawn trawl fisheries that accounted for 53.8% of elasmobranch catches (Pierce, 2008). However, the relatively recent implementation of bycatch reduction devices in this fishery has substantially reduced interactions with medium and large rays in the Bay (e.g. Brewer *et al*., 2006).

Table 19. Number of species of sharks and rays that occur in Moreton Bay and their current listing status by the IUCN. See Table 20 for species-specific detail.

IUCN Listing	No. of shark species
Critically endangered	3
Endangered	9
Vulnerable	11
Near threatened	7
Least concern	13
Data deficient	1
IUCN Listing	**No. of ray species**
Critically endangered	3
Endangered	4
Vulnerable	6
Near threatened	6
Least concern	7
Data deficient	2

Eight elasmobranch species were caught by extensive mesh-netting in the intertidal and subtidal zones of Moreton Bay (Pierce, 2008). These included six stingray species (White-spotted eagle ray [*Aetobatus narinari*], Estuary stingray, Black-spotted whipray [*Maculabatis astra*], Brown whipray [*M. toshi*], Reticulate whipray [*H. uarnak*], and the Blue-spotted stingray). Numerically, stingray catches were dominated by the Blue-spotted stingray, making up 53.8% of catches, and the Estuary stingray, accounting for 22.2% (Pierce, 2008). While stingrays are susceptible to being taken as bycatch in trawl, seine and gill nets, in the tunnel net fishery of Moreton Bay, stingray mortality is very low due to well-developed bycatch reduction practices (M. Giaroli, pers. comm.).

In evidence of an additional impact on the rays of Moreton Bay, a study investigating Perfluoroalkyl substances (PFAAs) in six species (White-spotted eagle ray, Estuary stingray, Black-spotted whipray, Brown whipray, Reticulate whipray, and Blue-spotted stingray) from a mass stranding event on North Stradbroke Island (Minjerribah) found that PFAAs were detectable in all liver samples (Townsend *et al.*, 2019). However, the cumulative impact of this and other pressures on shark and ray populations is unknown.

Despite the ongoing re-zoning of the Moreton Bay Marine Park to enhance habitat protection, the broader protection of elasmobranch diversity has not been an explicit focus of the marine park rezoning, except for specific species like the Grey nurse shark (*Carcharias taurus*) (Pierce, 2008).

The absence of comprehensive baseline and monitoring data for most elasmobranch species, along with the impacts from habitat degradation, fishing and pollution, makes it difficult to assess the current condition of the populations of these relatively vulnerable species in Moreton Bay.

5.10.4 Value

Ecological value

Sharks and rays contribute to the ecological system through their roles as predators, their influence on habitat structure, and their broader contribution to biodiversity and food web dynamics (Giaroli *et al.*, 2024). Many species move widely among different habitats (e.g., for feeding or spawning), thereby functionally linking assemblages, food webs, and ecosystems across the diverse seascape of Moreton Bay (Olds *et al.,* 2019).

As apex predators, sharks play a crucial role in maintaining the balance of marine food webs (Gilby *et al.*, 2019c). For example, the Australian weasel shark (*Hemigaleus australiensis*) is common in Moreton Bay and is noted for its 'cephalopod dietary specialisation' (Olds *et al.*, 2019), an essential predator-prey relationship. These, along with the many other predatory and scavenging roles played by sharks and rays, help sustain biodiversity and modify benthic communities (Olds *et al.*, 2019).

Stingrays play a crucial ecological role in structuring intertidal and subtidal soft-bottom ecosystems by feeding directly on benthic invertebrates and influencing sediment turnover through the excavation of feeding pits or depressions (Figure 22) (Pierce, 2008;

Giaroli *et al*., 2024). Their excavation of buried prey creates sediment turnover, which can influence the succession of invertebrate communities (Pierce, 2008; Giaroli *et al*., 2024). These feeding pits also provide nursery habitat for commercially important nekton (free swimming organisms), such as post larval whiting (*Sillago* spp) and penaeid prawns (Giaroli *et al*., 2024). Eastern Moreton Bay sites with higher ray feeding pit densities are estimated to host approximately 600,000 post-larval whiting and eight million post-larval penaeid prawns, underscoring their importance for local fisheries (Giaroli *et al*., 2024).

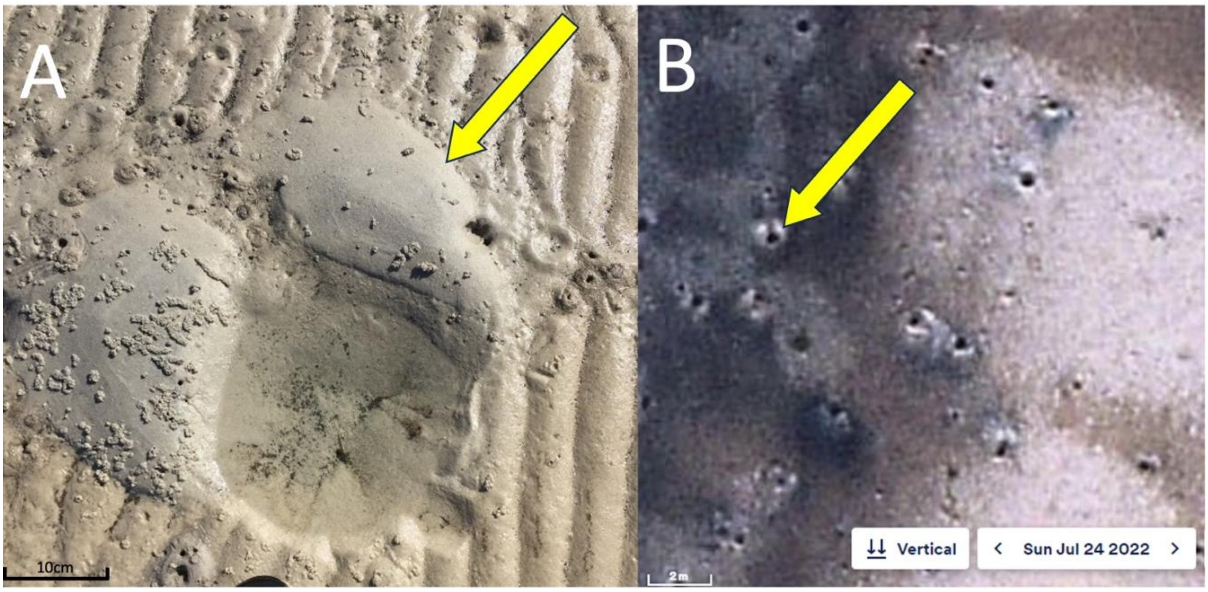


Figure 22. Images of stingray feeding pits in Quandamooka (Moreton Bay), Australia. (a) A water-filled stingray feeding pit with postero-lateral fans of sediment displaced by a foraging stingray. Bradbury's Beach, Dunwich (Goompi), Minjerribah (North Stradbroke Island). (b) Stingray feeding pits at Hays Inlet (−27°15 035 00 , 153°4 019 00), western Moreton Bay, showing postero-lateral sediment fans from a Nearmap aerial image. The image date function is visible in the lower right-hand corner and identifies the date the image was taken. Yellow arrows indicate a left sediment plume with respect to the orientation of the stingray. (from Giaroli et al., 2024).

Cultural value

Sharks and rays hold significant cultural value for Moreton Bay's Indigenous communities, particularly as sacred Aboriginal totems for saltwater people in coastal areas (Pinner *et al.,* 2019). The significance of these animals is also reflected in Aboriginal place names**.** For example, 'Ngarang-Wal' (the name for the Gold Coast Aboriginal Association Incorporated) translates to 'Shovel-nosed shark' and is an Aboriginal totem. This indicates a symbolic association with aspects of Aboriginal culture and connecting Indigenous people to these places as an expression of their historical, cultural and spiritual belonging (Ross *et al.,* 2019a).

Economic value

Although not directly targeted, the economic value of sharks and rays in Moreton Bay is primarily described through their contribution to the region's overall fisheries, both commercial (worth $24 million/year) and recreational (which estimated expenditure of $194 million/year) and indirectly through their ecological roles and conservation status (Olds *et al*., 2019; Thurstan *et al*., 2019).

As noted above (see Ecological value section), stingray feeding pits play a crucial role as nursery habitats for commercially important nekton, including post-larval whiting and penaeid prawns (Giaroli *et al*., 2024). This ecological function provides significant social and economic benefits to local communities by supporting valuable fisheries (Giaroli *et al*., 2024). For example, the Eastern king prawn (*Penaeus plebejus*) harvest in Queensland was valued at $64.8 million in 2019, and Sand whiting (*Sillago ciliata*) harvested from south-eastern Queensland had a retail value of over $8.6 million (Giaroli *et al*., 2024).

5.10.5 History

The history of shark and ray populations in Moreton Bay is characterised mainly by long-term degradation and altered abundance, primarily due to human activities (Pierce, 2008; Taylor, 2008; Olds *et al*., 2019). Major declines in large marine carnivores, including sharks and rays, have been reported for Moreton Bay since pre-settlement times, suggesting these vertebrate populations are severely degraded (Pierce, 2008).

European land-use practices significantly increased sediment flux into inshore regions by 1870 (Diggles, 2013). This, combined with organic enrichment from episodic flood events (starting 1887), is linked to the smothering of subtidal oyster reefs and broader ecosystem degradation that impacts fish and ray habitats (Diggles, 2013; Thurston *et al*., 2019) (e.g. see 5.7 Benthic Macrofauna: Sedimentation Impact Statement). The expansion of canal estates, Brisbane Airport, and the Port of Brisbane has led to eutrophication and pollution, which has also likely altered the Bay's nekton community (Taylor, 2008).

Overall, water quality degradation and coastal urbanisation have significantly altered fish and elasmobranch assemblages and habitats, reducing diversity and abundance across estuaries, seagrass meadows, and coral reefs, which are vital for many shark and ray species (Pierce, 2008; Olds *et al*., 2019).

Sharks and rays have been extensively exploited by commercial and recreational fishers over many decades (Johnson, 2010; Thurstan *et al*., 2019). Combined shark catches from commercial net, line, and trawl fisheries increased significantly from 20,608 kg in 1988 to 53,026 kg in 2003, with species such as the Dusky shark (*C. obscurus*) and the Common blacktip shark (*C. limbatus*) identified as vulnerable to these activities (Taylor, 2008).

Despite historical and ongoing impacts, Moreton Bay still supports a high diversity and abundance of elasmobranchs, including many ray species that are common predators in intertidal zones (Taylor, 2008; Giaroli *et al*., 2024) (Figure 23). The Bay continues to be important habitat and nursery grounds for both resident and migratory shark and ray species (Pierce, 2008; Taylor, 2008; Dudgeon *et al*., 2019). However, comprehensive historical baseline data on species-specific abundance and community composition for elasmobranchs are limited, making precise long-term historical assessments challenging (Pierce, 2008; Taylor, 2008).

5.10.6 Impacts of sedimentation

Sharks

Sedimentation in Moreton Bay, primarily stemming from human activities and flood events, has significantly altered fish habitats and assemblages, which are vital for shark populations (Dudgeon *et al*., 2019; Olds *et al*., 2019) (see conceptual model in Figure 24). Sedimentation contributes to increased turbidity, which is a crucial factor influencing the distribution of sharks (Pierce, 2008; Taylor, 2008). The juveniles of some shark species, such as the Pigeye shark (*C. amboinensis)*, the Dusky shark, and the Nervous shark (*C. cautus)*, are predominantly found in the more turbid waters of the western Bay, suggesting a preference or adaptation to these conditions (Taylor, 2008). Here, high turbidity may confer an advantage for some sharks by reducing the ability of their teleost (bony fish) prey to see the predator and evade capture (Taylor, 2008). However, larger predatory sharks also occupy these turbid areas, posing a threat to smaller elasmobranchs (Taylor, 2008).

Sediment-laden floodwaters can lead to a reduction in overall fish abundance, thereby impacting the food sources for sharks and rays (Taylor, 2008; Henderson *et al*., 2024). Additionally, sedimentation contributes to the accumulation of toxic trace elements in the marine environment, which can become bioavailable and impact species like stingrays (Townsend *et al*., 2019).

Rays

Sedimentation from river inputs, especially in the western Bay, contributes to increased turbidity, which is a crucial factor influencing the distribution of stingrays, as they are sensitive to changes in water quality, including salinity, temperature, dissolved oxygen, and pH (Giaroli *et al*., 2024).

Foraging stingrays leave pits on intertidal shores, with many of these pits becoming shallow pools as the tide recedes. They provide significant nursery habitats for the young of commercially important nekton, including whiting and prawns (Giaroli *et al*., 2024). Pollution, poor water quality and settled sediments from flood events can exclude stingrays from such shores, preventing the creation of nursery pool habitats and halting the bioturbation (sediment turnover) by rays that helps maintain habitat health. Importantly, the shores are also darkened by the covering of mud, which reduces their albedo (reflectiveness), leading to increased absorption of solar energy and warming. It is feared that nursery pools so affected will warm to temperatures lethal for juvenile prawns and whiting, turning their nurseries into death traps (I. Tibbetts, pers. comm.). The consequences may be dire for these animals and the ecological cascades that are linked to these species.

Three of the four most abundant rays in Moreton Bay – the Coral Sea mask ray (*Neotrygon trigonoides*), Estuary stingray, and Brown whipray – have limited freshwater penetration capacity (Giaroli *et al*., 2024). This limited tolerance means they must remain in higher-salinity water. Consequently, increased runoff and degraded water quality from urbanised, agricultural, and industrial catchments have likely contributed to their limited penetration into estuaries (Giaroli *et al*., 2024), thereby reducing their available habitat.

Sedimentation also facilitates the accumulation of toxic trace elements (e.g., arsenic, cadmium, copper, selenium) in the marine environment (Townsend *et al*., 2019). These elements, initially bound to mineral particles and organic matter in the sediment, can be liberated and become bioavailable, especially during rainfall and flood events (Townsend *et al*., 2019). This poses a risk to stingrays, as evidenced by studies showing accumulation of substances like perfluoroalkyl substances (PFAAs) in their livers following flood events, with smaller rays potentially taking up chemicals more rapidly and eliminating them more slowly (Townsend *et al*., 2019).

Poor water quality and the presence of pollutants have been linked with health disturbances and decreased reproductive health in elasmobranch populations (Cortés and Parsons, 1996). Reductions in habitat quality and quantity, such as those caused by sedimentation, have likely contributed to further population declines in stingrays (Pierce, 2008).

Rays are increasingly threatened with extinction, which may also compromise their key habitat features (e.g., feeding pits) on sedimentary shores (Giaroli *et al.,* 2024). The Estuary stingray's distribution largely overlaps with urbanised coastal areas in eastern Australia. This has led to the reduction, modification, and degradation of their habitat, which substantially increases the population-level risk to this species (Pierce, 2008).

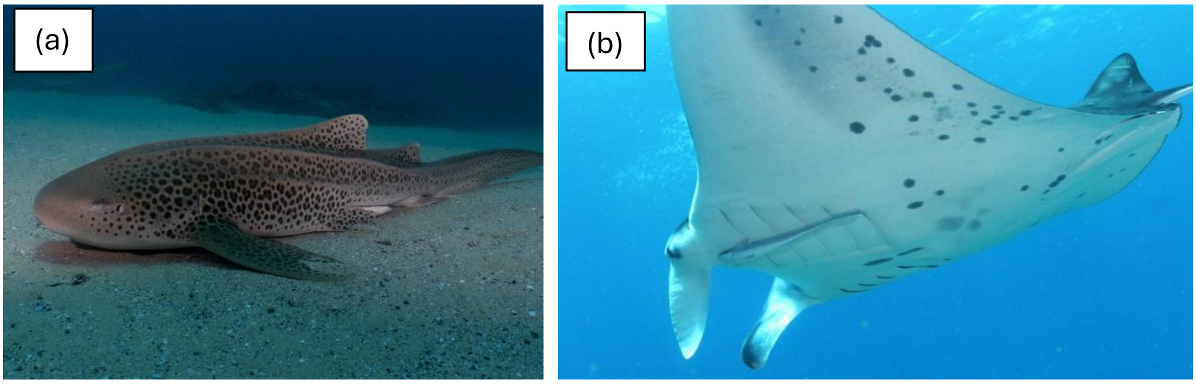


Figure 23. (a) The endangered Leopard shark (Stegostoma tigrinum), photo credit: M. Erdmann; (b) The vulnerable Reef manta ray (Mobula alfredi), Photo credit: K. Townsend.

5.10.7 Recommendations

To manage the impacts of sedimentation on shark and ray communities in Moreton Bay, most recommendations focus on reducing the influx of fine sediments, nutrients and pollutants from catchments and adopting informed management practices. Key recommendations include:

1. Implement effective catchment management, targeting reductions in nutrient and sediment loads (Diggles, 2013) by maintaining existing vegetation cover, restoring catchment riparian vegetation, and rehabilitation efforts in streams and tributaries (Gilby *et al*., 2016).
2. Implement intelligent design in urban water runoff systems (Gilby *et al*., 2016).
3. Increase environmental monitoring and develop new strategies to reduce pollutant inputs to the Bay, as coordinated programs are currently deficient, making it difficult to understand the impact of major weather events that cause flooding (Townsend *et al*., 2019).
4. Maximise the extent of natural habitats across estuaries to help mediate the impacts of floods, which transport sediment (Henderson *et al*., 2024).
5. Strategically place marine reserves to account for water quality gradients and areas less impacted by riverine runoff and floods, enhancing their effectiveness (Gilby *et al*., 2019a).

5.10.8 Expert reviews

Associate Professor Ian Tibbetts (School of the Environment, University of Queensland) and Dr Christine Dudgeon (School of Biomedical Sciences, University of Queensland) kindly provided expert review of the Sharks and rays: Sedimentation Impact Statement.

Table 20. List of sharks of Moreton Bay and abundance categories: A = abundant, C = common, U = uncommon, R = rare (from Johnson, 2010). Species listings under the IUCN Red List are indicated (taken from www.iucnredlist.org).

Shark Family/Species	Abundance	IUCN Listing
Chimaeridae		
Blackfin ghostshark *(Hydrolagus lemures)*	C	Near Threatened
Marbled ghostshark (*Hydrolagus marmoratus*)	U	Least Concern
Heterodontidae		
Crested horn shark (*Heterodontus galeatus*)	U	Least Concern
Odontaspididae		
Grey nurse shark (*Carcharias taurus*)	U	Critically Endangered
Alopiidae		
Thresher shark (*Alopias vulpinus*)	R	Vulnerable
Lamnidae		
Longfin mako (*Isurus paucus*)	R	Endangered
Shortfin mako (*Isurus oxyrinchus*)	U	Endangered
White shark (*Carcharodon carcharias*)	U	Vulnerable
Scyliorhinidae		
Grey-spotted catshark (*Asymbolus analis*)	U	Least Concern
Orange-spotted catshark (*Asymbolus rubiginosus*)	U	Least Concern
Sawtail catshark (*Figaro boardmani*)	U	Least Concern
Triakidae		
Gummy shark (*Mustelus walkeri*)	C	Data deficient
Hemigaleidae		
Australian weasel shark (*Hemigaleus australiensis*)	C	Least Concern
Snaggletooth shark (*Hemipristis elongata*)	R	Endangered
Carcharhinidae		
Australian sharpnose shark (*Rhizoprionodon taylori*)	U	Least Concern
Bull shark (*Carcharhinus leucas)*	C	Vulnerable
Common blacktip shark (*Carcharhinus limbatus*)	C	Vulnerable
Copper shark (*Carcharhinus brachyurus*)	R	Vulnerable
Dusky shark (*Carcharhinus obscurus*)	C	Endangered
Milk shark (*Rhizoprionodon acutus*)	U	Vulnerable
Nervous shark (*Carcharhinus cautus*)	U	Least Concern
Pigeye shark (*Carcharhinus amboinensis*)	C	Vulnerable
Sandbar shark *(Carcharhinus plumbeus*)	C	Endangered
Sicklefin lemon shark (*Negaprion acutidens*)	U	Endangered
Sliteye shark (*Loxodon macrorhinus*)	R	Near Threatened
Spinner shark (*Carcharhinus brevipinna*)	C	Vulnerable
Spottail shark (*Carcharhinus sorrah*)	C	Near Threatened
Tiger shark (*Galeocerdo cuvier*)	U	Near Threatened
Whitetip reef shark (*Triaenodon obesus*)	R	Vulnerable
Sphyrnidae		
Great hammerhead shark (*Sphyrna mokarran)*	U	Critically Endangered
Scalloped hammerhead shark (*Sphyrna lewini*)	C	Critically Endangered
Parascylliidae		
Collared carpetshark (*Parascyllium collare*)	U	Least Concern
Brachaeluridae		
Blind shark (*Brachaelurus waddi*)	U	Least Concern
Colclough's carpetshark (*Brachaelurus colcloughi*)	U	Vulnerable

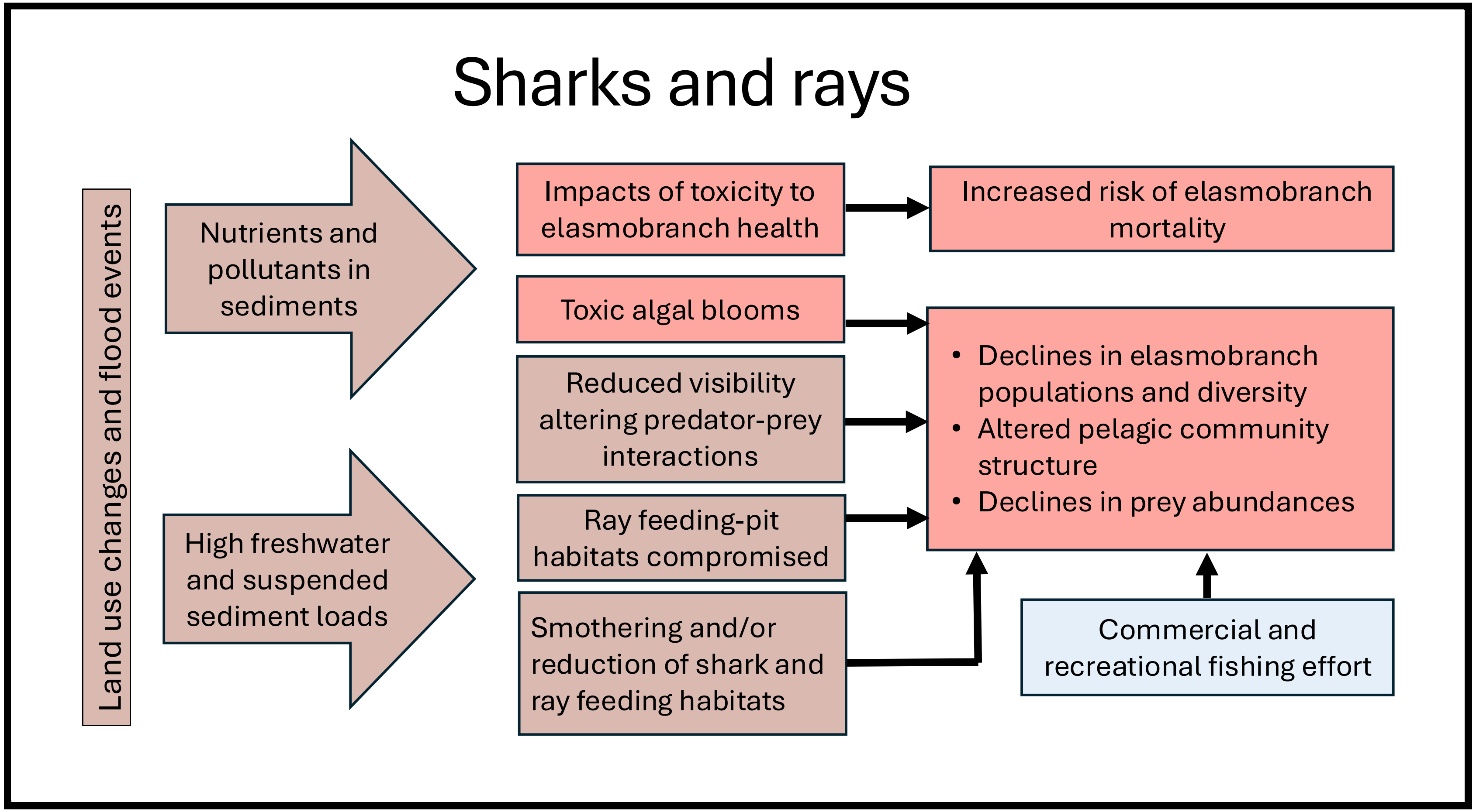
Shark Family/Species	Abundance	IUCN Listing
Orectolobidae		
Banded wobbegong (*Orectolobus halei*)	U	Least Concern
Ornate wobbegong (*Orectolobus ornatus*)	C	Least Concern
Spotted wobbegong (*Orectolobus maculatus*)	C	Least Concern
Hemiscylliidae		
Brownbanded bamboo shark (*Chiloscyllium punctatum*)	A	Near Threatened
Stegostomatidae		
Leopard shark (*Stegostoma tigrinum*)	C	Endangered
Rhincodontidae		
Whale shark (*Rhincodon typus*)	R	Endangered
Hexanchidae		
Bigeye sixgill shark (*Hexanchus nakamurai*)	R	Near Threatened
Squalidae		
Eastern longnose spurdog (*Squalus grahami*)	C	Near Threatened
Shortnose spurdog (*Squalus megalops*)	C	Least Concern
Squatinidae		
Eastern angelshark (*Squatina albipunctata*)	U	Vulnerable

Table 21. List of rays of Moreton Bay and abundance categories: A = abundant, C = common, U = uncommon, R = rare (from Johnson, 2010). Species listings under the IUCN Red List and EPBC Act 1999 are indicated (IUCN listings are taken from www.iucnredlist.org).

Ray Family/Species	Abundance	IUCN Listing
Pristidae		
Green sawfish (*Pristis zijsron*)	R	Critically Endangered
Rhinidae		
Bottlenose wedgefish (*Rhynchobatus australiae*)	C	Critically Endangered
Bowmouth guitarfish (*Rhina Ancylostoma*)	U	Critically Endangered
Rhinobatidae		
Eastern fiddler ray (*Trygonorrhina fasciata*)	U	Least Concern
Eastern shovelnose ray (*Aptychotrema rostrata*)	C	Least Concern
Torpedinidae		
Coffin ray (*Hypnos monopterygius*)	C	Least Concern
Rajidae		
Endeavour skate (*Dipturus endeavouri*)	C	Near Threatened
Sydney skate (*Dipturus australis*)	U	Near Threatened
Dasyatidae		
Australian whipray (*Himantura australis*)	R	Least Concern
Black-spotted whipray (*Maculabatis astra*)	U	Near Threatened
Blue-spotted stingray (*Neotrygon australiae*)	A	Data deficient
Brown whipray (*Maculabatis toshi*)	U	Least Concern
Coral Sea maskray (*Neotrygon trigonoides*)	C	Least Concern
Cowtail stingray (*Pastinachus ater*)	U	Vulnerable
Estuary stingray (*Hemitrygon fluviorum*)	U	Near Threatened
Pink whipray (*Himantura fai*)	U	Vulnerable
Reticulate whipray (*Himantura uarnak*)	C	Endangered
Round ribbontail Ray (*Taeniurops meyenii*)	U	Vulnerable
Thorntail ray (*Dasyatis thetidis*)	U	Vulnerable
Urolophidae		
Common stingaree (*Trygonoptera Testacea*)	U	Near Threatened
Kapala stingaree (*Urolophus kapalensis*)	R	Near Threatened
Yellowback stingaree (*Urolophus sufflavus*)	R	Vulnerable
Gymnuridae		
Australian butterfly ray (*Gymnura australis*)	C	Least Concern
Myliobatidae		
White-spotted eagle ray (*Aetobatus narinari*)	U	Endangered
Myliobatidae		
Cownose ray (*Rhinoptera neglecta*)	C	Data deficient
Japanese devil ray (*Mobula mobula*)	U	Endangered
Purple eagle ray (*Myliobatis hamlyni*)	T	Near Threatened
Pygmy devil ray (*Mobula eregoodoo*)	U	Endangered
Reef manta ray (*Mobula alfredi*)	U	Vulnerable
Southern eagle ray (*Myliobatis tenuicaudatus*)	R	Least Concern

5.10.9 Conceptual model - impacts of sedimentation on sharks and rays

Figure 24. Conceptual model that qualitatively describes the major impacts of sedimentation on shark and ray communities in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes.



5.11 Teleost Fish: Sedimentation Impact Statement

5.11.1 Status and trend summary

Goldspotted sweetlip (Plectorhinchus flavomaculatus)

Table 22 provides a qualitative assessment of the teleost fish communities in Moreton Bay, highlighting their current condition, future trajectory and the impacts of sedimentation. Moreton Bay features a variety of habitats that collectively support a diverse teleost fish fauna ('fish' hereafter). The overall current condition of fish in the Bay is rated as 'Variable', with 'Medium' confidence. This reflects a lack of historic and current information for the status of most fish species. Although most commercially fished species are designated as 'sustainable' in fisheries data, many appear to be on a declining trend. Recreational fishing pressure is very high in Moreton Bay, but catch impacts are largely unknown. As there is ample evidence of modified fish habitats, including evidence of an impacted east-to-west habitat gradient, there is high confidence that sedimentation has driven some of the variability in the current status (condition) of some fish populations.

The condition trend is noted as 'Declining' and with 'High' confidence. This reflects (i) the impacts of sedimentation on key habitats (such corals, shellfish reefs, seagrass beds and soft bottom communities) on which many fish species are dependent, (ii) the decline seen in most commercially fished species, (iii) the large and increasing recreational fishing effort in the Bay, (iv) the impacts of nutrient loads which are causing algal blooms and other system imbalances, (v) the impacts of rising sea temperatures. However, the contribution of sedimentation to the trend is assessed as 'Major' with 'High' confidence. The breadth and impact of these combined pressures is likely to be variable between species. While the impacts of climate change, including the frequency of large floods and associated sediment loads, are on an increasing trend. It also seems clear that, without substantial reversals of habitat loss due to sedimentation, the majority of fish species will remain on a declining trend.

Table 22. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for fish populations in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Variable	Medium
Contribution of sedimentation to the current condition	Variable	High
Condition trend	Declining	High
Contribution of sedimentation to trend	Major	High

5.11.2 Overview

Moreton Bay is recognised as a heterogeneous seascape featuring a mosaic of habitats that collectively support a diverse fish fauna (Olds *et al*., 2019) (Figure 25). The Moreton Bay Marine Park and adjacent continental shelf waters comprise at least 1,138 fish species (Johnson, 2010). This high diversity reflects the Bay's subtropical location, supporting both tropical and subtropical taxa. Approximately one-third of the fish species in the region are at the latitudinal extremes of their known distribution (Olds *et al*., 2019). Fish diversity is typically highest on reefs and seagrass meadows, and comparatively lower in shallow mangroves and over unconsolidated soft sediments (Olds *et al*., 2019).

No-take marine reserves have been enhancing fish abundance and diversity in specific ecosystems, including coral reefs and seagrass meadows, and contributing to the recovery of overfished species (Olds *et al*., 2019). However, this is not necessarily the case in other ecosystems, like estuaries and ocean beaches, where reserves are small and/or shallow, limiting their benefits for fish (Henderson *et* al., 2017; Olds *et al*., 2019; Gilby *et al*., 2019a). Restoration of impacted habitats, such as shellfish reefs, can also contribute to the recovery of fish communities (Gilby *et al*., 2021), including by supporting higher fish species richness and the abundance of harvestable fish (Gilby *et al*., 2019b, c).

5.11.3 Population status

Despite the diverse fish fauna in Moreton Bay, there is little monitoring of the status or health of most fish populations (Dr. Jeff Johnson, Qld Museum, Pers. Comm.). However, fish communities have been well studied in recent times, especially in relation to habitat associations and condition (e.g. Gilby *et al*., 2018, 2021; Henderson *et al*., 2017, 2020, 2021, 2024).

Most commercially fished species (a small subset of the Bay's fish fauna) undergo periodic fishery assessments (Teixeira *et al*., 2021), and their population status is described in section 5.15 Moreton Bay Fisheries: Sedimentation Impact Statement. This section identifies and describes 14 commercially fished species where an assessment for Moreton Bay could be inferred (from state-wide data). Most of these 14 species are assessed as ‘Sustainable’, although almost all show a declining trend in catches.

A broader suite of fish species is also harvested by recreational fishers, including many of the commercially harvested fish species. However, their status is not assessed elsewhere, other than those species involved in the commercial fishery assessments or assessments triggered by national or international listing process for threatened species (e.g. several shark and ray species – see 5.10 Sharks and Rays: Sedimentation Impact Statement).

The fish fauna of mangroves, seagrasses, inshore reefs, and intertidal flats are well sampled (e.g. Tibbetts and Townsend, 2010; Olds *et al*., 2012; Henderson *et al*., 2017;

Gilby *et al*., 2018a; Olds *et al*., 2019; Henderson *et al.,* 2021, 2024). By contrast, fish surveys in saltmarshes, soft sediments, offshore reefs and surf zones are fewer or incomplete (Olds *et al*., 2019). Fish diversity and abundances are typically highest on reefs and seagrass meadows, but most species move among habitats to feed and spawn (Olds *et al*., 2019). These movements connect habitats and link both fish assemblages and food webs across seascapes. However, the combined effects of water quality, coastal urbanisation and fishing also shape fish assemblages in Moreton Bay (Gilby *et* al., 2016; Olds *et al*., 2018, 2019; Henderson *et al*., 2024).

Impacts on populations

Human actions have substantially altered fish assemblages and habitats in Moreton Bay (Olds *et al*., 2019). Sedimentation, pollution and water quality degradation have contributed to declines in the ecological condition of specific habitats like seagrass meadows, coral reefs, and soft-sediment epibenthic communities. These changes in habitat condition have, in turn, altered the composition of fish assemblages and ecological functioning of these ecosystems (e.g. Gilby *et al.,* 2016; Olds *et al*., 2019; Thurstan *et al.,* 2019; Henderson *et al*., 2020). The shorelines of many estuaries and ocean beaches have also been developed, further degrading and reducing natural fish habitats (Olds *et al*., 2019). Current ongoing monitoring will be critical to the continuing understanding of fish populations in Moreton Bay.

Fishing is one of the most significant human pressures on fish in the Bay (Olds *et al*., 2019). Many teleost species are harvested by recreational and commercial fishers (Olds *et al*., 2019). In the Brisbane and Moreton regions in 2019-20, an estimated 350,000 recreational fishers put effort into fishing in this region (Olds *et al*., 2019). However, the impact of these fishers on fish populations is largely unknown.

Changes in water quality have detrimentally impacted fish habitats and led to alterations in fish assemblages in estuaries, seagrass meadows, and coral reefs (e.g. Henderson *et al*., 2017; Gilby *et al*., 2019a; Olds *et al*., 2019; Henderson *et al*., 2024; J. Johnson, Qld Museum, pers. comm.; also see other impact statements in this report). This includes the impacts of sedimentation, which are explored further in the Impacts of sedimentation section below.

Rising sea temperatures have likely led to the movement of some species' distribution to the south of the Bay (e.g. Last *et al*., 2011), such as Luderick (*Girella tricuspidata*) and Golden-lined spinefoot (*Siganus lineatus*) (J. Page, pers. comm.), and are expected to lead to the arrival of more tropical fish species in the Bay (Olds *et al*., 2019). This southern shift in distribution of some historically more tropical species has been a notable change over the past decade or so (Last *et al*., 2011). For example, the Whipfinn silver biddy (*Gerres filamentosus*), the Common ponyfish (*Leiognathus equulus*) and the Black sand bass (*Psammoperca datnioides*), which were absent or rare in Moreton Bay latitudes prior to the 2000s, are now more common (J. Johnson, Queensland Museum, pers. comm.). Such shifts in distribution are also becoming a substantial and additional influence on the structure of Moreton Bay ecosystems and the status of fish populations.

Figure 25. Fishes of Quandamooka, Moreton Bay. (a) Grubfish (Parapercis sp), photo credit: C. van der Berg; (b) Lionfish (Pterois sp.), photo credit: C Roelfseama; (c) Holocentridae sp, Photo credit: C. van der Berg.

5.11.4 Value

Ecological value

The fish in Moreton Bay hold significant ecological value by playing crucial roles in maintaining the health, structure, and functions of the Bay's diverse marine ecosystems (Olds *et al.,* 2019). Fish use a variety of habitats and often migrate between them. There is empirical evidence of fish foraging in diverse habitats like saltmarshes, mangroves, intertidal flats, seagrasses, surf zones, and rocky and coral reefs (Olds *et al.,* 2019). The combination of fish movement and fish ecological functions (e.g. herbivory, predation, scavenging) is essential for sustaining biodiversity, maintaining the structure of food webs, and influencing the composition of benthic communities, including coral reefs, seagrass meadows, and kelp forests (Tibbetts and Townsend, 2010; Pearson and Stevens, 2015; Olds *et al.,* 2019). For example, herbivorous fish actively consume algae that could otherwise overgrow seagrasses and corals (Olds *et al.,* 2019). This grazing activity enhances the resilience and recovery capacity of these ecosystems, particularly after disturbances such as floods (Olds *et al.,* 2019). For example, the Dusky rabbitfish (*Siganus fuscescens*) is a key herbivore on seagrass meadows and coral reefs near mangroves, reducing turf algae cover and increasing coral recruits (Gilby *et al*., 2019a; Henderson *et al*., 2020). Other key grazing fish include acanthurids, pomacentrids, and other siganids (Tibbetts and Townsend, 2010). However, another herbivore, Luderick, appears to have shifted its distribution to south of the Bay (see Impacts on populations section above), demonstrating a potential loss of resilience for some habitats in the Bay.

Cultural value

The fish fauna of Moreton Bay has historically been of immense cultural, social, and economic value to Indigenous Australians, and the region remains an important fishing area for them today (Olds *et al.,* 2019; Thurstan *et al.,* 2019). The Quandamooka people, comprising the Nunukul, Ngugi, Goenpul, and Gubbi Gubbi (also known as Kabi Kabi) peoples, continue to catch fish and shellfish as part of their traditional way of life, with mullet being culturally and economically significant (Thurstan *et al.,* 2019).

Traditional Custodians have a deeply held cultural responsibility, often referred to as a 'custodial ethic', to care for the waterways, which includes looking after fish populations and their habitats (Ross *et al*., 2019a).

Economic value

There are eight fish groups targeted commercially and assessed by QDPI in Moreton Bay: Sea mullet (*Mugil cephalus*), Sea bream (e.g. Yellowfin bream, *Acanthopagrus australis*), whiting (*Sillago spp.*), Tailor (*Pomatomus saltatrix*), Snapper (*Chrysophrys auratus*), flathead (*Platycephalus spp.*), Teraglin (*Atractoscion aequidens*) and Pearl perch (*Glaucosoma scapulare*) (Thurstan *et al.,* 2019). Another 13 species groups are commercially fished in the Bay, along with other regions in Queensland (see 5.15. Moreton Bay Fisheries: Sedimentation Impact Statement). Wild-caught commercial fisheries in Moreton Bay contributed an estimated $24–$30 million per annum to the economy, making it the most important region in the state by volume and value of fish per unit area (Thurstan *et al.,* 2019). The Fisheries Research and Development Corporation (FRDC) information on Queensland fisheries (see www.fish.gov.au/jurisdiction/queensland) indicates that the commercial fish sector in Queensland is dominated by fish species, but also includes a range of sharks, crustaceans, and molluscs (Fisheries Research and Development Corporation, 2023b).

Recreational fisheries are also a significant economic activity in Moreton Bay, and similarly dominated by fish. Common catches include Trumpeter Whiting, Yellowfin Bream, Sand Whiting, Snapper and Tailor (Thurstan *et al.,* 2019). Approximately one-third of Queensland's anglers live in the Brisbane region around Moreton Bay (Thurstan *et al.,* 2019). Direct expenditure by the recreational sector in Moreton Bay is estimated to be between $156 million and $194 million per annum (Thurstan *et al.,* 2019).

5.11.5 History

The history of fish populations in Moreton Bay reveals a dynamic landscape shaped by both natural forces and escalating human impacts, leading to significant alterations in species abundance, diversity, and ecosystem function over time (Olds *et al.,* 2019). For thousands of years prior to European settlement, Indigenous peoples (such as the Quandamooka people) consistently harvested fish from Moreton Bay, with fishing and hunting being central to their cultural identity and practices (Thurstan *et al.,* 2019). However, historical evidence suggests large marine vertebrate populations in the Bay are ‘severely degraded’ compared to pre-human times (Pierce, 2008).

With European settlement beginning in 1824, Moreton Bay was treated as an open-access ‘commons’, leading to unrestricted exploitation of fish and other marine animals for commercial and recreational purposes (Ross *et al.*, 2019b). Indigenous traditional fishing methods were often interrupted or halted (Thurstan *et al.*, 2019). From 1944–1981, commercial catches were dominated by Sea Mullet, Yellowfin Bream, whiting, Tailor, prawns, and crab species; with Sea mullet being the fish landed in the greatest quantities (Thurstan *et al.*, 2019).

Fish assemblages have been substantially altered by human actions for many decades, including water quality degradation, coastal urbanisation, and fishing (Olds *et al.,* 2019). For example, increases in nutrient, phosphate, and metal loading since

European settlement have led to a minimum 10-fold increase in algal production (Diggles, 2013) and subsequent impacts on fish habitats by altering the composition and abundance of fish in estuaries, seagrasses, and coral reefs (Olds *et al.,* 2019). The impacts include changes to the diversity and abundance of fish. Development of shorelines, canals, and artificial lakes has altered fish diversity, abundance, and diet in estuaries and surf zones in a variety of ways, including some species that have adjusted their diet to adapt to urban environments (e.g. Yellowfin bream, Snub-nosed garfish [*Arrhamphus sclerolepis*]) (Olds *et al.,* 2019).

5.11.6 Impacts of sedimentation

The impacts of sedimentation on epibenthic bivalve reefs in Moreton Bay are broadly described in the conceptual model (see Figure *26*). Sedimentation has significantly impacted fish populations and their habitats in Moreton Bay since 1824, primarily due to European land-use practices and urban development (Olds *et al.,* 2019). Increased sediment loads into the Bay have detrimentally impacted critical fish habitats, such as seagrass meadows, coral reefs, estuaries, mangroves, shellfish reefs and soft-sediment communities (Olds *et al*., 2019; Gilby *et al*., 2021). Sediment acts as a sink for persistent pollutants, such as trace elements (including legacy metals), which have shown increasing concentrations since the 1920s due to industrial, agricultural, and urban development (Townsend *et al.,* 2019). During flood events or when water quality is disturbed, these sediment-bound pollutants can be liberated and become toxic to marine life, including fish (Townsend *et al.,* 2019).

Grinham *et al*. (2024) describe the increase in sedimentation in the Bay in recent decades and note that:

- During major flood events, surface water nutrient and turbidity levels are elevated to 10 times above background.
- Fine sediment deposition has now impacted 98% of Moreton Bay.
- Porewater ammonium concentration can be elevated to 1000 times higher than surface waters.
- Annual sediment ammonium flux can be elevated to 180 times larger than the region's point source inputs.
- The 'clean sand' sediment class has been reduced in Moreton Bay from 442 km^2 to 30 km^2 in 50 years.

The elevated turbidity and sediment loads, particularly in the western and southern parts of the Bay, have substantially altered the composition and abundance of fish assemblages (Diggles, 2013). For example, Gilby *et al*. (2021) have shown that the effects of sedimentation and related disease have severely reduced shellfish reefs' biomass in the Bay, substantially reducing the overall carrying capacity for fish (production) in large areas of the Bay. This has now been shown in virtually all habitats in the bay (C. Henderson, pers. comm.). This west-to-east gradient in sedimentation and water quality is reflected in the corresponding decrease in fish diversity and abundance, which typically occurs along this gradient (Olds *et al.,* 2019). Increased sedimentation and turbidity can also lead to reductions in food availability and overall environmental quality, directly affecting fish growth, recruitment, and mortality rates across various trophic levels (Henly *et al.*, 2000).

Overall, Moreton Bay's fish populations, although still diverse, have undergone significant modification. Furthermore, pressures on fish populations in the Bay are likely to be increasing, along with a trend of increasing large floods and their associated sediment loads (Ball *et al.,* 2019; Olds *et al.,* 2019; Henderson *et al.*, 2024). Furthermore, the negative consequences of flooding, such as habitat destruction, water quality degradation, and increased water velocity, can persist for periods of up to several years or more (Henderson *et al.*, 2024). Effective conservation strategies require addressing broad catchment management to reduce sediment and nutrient loads (Diggles, 2013; Gilby *et al.*, 2016). However, achieving significant, scientifically recommended reductions and associated synergistic benefits may face considerable financial and political challenges (Gilby *et al.,* 2016).

5.11.7 Recommendations

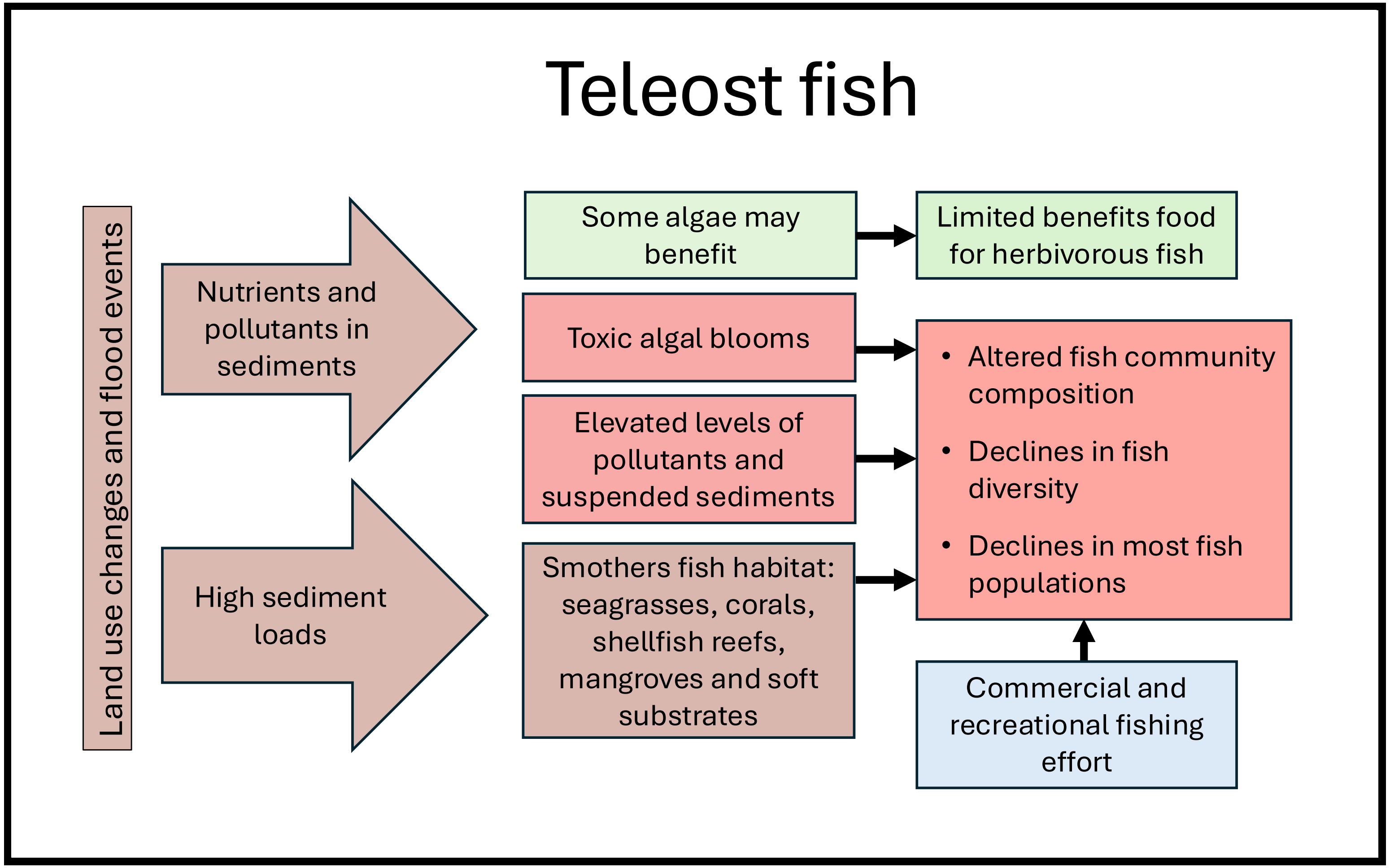
1. A broader "land-to-sea" integrated catchment management framework is necessary to manage the full suite of impacts from catchment-borne sedimentation and water quality degradation that affects coastal ecosystems and has negative impacts on fish yields (Gilby *et al.*, 2018b).
2. Substantially reduce terrestrial runoff to reduce the impacts of sedimentation, eutrophication and hypoxia on key benthic habitats (Gilby *et al.*, 2018b).
3. Place reserves in resilient areas of Moreton Bay where flood impacts, which often bring increased sedimentation, are lower (Gilby *et al.*, 2019a).
4. Prioritising restoration and managing estuarine habitats closer to the mouth of estuaries should be a key target. These areas are frequent transition zones for many fish species and are more likely to recover quickly from disturbances, such as floods, which increase sediment runoff (Henderson *et al.*, 2024).
5. Maximise the extent of natural habitats across estuaries for mediating the effects of floods and maintaining biodiversity and fisheries productivity (Henderson *et al.*, 2024). Maintaining or restoring natural habitats, such as mangrove forests, especially those closer to the estuary mouth, can help mitigate the deleterious effects of nutrient and sediment runoff from urbanised areas. These habitats can buffer waves and absorb nutrients during flood events (Henderson *et al.*, 2024).

5.11.8 Expert review

Dr Christopher (Chris) Henderson (Senior Lecturer in Animal Ecology, University of the Sunshine Coast) kindly provided an expert review of the Teleost fish: Sedimentation Impact Statement.

5.11.9 Conceptual model - impacts of sedimentation on teleost fish

Figure 26. Conceptual model that qualitatively describes the major impacts of sedimentation on fish communities in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes; green boxes indicate likely positive or neutral impacts/outcomes.



5.12 Sea Turtles: Sedimentation Impact Statement

Endangered Green turtle (Chelonia mydas) in Moreton Bay
Photo credit: S. Rabbitt

5.12.1 Status and trend summary

Moreton Bay is an important habitat for six sea turtle species, with most using the Bay as a feeding area. Table 23 provides a combined qualitative assessment of sea turtle populations in the Bay, highlighting their current condition, trend and the impacts of sedimentation. However, most of the species have broad migratory ranges and are subject to many significant threats throughout their ranges. These include interactions with fishing gear, starvation from the ingestion of plastic debris, parasitism (leading to immunosuppression and disease), loss of nesting and feeding habitats due to coastal development and sea level rise, impacts on sex ratios, and other factors. The International Union rates most species for Conservation of Nature (IUCN) as having some level of risk from extinction from one or more of these factors. Hence, their current condition is rated as ‘Poor’ with ‘High’ confidence. Sedimentation and other impacts vary between species. The contribution of sedimentation to turtles’ current condition in the Bay is primarily related to its impacts on seagrass, which Green turtles rely on. This contribution is considered to be ‘Moderate’, with ‘Medium’ confidence.

Although Green turtles show a recent increase in numbers in Moreton Bay, most turtle species in the Bay are in decline or poorly understood. Most threats, such as plastic ingestion, coastal development and sedimentation, exposure to toxic pollutants, sea level rise, and temperature increase, are likely to worsen in the decades ahead - including in Moreton Bay. Hence, the ‘Condition trend’ for sea turtles is rated as ‘Declining’ with ‘High’ confidence. There is also a substantial risk to the condition trend for Moreton Bay turtles from sedimentation and toxic pollutant impacts. This is due to (i) the large-scale coastal development surrounding the Bay and turtles’ dependence on benthic communities for food. These impacts were evidenced after the 2011, 2012 and 2021/22 floods, which led to large sediment load inputs, followed by substantial seagrass loss and major impacts on the epifaunal and infaunal communities on which sea turtle species rely. Hence, the contribution of sedimentation to this condition trend is likely to be ‘Moderate’ within the Bay, diluted to an extent by the broader suite of other significant impacting factors.

Table 23. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, on six species of sea turtles that occur in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Poor	Medium
Contribution of sedimentation to the current condition	Minor	Medium
Condition trend	Declining	High
Contribution of sedimentation to trend	Moderate	Medium

5.12.2 Overview

Moreton Bay is a vitally important habitat for six sea turtle species, with two of these, loggerhead and green turtles, maintaining significant resident populations (Limpus and Coffee, 2019). Moreton Bay is an important feeding habitat for sea turtles. The Green turtle (*Chelonia mydas*), Loggerhead turtle (*Caretta caretta*), Hawksbill turtle (*Eretmochelys imbricata*), Olive ridley turtle (*Lepidochelys olivacea*), and Flatback turtle (*Natator depressus*) are year-round foraging residents in the Bay (Limpus and Coffee, 2019). Leatherback turtles (*Dermochelys coriacea*) are migratory visitors to Moreton Bay, typically present during the autumn and winter months, but are not permanent residents (Limpus and Coffee, 2019).

Both Green and Loggerhead turtles in Moreton Bay are part of substantial foraging populations that contribute annually to nesting populations in the southern Great Barrier Reef (sGBR) and the South Pacific Ocean, respectively (Limpus and Coffee, 2019). While Moreton Bay itself is not a major breeding site for sea turtles, Limpus and Coffee (2019) note that Green and Loggerhead turtles migrate into Moreton Bay waters and nest annually at low density on the ocean beaches of the Bay Islands.

Extensive seagrass meadows are a dominant feature in Moreton Bay, particularly on the eastern side, and serve as crucial habitats for sea turtles (Maxwell *et al*., 2019; Cross *et al*., 2024). Sea turtles are most frequently encountered on the shallow, seagrass-dominated Eastern Banks, adjacent to Dunwich on Minjerribah, and extending northwards along the western face of Moreton Island (Limpus and Coffee, 2019). They also inhabit areas with fringing mangroves and shallow muddy flats in the southern part of the Bay, and throughout Deception Bay in the north-west (Limpus and Coffee, 2019).

Sea turtles generally undergo an ontogenetic (developmental) diet shift from a predominantly carnivorous, open-ocean phase as post-hatchlings to a benthic foraging strategy in coastal waters (Limpus and Coffee, 2019). The habitat and diet preferences of the post-hatchling phase of their life cycles are summarised below.

Green turtles

Green turtles exhibit long-term fidelity to specific foraging sites within Moreton Bay (Limpus and Coffee, 2019). Satellite telemetry indicates home ranges of 128.8 km^2 in the east, 23.7 km^2 in the south, and 121.8 km^2 in the northwest of Moreton Bay (Limpus and Coffee, 2019). Their feeding areas are highly conserved and localised, typically a few kilometres in diameter (Hermanussen *et al*., 2004). These habitats include the shallow, seagrass-dominated Eastern Banks, where they are most commonly encountered (Limpus and Coffee, 2019), as well as the fringing mangroves and shallow, muddy flats at the southern extent of the Bay and in Deception Bay (Limpus and Coffee, 2019).

Green turtles are the only primarily herbivorous sea turtle species (Forbes, 1996). In Moreton Bay, Green turtles are documented as year-round foraging residents (Limpus and Coffee, 2019), grazing mainly on seagrass (*Zostera capricorni* and *Halophila ovalis*) with the less abundant algae also consumed (mainly *Gracilaria sp.* and *Hypnea sp*)

(Limpus and Coffee, 2019; D. Booth, pers. comm.). The consumption of seagrass by green turtles can influence seagrass meadows, with grazing leading to increased leaf regrowth of their preferred species, *Halophila ovalis* (Maxwell *et al.*, 2019). They also opportunistically consume mangrove leaves and propagules (mainly *Avicennia marina*) as well as some gelatinous animal material (e.g. jellyfish) (Limpus and Coffee, 2019). However, after widespread flooding events, when seagrass beds are greatly reduced in abundance, the proportion of mangrove material in diets increases greatly (D. Booth, pers. comm.).

Loggerhead turtles

The Moreton Bay population of Loggerhead turtles is considered one of the most significant in the southern Pacific Ocean (Lanyon, 2019). This is, in part, because Loggerhead turtles are recognised as year-round foraging residents in Moreton Bay and the Bay is one of the most important feeding grounds for the Australian east coast population (Lanyon, 2019).

They use a range of habitats, including intertidal and subtidal seagrass meadows, coral and rocky reefs, and soft-bottom, deeper, subtidal habitats (Limpus and Coffee, 2019). Loggerhead turtles have been observed primarily feeding on portunid crabs, and benthic gastropod and bivalve molluscs (Limpus and Coffee, 2019). They also mine the substrate for infauna (invertebrates buried in the sediment) and consume gelatinous-bodied prey from the mid-water column and surface (Limpus and Coffee, 2019). Their diet can include over 100 different taxa (Limpus and Coffee, 2019).

Hawksbill turtles

Hawksbill turtles are year-round foraging residents in the waters of Moreton Bay, although only in small numbers (Dudgeon *et al.*, 2019; Limpus and Coffee, 2019; D. Booth, pers. comm.). Despite a paucity of specific studies on their foraging ecology, adult Hawksbill turtles are recognised as primarily spongivores but are also known to eat algae, soft corals and other sessile invertebrates (Berube *et al.*, 2012; Goatley *et al.*, 2012; Limpus and Coffee, 2019). In Moreton Bay, they have been observed selectively feeding on large sea anemones on subtidal rocky reefs (Limpus and Coffee, 2019).

Flatback turtles

Flatback turtles forgo a pelagic developmental period and spend their post-hatchling stages through to adulthood in neritic (coastal) foraging environments (Limpus and Coffee, 2019). They are year-round foraging residents in Moreton Bay (Limpus and Coffee, 2019). However, only occur in small numbers in the Bay (D. Booth, pers. comm.). While observations are limited, they are believed to have carnivorous diets, mainly consisting of soft-bodied invertebrates such as sea pens, soft corals, holothurians, and jellyfish (Limpus and Coffee, 2019).

Olive ridley turtles

Olive ridley turtles prefer tropical and subtropical open ocean areas and are characterised as nomadic opportunistic omnivores (Peavey *et al.*, 2017). Hence, they also only occur in small numbers in the Bay (D. Booth, pers. comm.). They do not undergo ontogenetic habitat shifts and may forage in both benthic and pelagic habitats (Peavey *et al*., 2017; Limpus and Coffee, 2019). Their oceanic diet primarily consists of planktonic items or organisms found on or near flotsam, such as algae, crustaceans, and salps, and they often forage through passive drifting (Peavey *et al*., 2017). They are also known to eat gastropods, cnidarians and benthic crustaceans (Peavey *et al*., 2017; Limpus and Coffee, 2019).

Although they are recorded as year-round foraging residents in the waters of Moreton Bay (Limpus and Coffee, 2019), there is no published information about their diet or preferred habitat in the Bay.

Leatherback turtles

Leatherback turtles also only occur in small numbers in the Bay (D. Booth, pers. comm.). They primarily consume a diet of gelatinous macro-zooplankton such as sea pens, jellyfish, soft corals, tunicates, holothurians and siphonophores (Frick *et al*., 2009; Dodge *et al*., 2011; Limpus and Coffee, 2019). They are year-round foraging residents in Moreton Bay and have been regularly reported to feed on the Blue blubber jellyfish (*Catostylus mosaicus*) (Limpus and Coffee, 2019).

5.12.3 Population status

Since the commencement of systematic capture-mark-recapture (CMR) studies in 1990, specific population trends have been observed for key species. Populations have been subject to a range of pressures globally, including the following:

- Entanglement and drowning mortality in fisheries bycatch (Hart *et al*., 2018; Fuentes *et al*., 2023; Mestre *et al*., 2025). However, in Moreton Bay, all otter trawl nets and some beam trawl nets must have an approved Turtle Excluder Device installed (*Queensland Fishery [General] Regulation 2019*), which can exclude most medium and large turtles from drowning within the nets while they are deployed (Brewer *et al*., 2006).
- Starvation mortality due to ingestion of plastic debris (Howell and Shaver, 2021; Fuentes *et al*., 2023; Glen *et al*., 2024; Yenney *et al*., 2024). A survey in Moreton Bay found that 33% of all deceased sea turtles between 2006 and 2011 had ingested marine debris.
- Existing and emerging diseases associated with pathogens and parasites are a growing concern. Historical analysis of stranding data indicates a steady increase in green turtles over the past 20 years, with disease being the primary cause (J. Bowtell, pers. comm.). The most recent comprehensive investigation, conducted by Flint *et al.* (2010), found that 41.8% of green turtle deaths were attributed to parasitism, likely reflecting the influence of external environmental stressors.
- Coastal development and habitat loss. This impacts both nesting and foraging grounds (Hart *et al*., 2018; Howell and Shaver, 2021; Martinez-Estevez *et* al., 2022; Fuentes *et al*., 2023; Glen *et al*., 2024; Read *et al*., 2024) and includes impacts of dredging, aquaculture, and vessel traffic (Fuentes *et al*., 2023).

- Climate change. The primary impact of climate change on sea turtles is through temperature-dependent sex determination, where rising sand temperatures at nesting sites skew sex ratios towards females, threatening reproductive viability (Goatley *et al*., 2012; Fuentes *et al*., 2023; Nguyen, 2025). Climate change also leads to sea-level rise, which impacts nesting beaches and can affect foraging habitats through events like marine heatwaves and storms (Goatley *et al*., 2012; Hart *et al*., 2018; Fuentes *et al*., 2023; Nguyen, 2025).
- Direct harvesting of eggs and meat. This remains a threat, although it has reduced from historical levels (Hart *et al*., 2018; Siegwalt *et al*., 2020; Howell and Shaver, 2021; Fuentes *et al*., 2023; Read *et al*., 2024). There is only a small indigenous take of sea turtles within Moreton Bay, and the nesting beaches for green and loggerhead turtles are protected from egg harvesting (D. Booth, pers. comm.).

As many sea turtle species have very wide global distributions, most of the pressures listed above will be occurring across their distribution range. These will have some impact on the population status of each species in Moreton Bay. The global vulnerability of sea turtles is reflected in Table 24, showing that five of the six species found in the Bay are listed as either Critically Endangered, Endangered or Vulnerable to extinction on the International Union for Conservation of Nature (IUCN) Red List. Hence, the population status of the six species found in the Bay is likely to be influenced by both the broader issues affecting sea turtles globally and local factors. Sea turtles mainly use Moreton Bay as an important feeding ground (see Overview section above) (Limpus and Coffee, 2019) and the quality of those habitats is a focus of this report.

Green turtles

Globally, Green turtles are listed as Endangered by the IUCN (IUCN, 2025) (Table 24), though subpopulation assessments can range more widely (Glen *et al*.,2024; Read *et al*., 2024). The foraging population of green turtles on the eastern banks of Moreton Bay has approximately tripled during the 25 years of CMR studies from 1990 to 2014 (Limpus and Coffee, 2019). This success is linked to a consistently increasing Green turtle nesting population in the southern GBR since strong protections began in 1950, resulting in regular recruitment of new immature sea turtles into Moreton Bay residency (Limpus and Coffee, 2019). Green turtle post-hatchlings are also at known risk of excessive mortality from blockage and compaction of the digestive tract (Howell and Shaver, due to ingestion of plastic debris (Limpus and Coffee, 2019). This aligns with an increase in post-hatchling strandings due to ingestion of plastics noted in the past 5 years (J. Bowtell, pers. comm.).

Loggerhead turtles

Globally, Loggerhead turtles are listed as Vulnerable by the IUCN (IUCN, 2025) (Table 24). Their populations have been declining in Moreton Bay (Limpus and Coffee, 2019), mainly attributed to excessive mortality of small post-hatchlings. Main impacting factors include ingesting plastic debris while travelling in the East Australian Current

(Limpus and Coffee, 2019), along with additional mortality from fisheries bycatch (Brewer *et al*., 2006), and particularly on the west coast of South America, where many juveniles forage (D. Booth, pers. comm.). These mortalities have led to a severely depleted recruitment of young loggerheads into Moreton Bay residency since the early 1990s (Limpus and Coffee, 2019). Additionally, the primary food sources of Loggerhead turtles (e.g. portunid crabs and bivalve molluscs) are also harvested and managed as fishery resources, which may be adding further pressure on their food source (J. Bowtell, pers. comm.).

Hawksbill turtles

Globally, Hawksbill turtles are listed as Critically Endangered (Table 24) and their numbers and habitat continue to decline worldwide (IUCN, 2025; Berube *et al*., 2012; Ferreira *et al*., 2018). Their populations are a fraction of their historical sizes, due mainly to excessive hunting because of the high value of their shell for craftwork and from mortality through encounters with fishing gear (Martinez-Estevez *et* al., 2022; Fuentes *et al*., 2023). However, they have been identified as one of the most abundant species in the Bay in systematic studies that began in 1990 (Limpus and Coffee, 2019).

Flatback turtles

Globally, Flatback turtles are listed as Data Deficient (IUCN, 2025) (Table 24). Although little is known about the population dynamics of Flatback turtles, they occur in areas with large trawling fleets and are known to be caught as trawl bycatch (Brewer *et al*., 2006). They are also known to incur mortality through interactions with ghost nets (discarded fishing gear) (Fuentes *et al*., 2023). Although they are year-round residents in Moreton Bay, they are not among the most abundant marine turtle species in the Bay (Limpus and Coffee, 2019).

Olive ridley turtles

Globally, Olive Ridley turtles are listed as Vulnerable (IUCN, 2025) (Table 24). One of the main impacts on their populations is through interactions with prawn trawl nets (e.g. Brewer *et al*., 2006). Although they are year-round residents in Moreton Bay, they are not among the most abundant marine turtle species in the Bay (Limpus and Coffee, 2019).

Leatherback turtles

Globally, Leatherback turtles are listed as Vulnerable (IUCN, 2025) (Table 24). However, their populations in the Pacific are critically endangered and continue to decline (Hays, 2008; Fuentes *et al*., 2023, J. Bowtell, pers. comm.). They have suffered ‘heavy declines’ due to interactions with fishing gear (Fuentes *et al*., 2023), but also due to prey limitation in the Pacific Ocean (Hays, 2008) and from a decrease in hatching success due to toxic pollutants (Martins *et al*., 2020; Fuentes *et al*., 2023).

They are migratory visitors to Moreton Bay, primarily during autumn and winter (Limpus and Coffee, 2019), and are therefore not considered abundant in the Bay. However, the frequency of encounters with leatherback turtles in the Moreton Bay region has substantially declined in recent decades (Limpus and Coffee, 2019).

Table 24. List of the six resident or regularly visiting sea turtles of Moreton Bay, noting their trend and categorisation under the IUCN Red List (IUCN listings are taken from www.iucnredlist.org). Colours used are based on the IUCN Red List.

Sea turtle species	IUCN Trend	IUCN Listing
Loggerhead turtle (*Caretta caretta*)	Decreasing	Vulnerable
Green turtle (*Chelonia mydas*)	Increasing	Endangered
Hawksbill turtle (*Eretmochelys imbricata*)	Decreasing	Critically endangered
Flatback turtle (*Natator depressus*)	Unknown	Data deficient
Olive ridley turtle (*Lepidochelys olivacea*)	Unknown	Vulnerable
Leatherback turtle (*Dermochelys coriacea*)	Declining	Vulnerable

5.12.4 Value

Ecological value

Sea turtles in Moreton Bay hold significant ecological value through their interactions with various habitats. Green turtles are important herbivores, grazing on algae and seagrass within the Bay (Limpus and Coffee, 2019; Maxwell *et al*., 2019; Sanchez *et al*., 2024). This grazing can influence the primary producer community structure and dynamics, and has been shown to increase leaf regrowth of preferred seagrass species, such as *Halophila ovalis* (Goatley *et al*., 2012; Maxwell *et al*., 2019; Sanchez *et al*., 2024).

Other species, such as Loggerheads, Hawksbills, Flatbacks and Olive ridleys, are carnivores that feed on various invertebrates and gelatinous prey (Limpus and Coffee, 2019; Glen *et al*., 2024). Hawksbill turtles, for example, help maintain healthy reef systems by consuming sessile invertebrates (like sponges) that compete with corals (Goatley *et al*., 2012; Martins *et al*., 2020; Sanchez *et al*., 2024).

Collectively, sea turtles contribute to the health and maintenance of seagrass beds and coral reefs, acting as biological transporters that introduce marine nutrients and energy to coastal ecosystems (Martins *et al*., 2020; Fuentes *et al*., 2023; Cross *et al*., 2024). They are considered essential for maintaining ecosystem functions and specific diversity within marine environments, such as Moreton Bay (Martins *et al*., 2020; Siegwalt *et al*., 2020; Cross *et al*., 2024).

Cultural value

Sea turtles hold significant cultural value for Indigenous people in Moreton Bay. They are considered sacred Aboriginal totems for saltwater people in coastal areas (Ross *et al*., 2019a), as demonstrated by their presence in Quandamooka Dreaming stories (Delaney, 2013). Historically, sea turtles were hunted for food by local Indigenous people in Moreton Bay, a practice that continued following European settlement until 1950 (Limpus and Coffee, 2019). For the Quandamooka people of

Moreton Bay, traditional hunting and fishing practices, including the use of seafood, are an important affirmation of cultural identity and continue to be an essential aspect of their lives (Townsend *et al.*, 2019).

Economic value

Sea turtles in Moreton Bay have historically held economic value primarily through commercial hunting and as a traditional food source (see Cultural value section above). Following the arrival of European settlers, sea turtles were hunted commercially in Moreton Bay from 1824 to 1950 (Limpus and Coffee, 2019). Prior to European colonisation and continuing after, sea turtles were also a traditional food source for the local Indigenous people in Moreton Bay (Limpus and Coffee, 2019).

Sea turtles contribute significantly to the biodiversity of Moreton Bay, particularly to the visible megafauna community, which supports the growing ecotourism activity in the Bay.

5.12.5 History

The shallow coastal waters of Moreton Bay have continuously supported marine turtle populations since sea levels rose after the last ice age (Limpus and Coffee, 2019). In recent history, sea turtles in Moreton Bay were hunted for food by local Indigenous people, then subject to commercial hunting by European settlers from 1824 to 1950 (Limpus and Coffee, 2019). Populations of sea turtles have been impacted differently in recent decades, as described above (see Population status and Value sections). Green turtles have increased in numbers since strong protections were introduced in the southern GBR (Limpus and Coffee, 2019). However, three species – Loggerhead, Hawksbill and Leatherback turtles – are all in decline (see Population status section above).

5.12.6 Impacts of sedimentation

The impacts of sedimentation on sea turtles in Moreton Bay are broadly described in the conceptual model (**Error! Reference source not found.**). Sedimentation is a local stressor in Moreton Bay that interacts synergistically with other factors like coral bleaching, acidification and diseases, contributing to the decline in the extent and health of reef, seagrass and other benthic habitats that sea turtle species are reliant on (Berube *et al.*, 2012; Bjorndal *et al.*, 2017). Smothering of these habitats by terrestrial mud deposits following major flood events in the Bay can ultimately affect sea turtles and other marine species (Grinham *et al.*, 2024). Elevated nitrogen from these deposits can also support toxic algal blooms, which can further lead to the smothering of seagrass (Grinham *et al.*, 2024).

Sedimentation can suppress herbivory (grazing) by herbivorous turtles on algal turfs and seagrass beds. It reduces the accessibility of these food resources and hence, the energy uptake per bite for Hawksbill and Green turtles (Goatley *et al.*, 2012; Bjorndal *et al.*, 2017).

Hawksbill turtles rely on sponges and other sessile invertebrates found on coral reefs (Berube *et al*., 2012; Martins *et al*., 2020; Martinez-Estevez *et al*., 2022; Sanchez *et al*., 2024). The degradation of coral reefs due to sedimentation (see 5.8 Hard Corals: Sedimentation Impact Statement) directly diminishes the health and extent of these essential food resources (Berube *et al*., 2012; Bjorndal *et al*., 2017).

Loggerhead turtles rely on benthic epifauna and infauna, including filter and suspension feeders (see Overview section above), as part of their diet. Most of these benthic groups are impacted by sedimentation through smothering or burying the organisms, or through excess exposure to suspended sediments (Saeck *et al*., 2019a; see 5.7 - Benthic Macrofauna – Sedimentation Impact Statement). Suspended sediments can impact water clarity and hence, seagrass and algal photosynthesis, and can affect the feeding success for filter and suspension feeders. The change in the bay from predominantly sandy to muddy bottoms across Moreton Bay increased from approximately 30% in 1998 to 70% in 2011 (Saeck *et al*., 2019a). This alteration of the substrate can permanently change habitats, making them unsuitable for species, including filter and suspension feeders, that are adapted to sandy environments (Saeck *et al*., 2019a).

The accumulation of pollutants in seagrass beds, which have been trapped in terrigenous sediments, exposes herbivorous Green turtles to pollutants such as dioxins (Hermanussen *et al*., 2004). Elevated concentrations of dioxins, comparable to those found in highly polluted areas in the Northern Hemisphere, have been observed in Moreton Bay's Green turtles (Hermanussen *et al*., 2004). This exposure is a concern, as a higher incidence of poor health, including fibropapilloma (tumour growth), has been observed in Green turtles from the more riverine-influenced southwestern feeding grounds. This is particularly evident when compared to less-impacted northeastern populations in the Bay, which may be correlated with these contaminant patterns (Hermanussen *et al*., 2004). This seagrass degradation can often lead to stress or alteration of the natural diet for prolonged periods of time, leading to immunosuppression and susceptibility to disease processes (J. Bowtell, pers. comm.).

5.12.7 Recommendations

1. Reduce marine debris at its source across all levels of government (local, state, national). This is critically important, as sea turtles frequenting the Bay and its surroundings experience significant impacts from debris ingestion (Townsend *et al*., 2019).
2. Continue to implement and enforce Moreton Bay Marine Park green zones and mandatory 'go slow' areas for recreational and commercial vessels, as these areas are designated high-use foraging sites for sea turtles (Limpus and Coffee, 2019; Pascoe *et al*., 2025).
3. Prioritise continued research and careful management of seagrass communities, which are critical for sea turtles and face ongoing threats (Maxwell *et al*., 2019).

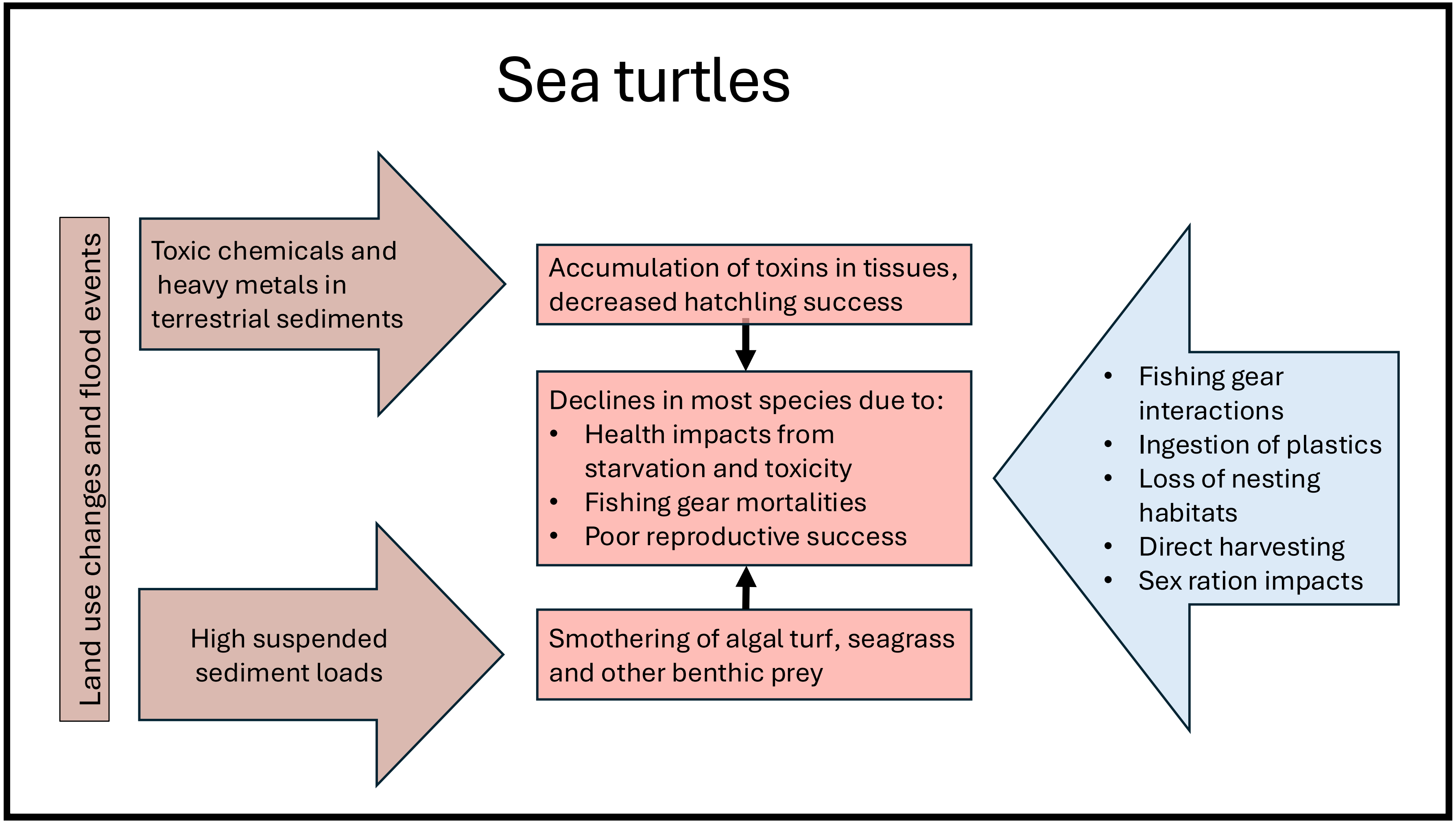
4. Reduce sediment loads which impact seagrass beds, algae and other benthic food sources. This will directly benefit sea turtles by increasing the quality of their food sources (Goatley *et al.*, 2012).
5. Evaluate spatial relationships between dioxin exposure and the health status of Green turtles to identify 'hotspots' for prioritised evaluations (Hermanussen *et al.*, 2004).
6. Develop and implement new strategies to reduce persistent pollutants (such as organic pollutants, trace elements, dioxins and perfluoroalkyl substances) entering Moreton Bay (Townsend *et al.*, 2019).
7. Increase biomonitoring of trace elements and other chemicals in sea turtles, using established baselines, and conduct further species-specific toxicological research to understand health risks and inform water quality guidelines (Townsend *et al.*, 2019).
8. Continue systematic capture-mark-recapture (CMR) studies and other research to gain further insights into the diet, habitat use, physiology, toxicology, genetics, and population dynamics of resident turtle populations (Limpus and Coffee, 2019).
9. Address primary sources of anthropogenic mortality, including boat strikes, entanglement in crab pots and fishing gear, and ingestion of synthetic debris (Limpus and Coffee, 2019).
10. Ongoing assessments of sea turtle food availability and nutritional quality and metabolic demands, coupled with gut microbiome analysis to improve understanding of how such changes can impact health.

5.12.8 Expert reviews

Dr David Booth (University of Queensland) and Dr Jacob Bowtell (University of the Sunshine Coast) kindly provided an expert review of the Sea Turtles: Sedimentation Impact Statement.

5.12.9 Conceptual model - impacts of sedimentation on sea turtles

Figure 27. Conceptual model that qualitatively describes the major impacts of sedimentation on sea turtle populations and health in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes.



5.13 Shorebirds: Sedimentation Impact Statement

Vulnerable Bar-tailed godwits at Oyster Point, Cleveland Photo credit: C. Walker

5.13.1 Status and trend summary

Moreton Bay remains a globally important site for migratory shorebirds, but its populations face complex challenges from both flyway-wide habitat loss and increasing local pressures. Table 25 provides a qualitative assessment of shorebird communities in Moreton Bay, highlighting their current condition, future trajectory and the impacts of sedimentation. The overall current condition of shorebirds in the Bay is rated as 'Fair', with 'High' confidence. This reflects studies that have indicated nine species are listed on the International Union for Conservation of Nature (IUCN) Red List as either Critically Endangered, Endangered, Vulnerable, or Near Threatened.

The condition trend is noted as 'Declining', with 'High' confidence. This mainly reflects local studies which note that 12 of 22 migratory shorebird species are in decline, mainly due to habitat loss and degradation, especially of intertidal mudflats in other regions of their international flyways. It is also important to note that resident coastal shorebird species have shown stable or increasing populations in the past. However, the underpinning analysis requires updating.

While sedimentation events (floods) are hypothesised to negatively impact prey availability, the observed short-term effects of sedimentation on shorebird numbers have been described as weak and/or of very short duration. A more widespread negative impact of sedimentation in Moreton Bay appears to be its role in mangrove encroachment and smothering of intertidal benthos, which reduces crucial open roosting and foraging habitats. However, managing material from shipping channel maintenance dredging has led to the creation of important artificial roosting habitats and the reuse of spoil, which has positively contributed to shorebird conservation by providing vital artificial roosting habitats at the Port of Brisbane. Hence, the contribution of sediment to the general declining trend for shorebirds is rated as 'Minor' with 'Medium' confidence.

Table 25. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, on shorebird populations in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Fair	High
Contribution of sedimentation to the current condition	Minor	Medium
Condition trend	Declining	High
Contribution of sedimentation to trend	Minor	Medium

5.13.2 Overview

Moreton Bay is an internationally important Ramsar wetland located at the terminus of the East Asian–Australasian Flyway (Clemens *et al*., 2012; Fuller *et al*., 2021), stretching from the Alaskan and Siberian breeding grounds down to Australia and New Zealand (Fuller *et al*., 2021). The Bay hosts a diverse range of shorebirds (e.g. Figure 28), with at least 32 species of migratory shorebirds observed during monitoring by the Queensland Wader Study Group (Fuller *et al*., 2021). Another 15 species of resident shorebirds have also been recorded from studies in the Bay (Table 28).

The Bay supports approximately 35,000 migratory shorebirds during the non-breeding season and has historically supported up to 50,000 migratory shorebirds (Lloyd *et al*., 2024). Thousands of young shorebirds also use it as a year-round nursery (Fuller *et al*., 2021). The Bay holds internationally important numbers (over 1% of the total flyway population) of nine migratory shorebird species, with a tenth species having exceeded this threshold at least once (Clemens *et al*., 2012; Fuller *et al*., 2021; Lloyd *et al*., 2024). Additionally, five species regularly occur in nationally important numbers (at least 0.1% of the population), and five more have exceeded this threshold at least once (Fuller *et al*., 2021).

5.13.3 Population status

Despite its global importance, the shorebird populations of Moreton Bay have declined rapidly in recent decades (Wilson *et al*., 2011). Global declines are attributed mainly to habitat loss and degradation, especially of intertidal mudflats in the Yellow Sea region, where over 50% loss has occurred (Murray *et al*., 2014; Studds *et al*., 2017). The IUCN Red Listings for 34 species that occur in the Bay also highlights the declining status for about two-thirds (23) of the species (Table 26, Table 27).

Studies also confirm that local threats within Moreton Bay may also play a role (Dhanjal-Adams *et al*., 2019). Some species may be impacted by long-term reduction in their primary food source: benthic macrofauna (Clemens *et al*., 2012) (see 5.7 – Benthic Macrofauna: Sedimentation Impact Statement). For example, Far Eastern Curlew (*Numenius madagascariensis*), Grey Plover (*Pluvialis squatarola*), and Red-necked Stint (*Calidris ruficollis*) have shown significant declining trends in their average summer counts at the Port of Brisbane between 2002 and 2022 (Lloyd *et al*., 2024). However, this trend is not consistent across all migratory species. For example, Whimbrels (*N. phaeopus*), which are not subject to habitat loss on the flyway, show stable populations in Moreton Bay (P. Lloyd, pers. comm.). Bar-tailed Godwit (*Limosa lapponica*), Great Knot (*C. tenuirostris*), and Broad-billed Sandpiper (*C. falcinellus*) have shown significant increasing trends at the Port during the same period (Lloyd *et al*., 2024).

Moreton Bay supports critically endangered species such as the Far Eastern Curlew, Curlew Sandpiper (*C. ferruginea*), and Great Knot (Wilson *et al.*, 2022). The Bay is one of the most critical non-breeding areas globally for the Far Eastern Curlew, regularly hosting just under 10% of the remaining world population (over 3,000 individuals) (Fuller *et al.*, 2021).

The Bar-tailed Godwit is the most abundant migratory shorebird in Moreton Bay, with counts regularly exceeding 10,000 individuals in summer (Fuller *et al.*, 2021). Curlew Sandpipers (*C. ferruginea*) are often observed in internationally important numbers at the Port of Brisbane, and Moreton Bay may be acting as a 'safe haven' for this nationally declining species (Fuller *et al.*, 2021).

Lesser Sand Plovers (*Charadrius mongolus*) occur in internationally important numbers (regularly exceeding 1,900 birds) in Moreton Bay, particularly relying on the Port of Brisbane (Fuller *et al.*, 2021). Red-necked Stints regularly occur in internationally important numbers (around 5,000 annually), with the Port of Brisbane being a frequent site for this species (Fuller *et al.*, 2021). Terek Sandpipers (*Xenus cinereus*) and Whimbrels are also found in internationally important numbers, though often in less accessible mangrove habitats, which can make accurate counting challenging (Fuller *et al.*, 2021).

Resident coastal shorebird species in Australia, such as the Australian Pied Oystercatcher (*Haematopus longirostris*) and the Sooty Oystercatcher (*H. fuliginosus*), have shown stable or increasing populations, unlike the declining migratory species (Wilson *et al.*, 2011; Clemens *et al.*, 2016). However, the underpinning analysis requires updating (R. Fuller, pers. comm., August 2025). In comparison, resident species that rely on inland wetlands, like Red-necked Avocet (*Recurvirostra novaehollandiae*), Black-winged Stilt (*Himantopus Himantopus*), Red-kneed Dotterel (*Erythrogonys cinctus*), and Black-fronted Dotterel (*Elseyornis melanops*) have shown significant declines (Clemens *et al.*, 2016).

The Port of Brisbane's Fisherman Islands is the single most important roosting area in Moreton Bay, regularly supporting about 20% and up to 39% of the bay's migratory shorebirds, including internationally significant numbers of six species (Lloyd *et al.*, 2024). The dredge reclamation ponds at Fisherman Islands have consistently supported 79-94% of the migratory shorebirds roosting at the port, highlighting the crucial role of artificially created sites in shorebird conservation (Lloyd *et al.*, 2024). Studies on foraging distribution in northern Moreton Bay show marked spatial variation in bird density, with some areas experiencing significant overlap between foraging birds and human recreational disturbance, particularly from off-leash dogs (Stigner *et al.*, 2016).

The most widespread threats to roosting sites are human disturbance (67 of 218 sites studied), development (43 sites), and mangrove encroachment, reducing visibility and space (25 sites) (Fuller *et al.*, 2021). Sea-level rise is an ultimate threat that exacerbates proximate threats like inundation of claypans, overgrowth of roost sites with mangroves, and loss of saltmarsh habitats (Fuller *et al.*, 2021). Off-leash dogs are a significant disturbance to foraging shorebirds at low tide, reducing bird numbers at a site by about 20% (Dhanjal-Adams *et al.*, 2015). Local losses of tidal flats to development have occurred, particularly around the Port of Brisbane, although the overall extent of tidal flats in Moreton Bay has remained relatively stable (Fuller *et al.*, 2021).

Benthic prey densities are also variable across the bay's intertidal flats, which influences shorebird foraging success (Fuller *et al.*, 2021). For example, Nudgee had a high density of polychaetes, consistent with the presence of large numbers of feeding shorebirds, while Sandgate had low densities (Fuller *et al.*, 2021).

Moreton Bay remains a globally important site for migratory shorebirds. Still, its populations face complex challenges from both flyway-wide habitat loss and increasing local pressures, necessitating continued monitoring and active management (Fuller *et al.*, 2021).

Table 26. A summary of 34 migratory shorebirds noted in Moreton Bay summarising: (i) the current listing status on the IUCN Red List (www.iucnredlist.org) and (ii) their population trend, where it is noted according to the recent literature (based on Clemens et al., 2016; Fuller et al.,2021). See Table 27for species-specific detail.

IUCN Listing	No. of Shorebird species	Population trend	No. of Shorebird species
Critically endangered	3	Decreasing	23
Endangered	2	Stable	5
Vulnerable	2	Increasing	4
Near threatened	5		
Least concern	22		

5.13.4 Value

Ecological value

Shorebirds in Moreton Bay hold significant ecological value primarily through their multifaceted impacts on intertidal mudflat ecosystems (Booty *et al.*, 2020). Shorebirds act as ecosystem engineers, directly influencing crucial ecosystem functions on intertidal mudflats, such as erosion protection, nutrient cycling, and carbon sequestration (Booty *et al.*, 2020). Their foraging activities, including bioturbation (physical disturbance from walking and feeding) and/or grazing of microphytobenthic biofilms, can lower the sediment's critical erosion threshold, making the mudflats less stable and more susceptible to erosion (Booty *et al.*, 2020). They significantly alter nutrient fluxes (e.g., nitrate, nitrite, phosphate and dissolved organic carbon) between the sediment and the water column (Booty *et al.*, 2020).

As primary consumers, shorebirds forage extensively on soft-sediment macroinvertebrates, including crustaceans, polychaetes, bivalves, and gastropods (Fuller *et al.*, 2021). This predation can exert significant top-down effects on the functioning of mudflat ecosystems (Booty *et al.*, 2020). Shorebirds and their population trends can serve as important integrators and indicators of the health and changing environmental conditions of mudflat ecosystems (Booty *et al.*, 2020).

Cultural value

Shorebirds in Moreton Bay hold significant cultural value, particularly for the Quandamooka People (Fuller *et al*., 2021). Their ecological value is interwoven with the Bay's broader 'outstanding environmental and cultural values' (Dean *et al.,* 2019; Nasplezes *et al.,* 2019). While specific shorebird species are not explicitly named as sacred Aboriginal totems, place names often reflect cultural ties to abundant local fauna, indicating a deep cultural connection to the Bay's wildlife (Pinner *et al*., 2019).

Economic value

The economic value of shorebirds in Moreton Bay is primarily indirect, stemming from their crucial role in maintaining healthy intertidal ecosystems that underpin various services and activities (Booty *et al*., 2020). Shorebirds contribute to vital ecosystem functions on intertidal mudflats, including erosion protection, nutrient cycling, and carbon sequestration (Booty *et al*., 2020). These functions help sustain the overall health and resilience of the Bay, which in turn supports other economically valuable activities.

Shorebirds contribute to the Bay's 'outstanding environmental and cultural values' (Dean *et al.,* 2019), which attract recreational users and tourists (Ross *et al*., 2019b; Pascoe *et al*., 2025). The presence of diverse and unique species, including shorebirds, provides 'important opportunities for scientific research and education' (Ross *et al*., 2019a). For instance, artificial shorebird habitats at the Port of Brisbane double as an 'educational facility visited by around 300 school children every year' (Lloyd *et al*., 2024). Birdwatching is also a recreational activity valued in the Bay (Ross *et al*., 2019b).

Significant economic resources are invested in the conservation and management of shorebirds, including the creation and ongoing maintenance of artificial roosting habitats like those at the Port of Brisbane and Manly Harbour (Fuller *et al*., 2021; Lloyd *et al*., 2024). These sites accommodate a substantial proportion of Moreton Bay's migratory shorebird population (up to 39% at the Port of Brisbane alone) (Fuller *et al*., 2021), demonstrating the value of committed financial allocations to enhance habitat options for shorebirds.

5.13.5 History

The population dynamics of shorebirds in Moreton Bay reveal a complex picture, generally characterised by declines in migratory species but with some localised increases and a more stable population trend for resident species (Clemens *et al*., 2016). Historically, many migratory shorebird populations in the East Asian-Australasian Flyway, of which Moreton Bay is a crucial part, have been rapidly declining. Australian citizen-science data from 1973 to 2014 indicated continental decreases in 12 of 19 migratory shorebird species, and in 17 of 19 species in southern Australia over the past 15 years (Clemens *et al*., 2016).

Table 27. List of 34 migratory or resident shorebirds of Moreton Bay noting their trend categories where published (1993-2008, Clemens et al., 2016) and listings under the IUCN Red List (taken from www.iucnredlist.org).

Shorebird Species	Trend	IUCN Red List Listing
Asian Dowitcher (*Limnodromus semipalmatus*)	Decreasing	Near Threatened
Bar-tailed Godwit (*Limosa lapponica*)	Increasing	Near Threatened
Bar-tailed Godwit (subspp *L. lapponica baueri)*	Decreasing	Vulnerable
Beach thick-knee (*Esacus magnirostris*)	Decreasing	Near Threatened
Black-tailed Godwit (*Limosa limosa*)	Decreasing	Near Threatened
Broad-billed Sandpiper (*Limicola falcinellus*)	Increasing	Least Concerned
Buff-breasted Sandpiper (*Calidris subruficollis*)	Decreasing	Vulnerable
Common Greenshank (*Tringa nebularia*)	Decreasing	Least Concerned
Common Sandpiper (*Actitis hypoleucos*)	Decreasing	Least Concerned
Curlew Sandpiper (*Calidris ferruginea*)	Decreasing	Critically Endangered
Double-banded Plover (*Charadrius bicinctus*)	Stable	Least Concerned
Far Eastern Curlew (*Numenius madagascariensis*)	Decreasing	Critically Endangered
Great Knot (*Calidris tenuirostris*)	Increasing	Critically Endangered
Greater Sand Plover (*Charadrius leschenaultii*)	Decreasing	Least Concerned
Grey Plover (*Pluvialis squatarola*)	Decreasing	Least Concerned
Grey-tailed Tattler (*Tringa brevipes*)	Increasing	Least Concerned
Latham's Snipe (*Gallinago hardwickii*)	Decreasing	Least Concerned
Lesser Sand Plover (*Charadrius mongolus*)	Decreasing	Endangered
Little Curlew (*Numenius minutus*)	Decreasing	Least Concerned
Long-toed Stint (*Calidris subminuta*)	Decreasing	Least Concerned
Marsh Sandpiper (*Tringa stagnatilis*)	Stable	Least Concerned
Oriental Plover (*Charadrius veredus*)	Stable	Least Concerned
Pacific Golden Plover (*Pluvialis fulva*)	Decreasing	Least Concerned
Pectoral Sandpiper (*Calidris melanotos*)	Unknown	Least Concerned
Red Knot (*Calidris canutus*)	Decreasing	Endangered
Red-necked Stint (*Calidris ruficollis*)	Decreasing	Near Threatened
Ruddy Turnstone (*Arenaria interpres*)	Decreasing	Least Concerned
Ruff (*Calidris pugnax*)	Decreasing	Least Concerned
Sanderling (*Calidris alba*)	Stable	Least Concerned
Sharp-tailed Sandpiper (*Calidris acuminata*)	Decreasing	Least Concerned
Terek Sandpiper (*Xenus cinereus*)	Decreasing	Least Concerned
Wandering Tattler (*Tringa incana*)	Unknown	Least Concerned
Whimbrel (*Numenius phaeopus*)	Decreasing	Least Concerned
Wood Sandpiper (*Tringa glareola*)	Stable	Least Concerned

This declining trend is consistent with the general reduction in migratory shorebirds returning to Moreton Bay each year from their breeding grounds (Fuller *et al.*, 2021). While habitat loss along migration routes, particularly in the Yellow Sea, is a major driver of these declines, local threats within Moreton Bay have also played a role (Fuller *et al.*, 2021).

Long-term monitoring data from 2002 to 2023 at the Port of Brisbane, a significant roosting site for shorebirds in Moreton Bay, provide more specific insights into the changes in population dynamics described above for a range of species (Lloyd *et al.*, 2024). The data indicate some species have shown significant decreasing trends and others have significant increasing trends. The four most common resident shorebird species (Pied Oystercatcher, Pied Stilt [*H. leucocephalus*], Red-capped Plover [*C. ruficapillus*], Red-necked Avocet) at the Port of Brisbane showed no significant long-term trend in their average annual counts from 2002 to 2022 (Lloyd *et al.*, 2024).

5.13.6 Impacts of sedimentation

The impacts of sedimentation on shorebird communities in Moreton Bay are broadly described in the conceptual model (see Figure 29). Moreton Bay is a dynamic environment where shorebird communities and populations are influenced by various factors as discussed above (see History and Population status sections), including the impacts of sedimentation. However, literature detailing the direct impact of sedimentation on seabirds and shorebirds is scant (Lukies *et al.*, 2021).

Shorebirds primarily forage on soft-sediment macroinvertebrates on intertidal mudflats during low tide to meet high energy demands, especially during migration (Athira *et al.*, 2022). It is hypothesised that sedimentation associated with major river flooding could have an immediate adverse effect on benthic invertebrate food availability for shorebirds on tidal flats (Clemens *et al.*, 2012). It reduces light penetration, smothers the seafloor and changes the composition of marine ecosystems (Lukies *et al.*, 2021). Sediments can clog the filters of filter-feeding macroinvertebrates, leading to reduced body condition, growth rates, or even direct mortality. Consequently, sediment-impacted areas are likely to support fewer shorebirds (Lukies *et al.*, 2021).

There is some evidence of a long-term decline in invertebrate densities along the mainland coast of Moreton Bay between 1997 and 2012, with a particularly rapid decline observed at Nudgee (Clemens *et al.*, 2012). A steady decline in the numbers of invertebrate animals was observed in the mid-intertidal and intertidal fringe sediments at three western Moreton Bay locations (Burpengary Creek, Nudgee Beach, and Tingalpa Creek), with a 7-8 fold reduction over 15 years in some areas (Clemens *et al.,* 2012). Indicative benthic sampling in northern Moreton Bay revealed spatially variable densities of potential prey, which in turn influenced shorebird abundance and diversity. For instance, Nudgee had a very high density of polychaetes, consistent with the presence of large numbers of feeding shorebirds, while Sandgate had low densities (Fuller *et al.*, 2021). Such declines in benthic invertebrates might have substantially reduced the carrying capacity of Moreton Bay over time. Still, it is possible that the effect on shorebirds could have been masked to some extent because they are also declining due to habitat loss in the Yellow Sea (R. Fuller, pers. comm., August 2025).

Despite the hypothesis of negative impacts, analyses of migratory shorebird numbers following three recent severe weather events (and associated sediment influxes) found no consistent changes in abundance directly attributable to these events across Moreton Bay (Clemens *et al*., 2012). The observed impacts were described as 'weak and/or of very short duration' (Fuller *et al*., 2021; Lloyd *et al*., 2024). After the January 2011 flood, an immediate displacement of about 2,000 shorebirds occurred in Moreton Bay, but numbers and distributions had returned to normal by the following summer (Clemens *et al.* 2012). Notably, after this flood, while some areas experienced a decline in bird numbers, the Port of Brisbane roosts saw an increase in migratory shorebirds, especially smaller species, suggesting a movement of birds to these alternative sites (Lloyd *et al*., 2024).

Mangrove growth poses a significant threat to shorebird roosting sites in Moreton Bay, particularly at 25 identified locations within the Bay (Fuller *et al*., 2021). Mangrove encroachment reduces the open space and visibility that shorebirds require for roosting (Fuller *et al*., 2021). Sedimentation plays a role in this process, as mangroves can trap sediment, which can dry out and potentially facilitate the movement of introduced predators (like cats and other pest mammals) into shorebird roost sites (Lukies *et al*., 2021). Regenerating mangroves, often enabled by sediment accumulation, can displace critical shorebird foraging and roosting habitats such as saltmarsh, seagrass beds, and bare sand/shell banks (Lukies *et al*., 2021). This displacement can alter the distribution and abundance of shorebirds (Lukies *et al*., 2021). The threat of mangrove expansion and saltmarsh decline is expected to be exacerbated by sea-level rise, which is predicted to lead to the 'overgrowth of roost sites with mangroves' (Fuller *et al*., 2021).

Conversely, human management of sediment has created important habitat for shorebirds in Moreton Bay. The Port of Brisbane reuses large volumes of dredged sediment to create new land, which has inadvertently or intentionally resulted in the creation of temporary and permanent shorebird habitats (Lloyd *et al*., 2024). The dredge reclamation ponds at the Port of Brisbane have consistently supported 79-94% of the migratory shorebirds roosting there, highlighting the significant role that artificially created sites can play in shorebird conservation (Lloyd *et al*., 2024). These ponds are attractive to smaller species like Curlew Sandpipers and Red-necked Stints because they provide shallow, nutrient-rich waters where birds can continue to feed on small invertebrates during high tide (Lloyd *et al*., 2024). This proximity to preferred foraging areas also contributes to the birds' preference for roosting at the Port, as does the limited disturbance due to restricted public access (Lloyd *et al*., 2024).

The Port of Brisbane has voluntarily created two large bird habitats, including a permanent artificial roost and a freshwater lake, on what would otherwise be industrial land (Lloyd *et al*., 2024). The management of these sites, including water levels and vegetation control, is crucial for their continued suitability for shorebirds (Fuller *et al*., 2021).

Figure 28. (a) Near threatened Black-tailed godwits, North Pine River. Photo credit: C. Walker; (b) Vulnerable Beach Thick-knee or Stone curlew, Minjerribah. Photo credit: C. Walker; (c) Critically endangered Far Eastern or Eastern Curlews, Cleveland. Photo credit: C. Walker.

Table 28. List of shorebirds noted from studies in Moreton Bay

Migratory Shorebirds (28 of 32 species)	Resident Shorebirds (15 species)
Asian Dowitcher (*Limnodromus semipalmatus*)	Australian Painted Snipe (*Rostratula australis*)
Bar-tailed Godwit (*Limosa lapponica*)	Australian Pied Oystercatcher (*Haematopus longirostris*)
Black-tailed Godwit (*Limosa limosa*)	Banded Lapwing (*Vanellus tricolor*)
Broad-billed Sandpiper (*Calidris falcinellus*)	Banded Stilt (*Cladorhynchus leucocephalus*)
Buff-breasted Sandpiper (*Calidris subruficollis*)	Beach Thick-knee (*Esacus magnirostris*)
Common Greenshank (*Tringa nebularia*)	Black-fronted Dotterel (*Elseyornis melanops*)
Common Sandpiper (*Actitis hypoleucos*)	Black-winged Stilt (*Himantopus himantopus*)
Curlew Sandpiper (*Calidris ferruginea*)	Bush Stone-curlew (*Burhinus grallarius*)
Double-banded Plover (*Charadrius bicinctus*)	Hooded Plover (*Thinornis cucullatus*)
Far Eastern Curlew (*Numenius madagascariensis*)	Masked Lapwing (*Vanellus miles*)
Great Knot (Calidris tenuirostris)	Pied Stilt (*Himantopus leucocephalus*)
Greater Sand Plover (*Charadrius leschenaultii*)	Red-capped Plover (*Charadrius ruficapillus*)
Grey Plover (*Pluvialis squatarola*)	Red-kneed Dotterel (*Erythrogonys cinctus*)
Grey-tailed Tattler (*Tringa brevipes*)	Red-necked Avocet (*Recurvirostra novaehollandiae*)
Latham's Snipe (*Gallinago hardwickii*)	Sooty Oystercatcher (*Haematopus fuliginosus*)
Lesser Sand Plover (*Charadrius mongolus*)	
Marsh Sandpiper (*Tringa stagnatilis*)	
Pacific Golden Plover (*Pluvialis fulva*)	
Red Knot (*Calidris canutus*)	
Red-necked Stint (*Calidris ruficollis*)	
Ruddy Turnstone (*Arenaria interpres*)	
Ruff (*Calidris pugnax*)	
Sanderling (*Calidris alba*)	
Sharp-tailed Sandpiper (*Calidris acuminata*)	
Terek Sandpiper (*Xenus cinereus*)	
Wandering Tattler (*Tringa incana*)	
Whimbrel (*Numenius phaeopus*)	
Wood Sandpiper (*Tringa glareola*)	

5.13.7 Recommendations

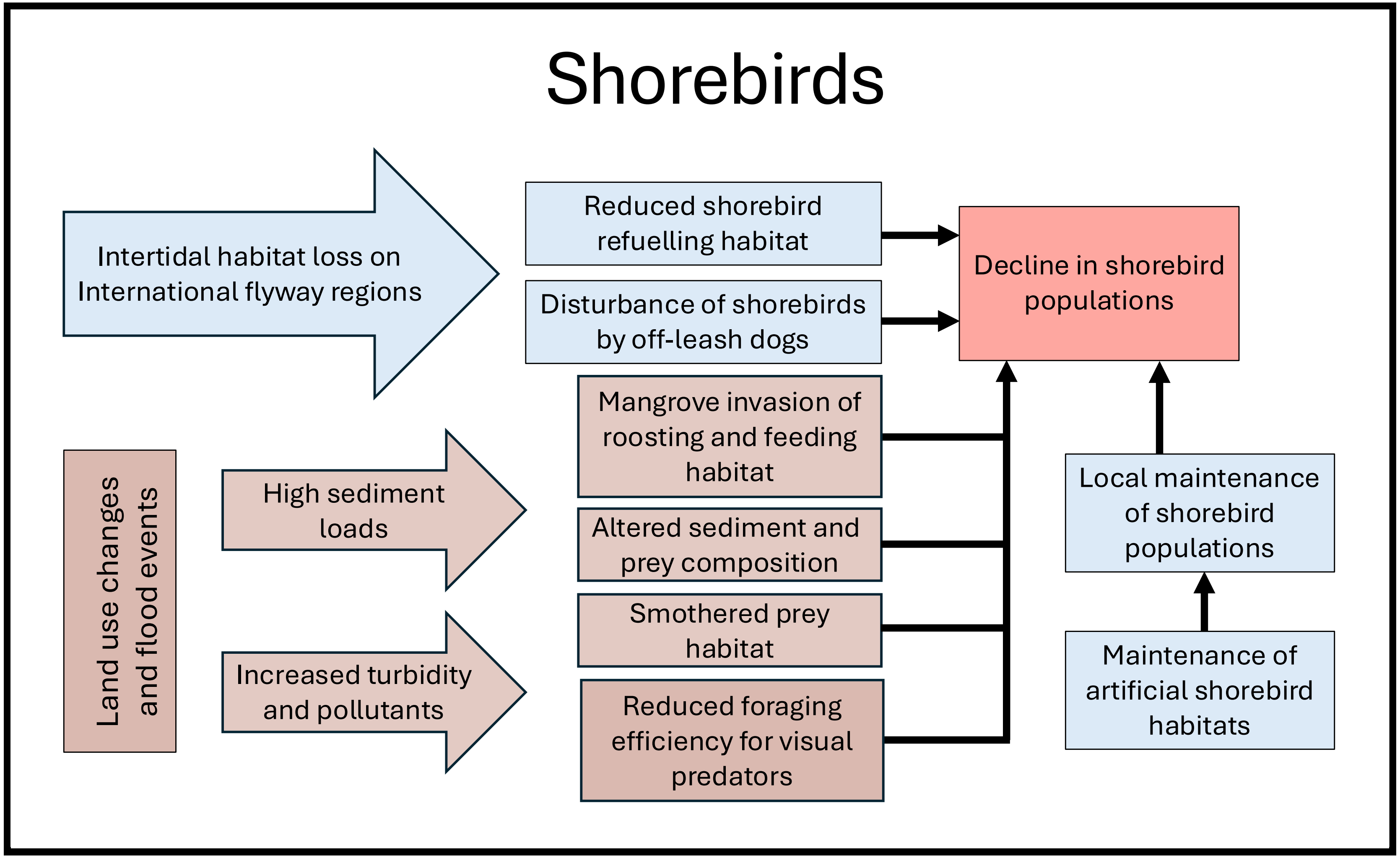
1. Minimise disturbance to foraging birds as the most urgent action (Fuller *et al.*, 2021).
2. Manage mangrove encroachment into shorebird habitats (e.g. saltmarshes). Mangroves can trap sediment, promoting growth that threatens roosting sites in Moreton Bay. This encroachment alters shorebird habitat by reducing the open space and visibility needed by many shorebird species. (Fuller *et al.*, 2021; Lukies *et al.*, 2021).
3. Strategically plan for artificial roost sites. The Port of Brisbane has used dredge material to create reclamation ponds, which serve as crucial, though temporary, high-tide roosting habitat for up to one-third of Moreton Bay's migratory shorebirds. However, these temporary reclamation areas are expected to be filled in by 2044. Planning should explore options such as enhancing existing roosts, constructing additional artificial sites and managing the dredge rehandling area to constitute effective shorebird roosting habitat (Fuller *et al.*, 2021; Lloyd *et al.*, 2024).
4. Implement erosion control in high-tide roosting sites for shorebirds. Erosion was identified as a threat at 14 roost sites. These roosting sites are areas above the high tide mark where migratory shorebirds gather to rest when their intertidal feeding grounds are submerged (Fuller *et al.*, 2021).
5. Implement active management of water levels in artificial roosts (like those at the Port of Brisbane and Manly Harbour) and claypan roosts to enhance their suitability for foraging and roosting shorebirds (Fuller *et al.*, 2021).
6. Improve stormwater runoff to reduce sediment discharge into the Bay and improve water quality. This would benefit shorebirds by potentially improving their benthic prey base (Fuller *et al.*, 2021).
7. Enhance monitoring of threats, including erosion and vegetation encroachment (mangroves), to identify where and how to take conservation action. This includes quantitative assessment and monitoring of threat effectiveness (Fuller *et al.*, 2021).
8. Address local declines in benthic invertebrates. There is some evidence of a long-term decline in invertebrate densities in parts of Moreton Bay. These declines are likely to be linked to sedimentation (Fuller *et al.*, 2021; Lukies *et al.*, 2021).

5.13.8 Expert reviews

Professor Richard Fuller (Centre for Biodiversity and Conservation Science, University of Queensland) and Dr Penn Lloyd (Senior Principal Ecologist, Biodiversity Assessment and Management PL) kindly provided expert review of the Shorebirds: Sedimentation Impact Statement.

5.13.9 Conceptual model - impacts of sedimentation on shorebirds

Figure 29. Conceptual model that qualitatively describes the major impacts of sedimentation on shorebird populations and health in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes.



5.14 Marine Mammals: Sedimentation Impact Statement

Endangered Dugong (Dugong dugong) in Moreton Bay
Photo credit: C. Cotterell

5.14.1 Status and trend summary

Moreton Bay supports a unique and diverse community of marine mammals, attributed to the Bay's distinctive geography. Table 29 provides a combined qualitative assessment of the resident marine mammal populations in the Bay (Dugong, Indo-Pacific bottlenose dolphins and Australian humpback dolphins), highlighting their current condition, future trajectory and the impacts of sedimentation. Population estimates have improved over time and, in most cases, demonstrate that the current condition of these mammal species is rated as 'Good', with 'High' confidence.

The dugong population in Moreton Bay is generally considered relatively stable. However, the impacts of large floods and the associated sedimentation have reduced the population by impacting the seagrass beds on which they feed. Dolphin populations also appear to be relatively stable, although there is a lack of reliable long-term data to determine their population trends, and concerns exist about potential declines in specific subpopulations. Sedimentation is known to impact dolphin habitats, including by indirectly affecting the availability of their prey. Severe coastal flooding events, characterised by heavy freshwater and sediment discharge as well as the delivery of a range of toxic pollutants, have been linked to increased mortality rates for inshore dolphins in Queensland.

The condition trend of these resident mammal species is rated as 'Stable', with 'Medium' confidence. But there are concerns for future populations, given that they are subject to indirect changes from sedimentation impacts on their food and prey habitats. Hence, the contribution of sediment to the condition trend is rated as 'Moderate' with 'Medium' confidence. However, dugong populations may experience higher risk from sedimentation impacts because of their reliance on seagrasses. This increased risk was demonstrated following the 2011 and 2012 floods, which led to seagrass loss and increased dugong mortality rates.

Table 29. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, on the three resident species of marine mammals in Moreton Bay: dugongs, Indo-Pacific bottlenose dolphins and Australian humpback dolphins.

Value condition assessment	Assessment	Confidence
Current condition	Good	High
Contribution of sedimentation to the current condition	Minor	High
Condition trend	Stable	Medium
Contribution of sedimentation to trend	Moderate	Medium

5.14.2 Overview

There are a number of marine mammals that use Moreton Bay, and their populations can be categorised into resident species and seasonal or occasional visitors. The resident mammals are dugongs (*Dugong dugon*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) and Australian humpback dolphins (*Sousa sahulensis*) (Chilvers *et al.*, 2005; Dudgeon *et al.*, 2019; Lanyon, 2019; Lanyon *et al.*, 2019). The seasonal or occasional visitors are Humpback whales (*Megaptera novaeangliae*) and Southern right whales (*Eubalaena australis*) (Chilvers *et al.*, 2005; Dudgeon *et al.*, 2019; Lanyon, 2019; Lanyon *et al.*, 2019; Cross *et al.*, 2024). Other cetaceans that are common offshore from Moreton Bay are Common dolphins (*Delphinus delphis*) and Dwarf minke whales (*Balaenoptera acutorostrata*).

Other sporadic visitors or strandings include Killer whales (*Orcinus orcinus*), Eden's whales (*B. edeni*), Sperm whales (*Physeter macrocephalus*), Pygmy sperm whales (*Kogia breviceps*), Blue whales (*B. musculus*), Blainville's beaked whales (*Mesoplodon densirostris*), Short-finned pilot whales (*Globicephala macrorhynchus*), Risso's dolphins (*Grampus griseus*), Fraser's dolphins (*Lagenodelphis hosei*), False-killer whales (*Pseudorca crassidens*), and Pantropical spinner dolphins (*Stenella longirostris*) (Chilvers et al., 2005; Lanyon, 2019; Lanyon et al., 2019).

The abundance and diversity of marine mammals in Moreton Bay are attributed to its unique geography at the boundary of two biogeographic regions, offering a mix of oceanic and bay environments, strong currents, and significant river inputs, which support a variety of habitats and prey (Chilvers *et al.,* 2005; Lukoschek and Chilvers, 2008; Lanyon*,* 2019).

This statement focuses on the resident and, to a lesser extent, the seasonal or occasional visitors.

Dugongs

Moreton Bay is home to the largest, southernmost resident population of dugongs on the east coast of Australia, and is globally unique for supporting a large dugong population in close proximity to a major city (Lanyon, 2003; Lanyon*,* 2019; Lanyon *et al.,* 2019). The vast majority (>95%) of dugongs in the Bay primarily inhabit the Eastern Banks area (including Maroom, Boolong, and Coonungai Banks). The environment in this region suits dugongs as the water is relatively clear, seagrass communities are abundant with their preferred genera (like *Halophila* species), the boating traffic threat is light, and deep-water refugia are nearby (Lanyon, 2003; Lanyon*,* 2019; Lanyon *et al.,* 2019). During winter, dugongs may disperse more widely across the Eastern Banks and move between the warmer oceanic waters of South Passage and cooler Bay waters through Rous Channel to minimise cold exposure (Lanyon, 2003; Lanyon *et al.,* 2019). Small numbers are also found in shallow seagrass areas in the western and southern parts of the Bay and Pumicestone Passage (Lanyon *et al.,* 2019). Dugongs in Moreton Bay form large grazing herds of 10 to 100 animals, with herds of up to 300 recorded (Lanyon*,* 2019; Lanyon *et al.,* 2019).

Indo-Pacific bottlenose dolphins

Indo-Pacific bottlenose dolphins are found throughout Moreton Bay, both within the Bay and on the oceanic side of the islands (Chilvers *et al.,* 2005). These dolphins appear to be dominant over humpback dolphins in terms of food competition and are more numerous in the Bay (Chilvers *et al.,* 2005; Lanyon *et al.,* 2019).

Australian humpback dolphins

Moreton Bay hosts the most southerly resident population of Australian humpback dolphins (Lanyon*,* 2019; Lanyon *et al.,* 2019). They are mainly found on the western side of the Bay in shallow, nearshore waters, often associated with rivers, particularly the lower reaches of the Brisbane River, extending north to Mud Island and the Western Banks off Scarborough (Parra *et al.*, 2004; Chilvers *et al.,* 2005; Lanyon*,* 2019; Lanyon *et al.,* 2019). Peripheral core habitats include southern Bribie Island and Amity Channel near Minjerribah (Lanyon*,* 2019; Lanyon *et al.,* 2019).

Australian humpback dolphins tend to occur in smaller groups than bottlenose dolphins, typically comprising three to four individuals. However, groups of up to 31 have been reported (Lanyon *et al.,* 2019). They are generalist piscivores (fish feeders) and opportunistically feed on trawler bycatch (Lanyon *et al.,* 2019).

Humpback whales

Humpback whales migrate along the eastern Australian coast between May and October, passing very close to Point Lookout (North Stradbroke Island) and Cape Moreton (Moreton Island) (Noad *et al.,* 2006; Lanyon*,* 2019; Lanyon *et al.,* 2019). Many enter the northern part of Moreton Bay during their southward spring migration (Lanyon *et al.,* 2019).

Southern right whales

Though historically depleted, small numbers have been sighted annually in Moreton Bay since 1999, often near Victoria Point (Lanyon*,* 2019; Lanyon *et al.,* 2019). Their presence suggests a possible range extension or return to historical grounds (Lanyon*,* 2019).

5.14.3 Population status

Dugongs

Dugongs are listed as 'Vulnerable' to extinction globally on the IUCN Red List of Threatened Species (IUCN, 2025) (Table 30). Population estimates of dugongs from aerial surveys between 2013 and 2016 ranged from 601 to 759 individuals (Lanyon *et al.,* 2019). Earlier estimates from 1995 surveys suggested a population of 850–1000 dugongs (Lanyon, 2003), with estimates generally fluctuating between 600 and 950 (Preen, 1993; Lanyon, 2003). A mark-recapture program active since 2001 identified over 780 individual dugongs by 2018, suggesting a stable population with little gene flow in or out of the Bay (Cope *et* al., 2015; Lanyon*,* 2019; Lanyon *et al.,* 2019). While the population appears stable with no discernible decline, it faces ongoing threats, including boat strikes, traditional Indigenous hunting (for non-commercial, communal needs), and habitat degradation due to coastal development, pollution, and the increasing frequency and severity of storms and floods (Lanyon, 2003, 2019; Lanyon *et al.,* 2019).

Indo-Pacific bottlenose dolphins

Indo-Pacific bottlenose dolphins are listed as 'Near Threatened' on the IUCN Red List of Threatened Species (IUCN, 2025). Moreton Bay's population of Indo-Pacific bottlenose dolphins is considered large compared to many other inshore bottlenose dolphin populations globally, due to the Bay's high productivity and habitat diversity (Lukoschek and Chilvers, 2008). Two genetically and ecologically distinct subpopulations exist within Moreton Bay: one in shallow nearshore areas of the southern Bay (South sub-population) and another in deeper open waters of northern-central Moreton Bay (North sub-population) (Chilvers *et al.*, 2005; Ansmann *et al.,* 2013, 2014).

The overall population size for the entire Moreton Bay region was estimated at 554 individuals (95% confidence interval: 510–598) based on surveys conducted between 2008 and 2010 (Ansmann *et al.,* 2013). The South sub-population was smaller (193 individuals), while the North sub-population was more numerous (446 individuals) (Ansmann *et al.,* 2013). Earlier estimates from 1997-1998 surveys covered a smaller central-eastern area of Moreton Bay (350 km^2) and estimated between 673 and 818 individuals (Chilvers *et al.,* 2005; Lukoschek and Chilvers, 2008). It appears that the populations of Indo-Pacific bottlenose dolphins in Moreton Bay are not exhibiting a general decline, although concerns exist about potential declines for specific subpopulations (Ansmann *et al.,* 2013). There is also a lack of reliable long-term data to determine population trends (Lanyon *et al.,* 2019).

Australian humpback dolphins

Australian humpback dolphins are listed as 'Vulnerable' on the IUCN Red List of Threatened Species (IUCN, 2025). Populations do not show a clear or consistent decline based on available population estimates, though they are considered vulnerable due to various threats (Parra and Cagnazzi, 2016; Lanyon, 2019; Lanyon *et al.,* 2019).

Population estimates of Australian humpback dolphins for Moreton Bay include 119 to 163 individuals from 1984-1987 studies, and 128 to 139 adult-sized dolphins from 2014-2016 surveys (Chilvers *et al.,* 2005; Parra and Cagnazzi, 2016; Lanyon, 2019; Lanyon *et al.,* 2019).

Genetic studies suggest limited gene flow between the Moreton Bay group and the nearest population in the Great Sandy Strait (Lanyon *et al.,* 2019).

Humpback whales

Humpback whales are listed as 'Least Concern' on the IUCN Red List of Threatened Species (IUCN, 2025). The Humpback whale population has shown a remarkable recovery since protection in 1973, with an estimated population of almost 26,000 in 2015, increasing at about 11% per annum (Lanyon, 2019; Lanyon *et al.,* 2019).

Southern right whales

Southern right whales are listed as 'Least Concern' on the IUCN Red List of Threatened Species (IUCN, 2025). Though historically depleted, small numbers have been sighted annually in Moreton Bay since 1999, often near Victoria Point (Lanyon, 2019; Lanyon *et al.*, 2019). Their increasing presence suggests a possible range extension or return to historical grounds (Lanyon, 2019; Lanyon *et al.*, 2019).

Table 30. List of the five resident or regularly visiting mammals of Moreton Bay, noting their trend categories where published (Lanyon, 2019; Lanyon et al., 2019) and their categorisation on the IUCN Red List (IUCN listings are taken from www.iucnredlist.org). Colours used are based on the IUCN Red List.

Marine mammal species	Trend	IUCN Listing
Dugongs (*Dugong dugon*)	Stable	Vulnerable
Indo-Pacific bottlenose dolphins (*Tursiops aduncus*)	Stable	Near Threatened
Australian humpback dolphins (*Sousa sahulensis*)	Stable	Vulnerable
Humpback whales (*Megaptera novaeangliae*)	Increasing	Least Concern
Southern right whales (*Eubalaena australis*)	Increasing	Least Concern

5.14.4 Value

Ecological value

In Moreton Bay, dugong populations hold significant ecological value within the marine ecosystem as obligate (dependent) grazers on tropical seagrass. As seagrass specialists, the distribution and abundance of dugongs are highly correlated with the presence and health of seagrass meadows (Chilvers *et al.*, 2005). Their intensive grazing habits, sometimes referred to as 'cultivation grazing', actively structure seagrass meadows (Preen, 1995; Scott *et al.*, 2022). This process can alter the species composition of seagrass beds, favouring fast-growing, nutritious pioneer species like *Halophila ovalis* over slower-growing, less preferred species like *Zostera capricorni* (Preen, 1995). This effectively improves the quality and concentration of their diet and supports the dugong population.

Given that dugongs and marine mammals are subject to a prediction of ecological extinction in other coastal areas (such as the Caribbean reef systems), they serve as a valuable indicator species for the ecological health of the Bay (Chilvers *et al.*, 2005; Lukoschek and Chilvers, 2008; Lanyon, 2019).

Dolphin populations in Moreton Bay hold significant ecological value within the marine ecosystem due to their roles as top predators. Both the Indo-Pacific bottlenose dolphins and Australian humpback dolphins are top-level carnivores and high-order predators within the Moreton Bay food web (Chilvers *et al.*, 2005; Ansmann *et al.*, 2013; Dudgeon *et al.*, 2019; Lanyon, 2019). They are generalist foragers, preying on a variety of fish and cephalopods, and some exhibit specialised foraging strategies (Lanyon, 2019; Lanyon *et al.*, 2019; Allen, 2021). Their feeding habits, including opportunistic feeding on trawler bycatch, demonstrate their adaptability within the bay's altered environments (Corkeron,1990; Lukoschek and Chilvers, 2008; Lanyon, 2019; Lanyon *et al.*, 2019).

The Indo-Pacific bottlenose dolphins in Moreton Bay are divided into two genetically distinct subpopulations, adapted to different ecological niches (Ansmann *et al*., 2013, 2014; Lanyon *et al.,* 2019). One subpopulation inhabits the deeper, northern/central parts of the bay, foraging on pelagic fish, while the other occupies shallow, nearshore/demersal habitats in the southern bay (Ansmann *et al*., 2014; Lanyon, 2019). Australian humpback dolphins exhibit a more restricted inshore distribution, preferring shallow waters near river mouths (Parra and Cagnazzi, 2016; Lanyon, 2019; Lanyon *et al.,* 2019). This resource partitioning underscores the importance of maintaining the diverse range of habitats within Moreton Bay for the preservation of these distinct populations and their genetic diversity (Ansmann *et al*., 2014).

Cultural value

Dugongs and dolphins hold significant cultural value, particularly for Indigenous communities such as the Quandamooka people in Moreton Bay. They are considered sacred Aboriginal totems for saltwater people, signifying a deep spiritual connection and ancestral links to waterways (Pinner *et al*., 2019; Ross *et al*., 2019a), as demonstrated in Quandamooka Dreaming stories (Delaney, 2013).

Dugongs contribute to the symbolic meaning of places, influencing Indigenous place names and folklore, thus connecting people to their historical, cultural, and spiritual heritage in the land and sea country (Pinner *et al*., 2019). This connection implies an intimate, reciprocal relationship where the well-being of dugongs is intrinsically tied to the well-being of the people (Pinner *et al*., 2019).

Historically and in contemporary society, dugongs are an important food source for Indigenous communities, hunted for their flesh and oil (Thurston *et al*., 2019; Townsend *et al*., 2019; Allen, 2021; Scott *et al*., 2022). This traditional hunting is essential for maintaining social relations, traditional ceremonies, and community cohesiveness (Lanyon, 2019; Townsend *et al*., 2019). This also extends to the affirmation of cultural identity and the recognition of natural elements as ‘cultural resources’, which carry deep cultural significance beyond mere consumption (Pinner *et al*., 2019).

The Indigenous Traditional Owners of Moreton Bay have legal rights under the *Native Title Act 1993* to take marine resources, including dugongs, for non-commercial communal needs.

Cetaceans, including dolphins, hold deep significance for the culture of many Aboriginal communities, as celebrated in traditional and contemporary songs, stories, dance, and art (Allen, 2021). Their presence contributes to the symbolic meaning of places and connects people to their heritage (Allen, 2021) as demonstrated by their featuring role in Quandamooka Dreaming stories (Delaney, 2013). Historically, there's evidence of mutually beneficial foraging relationships between Australian Aboriginals and Indo-Pacific bottlenose dolphins in Moreton Bay, where they cooperated to herd and capture migrating mullet (Lanyon *et al.,* 2019; Allen, 2021).

Economic value

Dugong and dolphin populations in Moreton Bay contribute to the region's economy primarily through wildlife tourism. The harvesting of dugongs for traditional use represents an important subsistence value for the Quandamooka people (Lanyon, 2019; Townsend *et al.*, 2019). Both of the Bay's dolphin species are a focus of boat-based dolphin watching tours and hand-feeding operations at two shore-based sites in Southeast Queensland (Chilvers *et al.,* 2005; Lanyon, 2019; Allen, 2021).

Marine mammals contribute significantly to the biodiversity of Moreton Bay, particularly to the visible megafauna community, which supports the growing ecotourism activity in the Bay.

5.14.5 History

Aboriginal people have traditionally harvested dugongs in Moreton Bay (Chilvers *et al.,* 2005). However, from 1847 (or earlier), a commercial dugong oil industry operated in Moreton Bay, continuing intermittently until about 1920 (Chilvers *et al.,* 2005; Thurston *et al.*, 2019) with a brief resurgence during World War II. This exploitation is believed to have depleted the dugong population in the Bay (Lanyon, 2003; Chilvers *et al.,* 2005; Thurston *et al.*, 2019). By the 1960s, it was thought that only a few dugongs remained in Moreton Bay. However, aerial surveys in the mid-1970s established that a population of at least 300 individuals existed, with suggestions that numbers were beginning to increase (Lanyon, 2003; Chilvers *et al.,* 2005). However, as the western shoreline of the Bay became increasingly urbanised, leading to seagrass loss and modification, the dugongs' range contracted primarily to the eastern bay (Lanyon, 2003; Lanyon, 2019). Moreton Bay's dugong population has subsequently appeared stable during the late 20th century (see Population status section above), contrasting with declines reported in other parts of the species' range. (Lanyon, 2003; Chilvers *et al.,* 2005).

Indo-Pacific bottlenose dolphins have a long history of association with people in Moreton Bay, including mutually beneficial cooperative hunting relationships with Indigenous fishers as described above. Scientific studies on both the Indo-Pacific bottlenose dolphins and Australian humpback dolphins began in Moreton Bay in the late 1970s (Chilvers *et al.,* 2005). A study in the 1980s reported high rates of shark injuries (36.6%) on bottlenose dolphins, potentially linked to a concentration of sharks and dolphins around trawlers (Lanyon *et al.,* 2019). Following a decline in trawling effort from 1999 to 2008, the distinct 'trawler' and 'non-trawler' Indo-Pacific bottlenose dolphin social structure disappeared, reverting to a more conventional fission-fusion pattern (Lanyon, 2019; Lanyon *et al.,* 2019). This pattern is a type of social organisation where the size and composition of groups change frequently through individuals frequently splitting from (fission) and merging into (fusion) different groups depending on food, predation risk, and social context.

Moreton Bay continues to support significant and diverse dolphin populations despite its proximity to a major urban centre and ongoing threats from habitat degradation, vessel traffic, pollution, and entanglement (Chilvers *et al.,* 2005; Lukoschek and Chilvers, 2008; Lanyon, 2019; Lanyon *et al.,* 2019).

5.14.6 Impacts of sedimentation

Figure 30 provides a conceptual model to broadly describe the impacts of sedimentation on marine mammals in Moreton Bay.

Dugongs

Fine sediment deposition, particularly from major flood events, can smother seagrass beds, reduce light availability, and alter the benthic habitat from sandy to muddy (Todd *et al.,* 2015; Saeck *et al.,* 2019a; Grinham *et al.,* 2024). This directly destroys or modifies the dugongs' preferred seagrass species, which are vital for their nutrition (Preen, 1995; Lanyon, 2019).

The significant rainfall and flood event in 2011 caused severe degradation of inshore water quality and seagrass habitats in Moreton Bay (see Section 4, 'Sedimentation - Sources and Issues'). After these events the mortality rates for dugongs along the Queensland coast increased markedly, as their seagrass food source was destroyed (Lanyon, 2019). When seagrass habitats are lost or degraded, dugong reproductive rates decline, which can lead to decreased fecundity, lower calf counts, and potentially reduced juvenile survivorship (Fuentes *et* al., 2016; Lanyon, 2019; Lanyon *et al.,* 2019; Lanyon *et al.,* 2025). However, the impact of seagrass losses due to sedimentation in the Bay is moderated on the Eastern Banks - the main dugong feeding area - due to its short water residence times (3-5 days) and hence, higher sediment flushing rates (Gibbes *et al*., 2014).

Meagre and Limpus (2014) found that peak mortality of dugongs followed sustained periods of elevated freshwater discharge (with an eight-month lag) and low air temperature (with a two-month lag). These were explained by food limitation (as described above for seagrass loss via exported freshwater and sediments following floods) and direct impacts on health of cold-stress syndrome (Owen *et al*., 2013).

Sediments can also act as a vehicle for transport and accumulation of toxic pollutants like Organochlorine pesticides and PCBs, Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (PCDD/Fs), heavy metals, and biotoxins and harmful algal blooms (O'Shea *et al*., 2018; Grinham *et al*., 2021), into the Bay's waters and benthic habitats. The heavy metals identified in surface sediments exceeded background reference ranges and pose a medium to high risk to benthic biota (Townsend *et al.,* 2019). These contaminants become bioavailable when sediments are disturbed or water quality changes (Townsend *et al*., 2019), and dugongs can be exposed through their diet (Gaus *et al.,* 2004; Hermanussen *et al*., 2004; O'Shea *et al*., 2018; Lanyon *et al.,* 2019; Townsend *et al.,* 2019). Adverse effects from such pollutants may represent a significant health risk to dugongs (O'Shea *et al*., 2018). However, there is a lack of specific information on dugong sensitivity to these compounds, which prevents a more conclusive determination of impacts (Gaus *et al.*, 2004). These impacts are better studied for dolphins and are described below.

Dolphins

Severe coastal flooding events, characterised by heavy freshwater and sediment discharge, have been linked to increased mortality rates for inshore dolphins in Queensland (Meager and Limpus, 2014; Parra and Cagnazzi, 2016; Allen, 2021). Freshwater discharge has a strong influence on the distribution, abundance, and phenology of fish and crustaceans, which serve as primary prey resources for inshore dolphins (e.g., Gillanders and Kingsford, 2002). Sedimentation in Moreton Bay primarily impacts dolphins through habitat degradation and the transport of pollutants. The direct impact of habitat smothering through sedimentation is more pronounced on species like dugongs and turtles, which feed on seagrass that can be buried or degraded. However, similar widespread habitat alteration impacts the broader marine ecosystem (Grinham *et al.,* 2024), which indirectly affects the availability of prey for dolphins (Todd *et al.,* 2015).

Dolphins, especially the smaller southern subpopulation of Indo-Pacific bottlenose dolphins, which prefer shallow, nearshore waters and river mouths, are highly exposed to land-based pollutants through their diet (Lanyon, 2019; Lanyon *et al.,* 2019).

Australian humpback dolphins also show concentrations of contaminants in their tissues (Parra and Cagnazzi, 2016; Lanyon, 2019; Townsend *et al*., 2019). As apex predators, they are susceptible to bioaccumulation, which can lead to adverse physiological effects (Parra and Cagnazzi, 2016; Lanyon, 2019). Adverse effects on dolphins from toxic pollutants (described above in Dugong section) has been studied and includes: impaired immune function and increased susceptibility to diseases (Todd *et al.,* 2015; Parra and Cagnazzi, 2016; Lanyon, 2019), reproductive anomalies such as premature pupping, calf mortality and low reproductive rates (Todd *et al.,* 2015; Townsend *et al*., 2019; Allen, 2021), neurological and developmental effects (Gaus, 2004; Todd *et al.,* 2015), metabolic impairment (Parra and Cagnazzi, 2016), skin lesions and diseases (Lanyon, 2019; Allen, 2021) and increased susceptibility to other stressors (Todd *et al.,* 2015).

5.14.7 Recommendations

1. Protect seagrass habitats from physical and chemical degradation caused by factors such as coastal development and increasing frequency and severity of storms and coastal flooding, which exacerbate sedimentation and poor water quality (Lanyon *et al.,* 2019; Lanyon *et al*., 2025).
2. Develop strategies to reduce the discharge of sediments and associated pollutants, such as heavy metals (e.g., lead) and persistent organic pollutants (e.g., PCBs, DDTs), into estuarine and coastal waters (Ansmann *et al.,* 2013, 2014; Parra and Cagnazzi, 2016; Lanyon, 2019; Townsend *et al*., 2019; Allen, 2021). This includes efforts to improve farming practices to minimise sediment and nutrient runoff (Parra and Cagnazzi, 2016).
3. Monitor the health of dugong and dolphin populations and individuals (e.g. through contaminant exposure and population trends) to screen for and mitigate

emerging health-related problems linked to habitat deterioration (Lanyon *et al.,* 2019), as well as to detect potential declines and understand the long-term effects of habitat degradation (Ansmann *et al.,* 2013; Lanyon*,* 2019; Lanyon *et al.,* 2019; Townsend *et al.*, 2019).

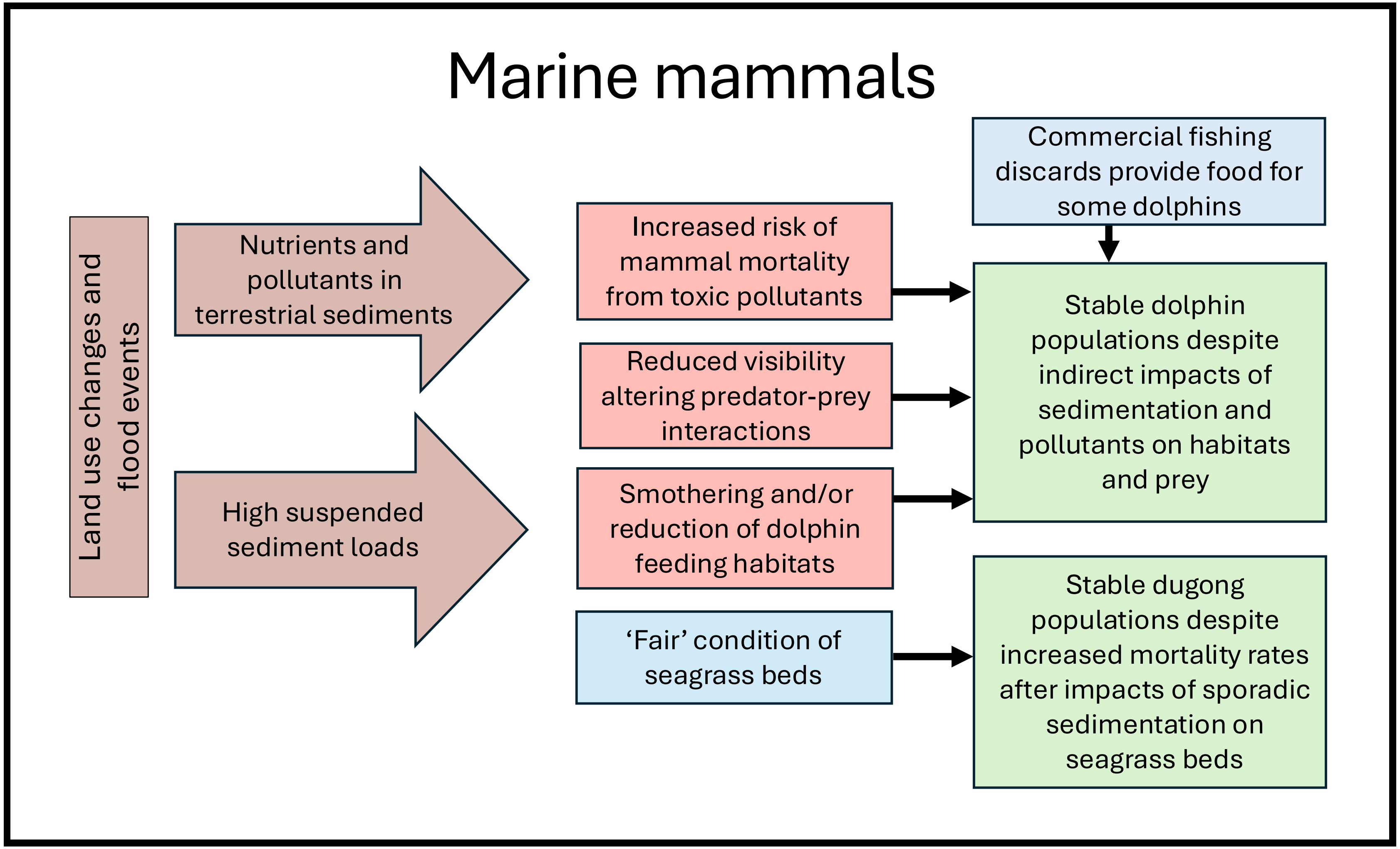
4. Implement improved pollutant management strategies, including better coordinated monitoring programs, to understand and reduce the impacts of major weather events like floods that cause significant sediment runoff (Townsend *et al*., 2019).
5. For activities like dredging that cause sedimentation, undertake careful planning, avoid sensitive areas, and use environmental windows during critical times to minimise impacts on seagrass, shellfish reefs and marine organisms (Todd *et al.,* 2015).

5.14.8 Expert review

Prof. Helene Marsh (James Cook University) kindly provided an expert review of the Marine Mammals: Sedimentation Impact Statement.

5.14.9 Conceptual model - impacts of sedimentation on marine mammals

Figure 30. Conceptual model that qualitatively describes the major impacts of sedimentation on marine mammal populations and health in Moreton Bay. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes; green boxes indicate likely positive or neutral impacts/outcomes.



5.15 Moreton Bay Fisheries: Sedimentation Impact Statement

Moreton Bay trawlers
Photo credit: S. Eayrs

5.15.1 Status and trend summary

Table 31 provides a qualitative assessment of fisheries in Moreton Bay, highlighting key aspects of their current condition, future trajectory and the impacts of sedimentation. Moreton Bay is heavily fished by a combination of commercial and recreational fishing. At least 28 species are commercially fished in the Bay and it has the highest concentration of recreational fishing effort in the state, despite its relatively small spatial area.

Most commercially fished species are currently assessed as being harvested sustainably, and many of these are also targeted and fished recreationally. In combination, these assessments and the management of commercially important species suggest, with 'Medium' confidence, that most fished populations in Moreton Bay are currently in 'Fair' condition. The assessments also indicate, with 'High' confidence, that the condition trend for these fished populations is relatively 'Stable'.

However, the contribution of sedimentation to their current condition and trend is difficult to assess due to the unknown impacts of ecological cascading between species and habitats that they rely on, and the potential variability of impacts between species groups fished (and hence, a variety of potential impacts). Hence, an assessment of 'Unknown' is ascribed to the impacts of sedimentation on the condition and trend of fished species. The risk to this valuable group of species should be closely monitored, given the interaction between declining environmental conditions (such as sedimentation) and the substantial impacts of fishing effort.

Table 31. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for fisheries in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Fair	Medium
Contribution of sedimentation to the current condition	Unknown	Medium
Condition trend	Stable	High
Contribution of sedimentation to trend	Unknown	Medium

5.15.2 Overview

Commercial fishing

Moreton Bay commercial fisheries totalled 2,254 tonnes in the 2013-14 year and produced about 12% of Queensland's total fish catch, despite comprising only 3% of the Queensland coastline (Thurstan *et al.,* 2019). A wide range of species are commercially fished in Moreton Bay, including teleost fish, sharks and a range of invertebrates. Of the 76 species or species groups fished in Queensland that have undergone periodic fishery assessments (www.fish.gov.au/jurisdiction/queensland) by the Queensland Department of Primary Industries (QDPI), distribution maps indicate that 28 of these are fished in Moreton Bay (Fisheries Research and Development Corporation, 2023b).

Indigenous and recreational fishing

Moreton Bay also serves as an important fishing area for Indigenous peoples (see Cultural value section) and recreational anglers (Olds *et al*., 2019). A broad 2013 survey of recreation anglers who fish in Moreton Bay reported catching 74 different species (Thurstan *et al*., 2019; Webley *et al*., 2015). In this survey, the most commonly harvested finfish were Trumpeter whiting (*Sillago maculata)*, Yellowfin bream (*Acanthopagrus australis*), and Sand whiting (*S. ciliata*) (Webley *et al*., 2015).

QDPI recently published the results from a 2019-20 statewide recreational fishing survey (Teixeira *et al*., 2020). They estimated that 943,000 Queenslanders participated in 2.8 million days of recreational fishing in Queensland during the 12 months preceding the survey. They also note that most of this effort occurred in South-east Queensland waters, and that Moreton Bay had the highest concentration of recreational fishing effort in the state, despite its smaller spatial area (Teixeira *et al*., 2020). Recreational fishing in Queensland is open access, meaning no license is required. However, various size limits, in-possession limits, and gear restrictions are in place for different species (Thurstan *et al.,* 2019).

5.15.3 Population status

Commercially fished species

The fishery status assessments of commercially fished species by QDPI (www.fish.gov.au/jurisdiction/queensland) provide some evidence of the status of these populations, including whether they are being sustainably fished or not (Fisheries Research and Development Corporation, 2023b). In broad terms, these assessments indicate whether fished populations remain relatively stable and are not declining towards extinction, rather than whether they are maintaining natural population levels. Although it is difficult to distinguish the impacts of fishing on population changes from other factors, the fishery status of species is used here as an indicator of population status.

Of the 28 species or species groups commercially fished in Moreton Bay, none have populations that are restricted to Moreton Bay. Population status assessments for all species (or groups) are done at the whole-of-population level, making assessments for 'Moreton Bay only' complex and confounded by issues outside of the Bay. Consequently, an assessment of the population status of commercially fished species in Moreton Bay was restricted to twelve species that have a substantial proportion (usually half or more) of their Queensland fishing effort distribution in Moreton Bay (Table 32). The remainder (16) have the majority of the distribution of their fishing effort in other areas of Queensland.

Of the 12 species with substantial proportions of the fishing effort occurring in Moreton Bay, ten have been assessed as 'Sustainable', one as 'Depleted' and one as 'Undefined' (Table 32). These assessments, along with the ongoing management of commercially important species, indicate that most fished populations in Moreton Bay are currently in a relatively stable condition.

Table 32. Commercially fished species with substantial proportions of their total Queensland fishing effort occurring in Moreton Bay, along with their fishery assessment status (www.fish.gov.au/jurisdiction/queensland).

Species	Fishery status	Species	Fishery status
Eastern school prawn	Sustainable	Sea mullet	Sustainable
Dusky flathead	Sustainable	Snapper	Depleted
Luderick	Sustainable	Tailor	Sustainable
Mulloway	Undefined	Yellowfin bream	Sustainable
Sand whiting	Sustainable	Yellowtail scad	Sustainable
School mackerel	Sustainable	Common blacktip shark	Sustainable

Thurston *et al*. (2019) noted that Sea mullet (*Mugil cephalus*) and whiting (*Sillago* species) landings have shown an overall decline in the logbook time series since 1988, while Yellowfin bream landings remained more stable over the same period. Mr John Page, a well-known commercial tunnel-net fisher in Moreton Bay (see section on John Page story), noted Sea mullet have been more heavily fished in recent times due to the ability of fishers to spot a larger proportion of mullet schools using drones (J. Page, pers. comm.). Mr Page (pers. comm.) also noted that Sea mullet catches have shown substantial declines from previous years. He also suggests that the Luderick (*Girella tricuspidate)* population appears to be moving out of the Bay to more southern latitudes, as predicted from rising temperatures (Last *et al*., 2011).

Recreationally fished species

The 2019–20 statewide recreational fishing survey provides general catch trends for Queensland, but it does not offer specific, detailed catch trends for individual species within Moreton Bay for that period (Teixeira *et al*., 2020). Therefore, it is not possible to assess the population status or trends for fish impacted solely by this sector in Moreton Bay.

The most commonly targeted and caught species by recreational fishers in Moreton Bay are also targeted commercially and from the same populations (e.g. Whiting spp, Yellowfin bream, Dusky flathead, Luderick, Mulloway [*Argyrosomus japonicus*], School mackerel [*Scomberomorus queenslandicus*], Snapper and Tailor [*Pomatomus saltatrix*]). Thurstan *et al.* (2019) and Teixeira *et al*. (2020) also note that recreational fishing pressure in Queensland continues to increase.

Indigenous cultural fishing is considered to be at very low levels of effort and, therefore, has a low impact on the species harvested (see Cultural Value section).

Although the QDPI assessments indicate that most commercially fished species are not on a declining trend, they do not generally imply that these species are near healthy population levels. Furthermore, as many species are also subject to substantial, but unquantified, recreational fishing effort, the status of populations of fished species in Moreton Bay should be considered in a precautionary manner.

Impact of the marine park rezoning

While there is evidence of increased numbers and biomass for some species targeted by recreational fishers in new protected zones (from 2010) (Haywood *et al.,* 2019), the overall impact of the marine park rezoning on recreational fisheries is uncertain due to other external factors (Pascoe *et al*., 2025). For example, catch rates in Moreton Bay were higher immediately after rezoning in 2010, but declined by 2019 to levels comparable with other regions (Pascoe *et al*., 2025). A study of no-take marine reserves that prohibit fishing has shown that this form of spatial protection promotes fish abundance and diversity in some ecosystems (e.g. coral reefs, seagrass meadows) (see Ecological value section below), but not in others (e.g. estuaries, ocean beaches) (Olds *et al*., 2019).

5.15.4 Value

Ecological value

Species that are commercially and recreationally fished in Moreton Bay contribute significantly to the ecosystem through various ecological functions. For example, herbivores, such as the Dusky rabbitfish (*Siganus fuscescens*), graze on algae on coral reefs and in seagrass meadows and have significant positive effects on the structure of coral reefs and the physiology of seagrass species (Gilby *et al*., 2019c). This function helps to reduce turf algae cover and can increase coral recruits on reefs, particularly those near mangroves (Olds *et al*., 2019). This herbivory also improves the capacity of these ecosystems to recover from disturbances, such as flood impacts (Gilby *et al*., 2019c).

Fish can also play important predatory roles that are crucial for maintaining the structure of food webs within ecosystems (Olds *et al*., 2019). Recreationally important species, like Yellowfin bream, also serve as prominent scavengers. They are omnivorous predators and scavengers, playing a crucial role in recycling nutrients within coastal food webs (Olds *et al*., 2019). The sensitivity of this scavenging function in estuarine fish to environmental changes (e.g. water quality, fishing pressure, urbanisation) can make it a useful indicator of ecosystem health (Olds *et al*., 2019).

Many commercially and recreationally important fish and prawn species use different habitats throughout their life cycles for purposes such as feeding, seeking refuge from predators, and serving as spawning or nursery sites (Olds *et al.*, 2019). The movements of species among habitats such as mangroves, seagrasses, and coral reefs functionally connect these diverse habitats, thereby linking fish assemblages and food webs across the seascape of Moreton Bay (Olds *et al.*, 2019). Shallow reefs within the Bay also act as important 'stepping stones' for some species during their migrations (Olds *et al.*, 2019).

The presence and diversity of these fish assemblages are fundamental to the overall biodiversity and health of Moreton Bay's marine ecosystems (Olds *et al.*, 2019). Increases in the abundance and/or biomass of targeted species within marine reserves (such as Snapper, Spangled emperor [*Lethrinus nebulosus*], Redthroat emperor [*L. miniatus*], Blackspot tuskfish [*Choerodon schoenleinii*], Maori rock cod [*Epinephelus undulatostriatus*], and Goldspot wrasse [*Bodianus perdition*]) demonstrate that these relatively new protections are having a beneficial effect on key species (Haywood *et al.,* 2019); and hence, on the overall health of the Bay's ecosystems.

Cultural value

Fishing, including for finfish and shellfish, are integral to contemporary Indigenous society and practices within Moreton Bay. Indigenous groups, such as the Quandamooka people, maintain strong cultural connections to this region and its resources (Thurstan *et al.,* 2019). Certain species hold special cultural and economic significance. For example, mullet is culturally important for the Aboriginal people of Quandamooka (Thurstan *et al.,* 2019). Oysters were also historically harvested and are currently farmed by Aboriginal people in the region (West *et al.,* 2019; J. Ladbroke-Parkin, pers. comm.). Aboriginal place names in Moreton Bay often carry symbolic meaning linked to community identity and specific species. For instance, Bribie Island is called 'Yurin,' meaning 'place of mud crabs' (Ross *et al.*, 2019a).

These values are reflected in the Native Title rights recognised for the Quandamooka People, which include the right to take, use, share, and exchange traditional natural resources (including those fished) for any non-commercial purpose within their traditionally accessed waters (Thurstan *et al.,* 2019).

Economic value

Moreton Bay is considered one of Australia's most intensively used coastal systems for fisheries (Thurstan *et al.,* 2019). Recreational fisheries are the largest and most significant economic fishery activity, with direct expenditure by the sector in Moreton Bay estimated to be between $156 million and $194 million per annum (Thurstan *et al.,* 2019).

The most valuable commercially fished sector is the prawn trawl fishery, with a gross value of production of $4.6 million per annum in 2010 (Courtney *et al.,* 2012).

The farmed oyster industry in Moreton Bay had an annual value of approximately $500,000 in recent years, despite fluctuating production (West *et al.,* 2019). Land-based prawn farms, primarily for Black tiger prawns (*Penaeus monodon*), contributed over $20 million per annum in 2014, making up the bulk of Moreton Bay's aquaculture production.

5.15.5 History

Commercial fishing in Moreton Bay began in the 1840s in the Brisbane River. Early efforts targeted Greasyback, School, and Banana prawns (Thurstan *et al.*, 2019). The industry diversified in the early 1900s and saw rapid growth in the 1950s after a ban on otter trawling was lifted, making the Moreton Bay otter trawl fishery one of Queensland's most effort-intensive in Queensland coastal waters (Thurstan *et al.*, 2019). Historically, mullet was the finfish landed in the greatest quantities averaging 651 tonnes per year (1944–1981). Other relatively important species historically included Yellowfin bream, Whiting spp, Tailor, prawns, and crabs (Thurstan *et al.*, 2019). Since 1988, prawns, mullet, bream, whiting, Blue swimmer crabs, Mud crabs, and squid have been caught in the greatest commercial quantities.

The oyster industry, exploited by Indigenous peoples for generations, was over-exploited by early settlers (see Section 5.9. Epibenthic Bivalve Reefs: Sedimentation Impact Statement), leading to regulations and the start of organised farming in the 1870s (Thurstan *et al.*, 2019).

Recreational fishing has a history of over 130 years in Moreton Bay, with the Queensland Fisheries Act of 1877 formally distinguishing it from commercial activities (Thurstan *et al.*, 2019). After the 1950s, recreational fishing participation increased due to the availability of more affordable vehicles, boats, and technology (Thurstan *et al.*, 2019). While no license is required for recreational fishing, size limits, in-possession limits, and gear restrictions have been in place since the late 19th century, with major reforms introduced in 1993 (Thurstan *et al.*, 2019).

5.15.6 Impacts of sedimentation

Sedimentation in Moreton Bay has both direct and indirect impacts on commercially and recreationally fished species and their supporting ecosystems (see conceptual model in Figure 31). As described in other sections, overall changes in water quality due to sedimentation detrimentally impact fish habitats, altering the composition and abundance of fish assemblages in estuaries, seagrass meadows, and coral reefs (Olds *et al.*, 2019). Sedimentation impacts photosynthetic primary producers (Saeck *et al.*, 2019a) through reduced water clarity. Therefore, fished species that rely on plant-based ecosystems (such as seagrass) can be heavily affected. While herbivorous fish, such as the Dusky rabbitfish, consume algae that would otherwise overgrow seagrass and corals, and improve ecosystem recovery from past flood impacts (Olds *et al.*, 2019), chronic or increased sedimentation could overwhelm this natural resilience.

Sedimentation also impacts other benthic habitats, including seagrasses, corals and sandy bottom habitats, through smothering and increases in mud content (Grinham *et al.*, 2024; Saeck *et al.*, 2019a). For example, the decline of the oyster (*Saccostrea glomerata*) industry in Moreton Bay, once a significant fishery, was linked to flood events and poor water quality, which led to disease and over-exploitation of natural beds (Thurstan *et al*., 2019) (see Section 5.9. Epibenthic Bivalve Reefs: Sedimentation Impact Statement).

The shift from sandy to muddy bottoms directly impacts species that prefer or rely on sandy substrates, such as the Greasyback prawn (*Metapenaeus bennettae*), which is among the most numerous and commercially important species in Moreton Bay (Grinham *et al*., 2024). The smothering of seagrass meadows and coral reefs by fine sediments (Saeck *et al.,* 2019a) is detrimental to numerous commercially and recreationally important fish and prawn species, as these habitats serve as crucial feeding areas, refuges from predators, and nurseries, especially for penaeid prawns (Courtney *et al*., 2012). The long-term alteration of habitats from predominantly sandy to muddy could permanently change many areas necessary for these species (Saeck *et al.,* 2019a).

Although there is no assessment of the economic impacts of sedimentation on Moreton Bay fisheries, there is likely to be links between the habitat losses described in other sections of this report and the declines in commercial fisheries. However, the combined roles of fishing effort, sedimentation, and other factors on commercial fishery catches remain unclear.

Direct impacts on recreational fisheries by sedimentation are also difficult to ascertain as the data describing the other main impacts (change in catches or effort) are not well understood and therefore cannot be compared and taken into account. However, expert information (above) suggests that many recreationally fished species are in decline, either through increased recreational fishing effort, combined fishing effort of commercial and recreational catches (as many species are targeted by both sectors), or through the loss of key habitat for fished species.

5.15.7 Recommendations

1. Prioritise and fund management actions that reduce diffuse sediment loads originating from the catchment (Saeck *et al*., 2019b). This action is urgent, as the adverse effects of sediment are likely to increase in the future (Saeck *et al*., 2019b).
2. Improve catchment management and rehabilitation to achieve the regional management plan target for a 50% reduction in sediment loads entering Moreton Bay (Leigh *et al*., 2013). This reduction is estimated to involve the rehabilitation of 6,000 km of the 24,000 km of waterways in priority areas, and especially in the Upper Lockyer catchment (Saeck *et al*., 2019b).
3. Improve protection and restoration of streambank vegetation (Saeck *et al*., 2019b), as the loss of riparian vegetation reduces channel protection and catchments without riparian vegetation export significantly more sediment (Olley *et al*., 2015b).
4. Implement best land management practices to reduce the loads of sediment (and nutrients) from catchments (Leigh *et al*., 2013), including management of stormwater flow from new developments and construction sites, and using

innovative stormwater management practices designed into new developments (Saeck *et al*., 2019b).

5.15.8 Expert review

A scientific fisheries expert (anonymous) kindly provided an expert review of the Moreton Bay fisheries: Sedimentation Impact Statement.

5.15.9 John Page Story

John Page is an experienced and well-known tunnel-net fisher in Moreton Bay (e.g. see Leaving turtles and rays at the door: How tunnel netting ensures sustainable seafood in Moreton Bay | News and media). John recognises that in recent decades there have been beneficial changes to the Bay's ecosystems, such as improved sewage treatment and reduced toxin loads from the Brisbane River, in particular. However, John says that 'Overall, fish populations have decreased in Moreton Bay' and he has very well-honed views on why that is. He notes that a range of issues are impacting fish populations, such as migration of some species to higher latitudes due to increasing water temperatures. However, the impacts of increased sedimentation and nutrient loads have, by far, the greatest impacts on commercial fishing.

John tells of how many areas that once had consolidated substrates are now so silted up that they no longer attract the many fish species that he targets in his tunnel netting operation. Other habitats become heavily silted following flood events and can take at least three to five years to recover to the point where the pre-flood fish communities return. John has observed the stark difference in fishery production between areas in the Bay that are more protected from siltation plumes (where he continues to fish) and those that have been lost to the fishery following flooding.

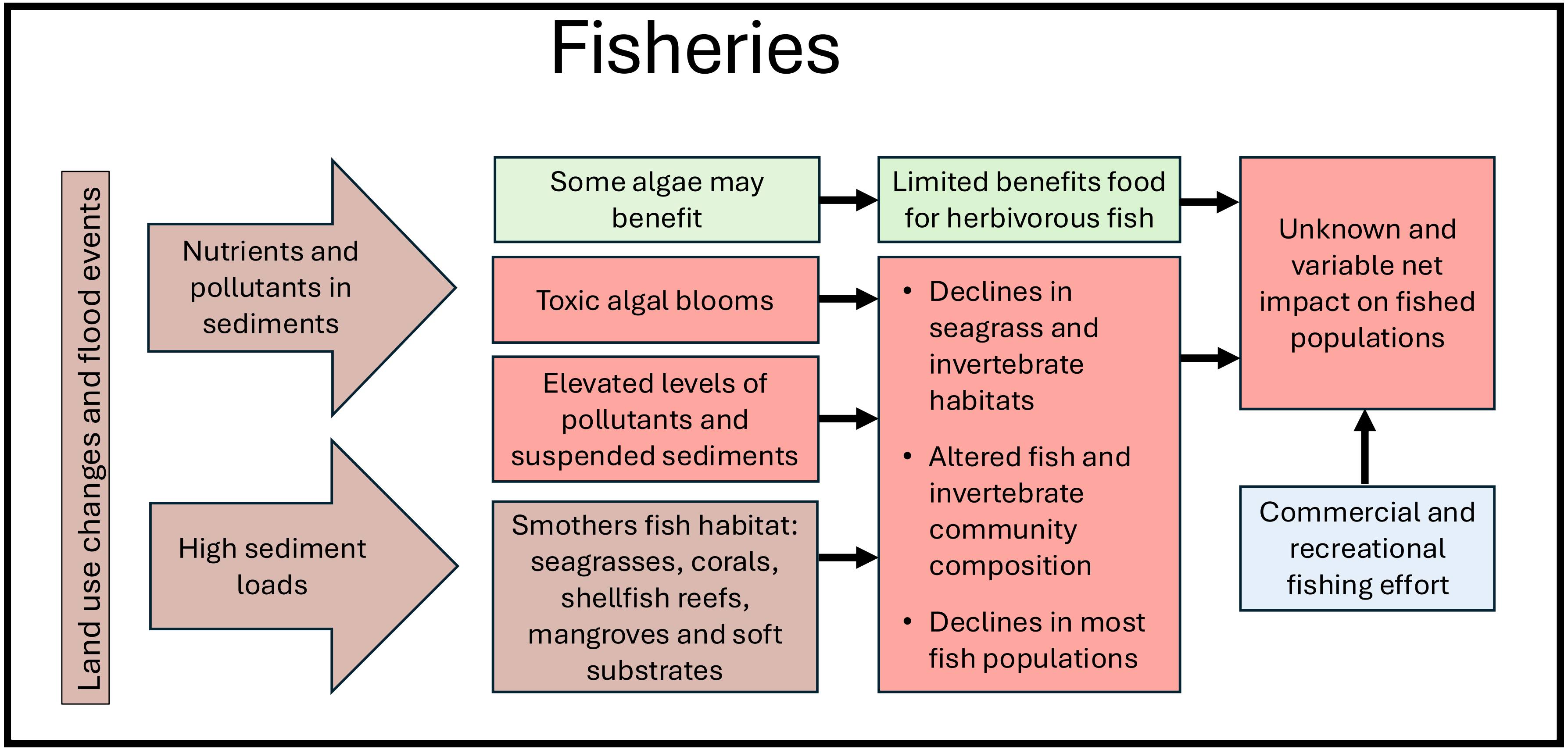
John Page inspecting catches in his tunnel netting operation. Photo courtesy of John Page.

John has also seen how the nutrient influxes that accompany flood events (and sediment resuspension events) can impact fish communities. He has noted how recent flood events are also followed by toxic algal blooms in shallow coastal waters, which can greatly reduce the productivity of inshore habitats for many months.

Consequently, John believes that urgent measures should be taken to help protect fish populations in the Bay. He recommends that sediment loads entering the Bay can and should be curtailed to help benthic habitats and the fish communities they support survive, such as seagrass beds, corals and consolidated substrates. This action would also likely reduce the high nutrient loads that have a detrimental effect on fish communities. He also notes that protecting spawning windows (e.g. using temporal closures) can be an important strategy to help rebuild fish populations.

5.15.10 Conceptual model - impacts of sedimentation on fisheries

Figure 31. Conceptual model that qualitatively describes the major impacts of sedimentation on Moreton Bay fisheries. Brown boxes signify sedimentation-related processes; blue boxes signify other relevant and interacting consequential inputs or impacts; red boxes signify adverse impacts/outcomes; green boxes indicate likely positive or neutral impacts/outcomes.



5.16 Visual Amenity: Sedimentation Impact Statement

5.16.1 Status and trend summary

Eastern Moreton Bay
Photo credit: D. Brewer

The visual appeal and beauty of Moreton Bay - including its colours, flora, fauna, and water clarity - is highly valued, but is vulnerable to the impacts of pollution and unchecked development (Sarker *et al.*, 2008; Ross *et al.*, 2019a). There has been a notable decline in Moreton Bay's visual amenity, largely due to the physical impacts of development and urbanisation in the catchment and pollution from sewage (Pollard *et al.*, 2004; Sarker *et al.*, 2008; Ross *et al.*, 2019a). This change is primarily described as a deterioration or loss (Ross *et al.*, 2019a).

Table 33 provides a qualitative assessment of the visual amenity in Moreton Bay, its their current condition, future trajectory and the impacts of sedimentation. The overall current condition of the Bay's visual amenity is rated as 'Fair, with 'High confidence. This reflects increased suspended sediment loads from development impacts and pollution, which significantly affect water quality and visual amenity. Hence, the contribution of sedimentation to the current condition of visual amenity in Moreton Bay is considered 'Moderate' with 'Medium' confidence.

The condition trend of visual amenity in the Bay is assessed as 'Declining', with 'High' confidence. The contribution of sedimentation to the condition trend of visual amenity in Moreton Bay is considered 'Major' with 'High' confidence due to the unprecedented loads of sediment currently residing in the bay and the high likelihood of ongoing resuspension into the future.

Table 33. Qualitative assessment of the overall status and trend in condition, and of the likely severity and direction of sedimentation-specific impacts, for visual amenity in Moreton Bay.

Value condition assessment	Assessment	Confidence
Current condition	Fair	High
Contribution of sedimentation to the current condition	Moderate	Medium
Condition trend	Declining	High
Contribution of sedimentation to trend	Major	High

5.16.2 Overview

In the context of the marine environment, visual amenity (also referred to as scenic amenity) is defined as a measure of the physical appeal and beauty of a place (Preston, 2006; Ross *et al.*, 2019a), as it contributes to the collective appreciation of open space by the community (Preston, 2006). The terms 'visual amenity' and 'scenic amenity' are used interchangeably in this document, based on the terminology found in the respective reference sources.

Visual amenity encompasses the aesthetic qualities of the environment, such as the colours (e.g. the blues and beiges of the Bay), flora, fauna, and the clarity of the water (Ross *et al.*, 2019a). It also includes the scenic quality of wider landscapes and seascapes (Ross *et al.*, 2019a).

Visual amenity is a widely shared and deeply appreciated value among residents and Traditional Custodians alike in Moreton Bay and its associated waterways (Ross *et al.*, 2019a). Approximately 71% of non-Aboriginal participants in one study expressed an appreciation for the beauty of the waterways (Ross *et al.*, 2019a).

Visual amenity is quantitatively measured by combining two components (Preston, 2006):

1. A scenic preference rating, which is the community's liking for scenery, often measured through photographs (Preston, 2006).
2. A visual exposure rating, which measures the extent to which a place is seen from important public viewing locations (e.g. roads, recreation areas, schools, golf courses) (Preston, 2006).

Visual amenity is considered an element of Landscape Character and is applicable across various environments, including coastal areas, oceans, estuaries, beaches, and dunal vegetation (Preston, 2006).

While non-Aboriginal people value the current beauty of the waterways, Traditional Custodians also hold this value but often recall the past beauty, regretting its long-term deterioration due to ongoing development, urbanisation, and population growth (Ross *et al.*, 2019a). Traditional Custodians also use the aesthetic qualities of waterways as indicators of ecosystem health (Ross *et al.*, 2019a).

5.16.3 The importance of visual amenity in Moreton Bay

Visual amenity is a highly important feature of Moreton Bay and its associated waterways. Key characteristics that underpin this importance include:

1. Economic contribution: scenic amenity is a primary driver of economic wealth in coastal cities within the region, significantly boosting tourism and urban development industries (Preston, 2006).
2. Quality of life and identity: visual amenity contributes to the quality of life and prosperity of the region, and waterways can convey cultural, community, and personal identity (Preston, 2006; Ross *et al.*, 2019a).

3. Recreational value: visual amenity supports a wide range of recreational activities, with the loss of visual amenity impacting these opportunities (Pollard, 2004; Ross *et al*., 2019a, b).
4. Environmental coincidence: areas with high scenic amenity often align with areas of high environmental value (Preston, 2006).

However, the visual amenity of Moreton Bay is also vulnerable. Issues like poor water quality and sewage overflows can lead to a significant loss of visual amenity, impacting recreational quality and reflecting environmental degradation (Pollard, 2004; Sarker *et al*., 2008).

5.16.4 Factors which cause loss of visual amenity in Moreton Bay

The loss of visual amenity in Moreton Bay can be attributed to several factors, primarily stemming from the impacts of development and pollution (Ross *et al*., 2019a).

Development, urbanisation and poor water quality

Ongoing development, urbanisation, and population growth within the Moreton Bay catchment have led to a significant degradation of marine environments and a lamentable loss of past beauty, particularly from the perspective of Traditional Custodians (Ross *et al*., 2019a). Historical land clearing and agricultural practices in the Moreton Bay catchment have contributed to substantial erosion, and the problem is exacerbated by low retention of riparian vegetation (Sarker *et al*., 2008). The historical removal and low retention of riparian (riverfront) vegetation also contribute to the problem of sediment and nutrient runoff into rivers, thereby affecting water quality and its visual appeal (Sarker *et al*., 2008).

Turbidity caused by high sediment loads from catchments significantly affects water quality and visual amenity (Sarker *et al*., 2008). Turbidity can result in ‘brown, turbid water’ (Sarker *et al*., 2008). Run-off of nutrients (nitrogen and phosphorus) from sources like fertilisers and stock dung is also a significant problem, contributing to water quality issues (Sarker *et al*., 2008) which can lead to algal blooms (Sarker *et al*., 2008). These algal blooms may then visually degrade the waterways.

Traditional Custodians often use the aesthetic qualities of waterways, including water clarity, as indicators of ecosystem health (Ross *et al*., 2019a).

Sewage overflows and gross pollutants

The discharge of untreated sewage into local waterways, particularly during system overloads or breakdowns, directly impacts visual amenity (Pollard *et al*., 2004). Sewage overflows, in both dry and wet weather, also pose an unacceptably high public health hazard for potential swimmers, leading to a ‘loss of amenity for recreational activities’ until the overflow stops and there's a complete tidal exchange (Pollard *et al*., 2004).

Major investments in the early 2000s to reduce nitrogen loads from sewage treatment plants by approximately 70% led to an apparent stabilisation of these loads into the Bay (Saeck *et al*., 2019b; Coates-Marnane *et al*., 2020).

5.16.5 Recommendations

Improving visual amenity in Moreton Bay requires a multi-faceted approach involving policy, community engagement, and environmental restoration efforts. Key recommendations include:

1. Prioritise water quality improvement:
   - Use upstream management options, such as controlling stormwater ingress and using larger sewers, to store and transport wet weather flows to wastewater treatment plants (Pollard *et al.*, 2004).
   - Adopt a common-pool resource (CPR) approach for water quality management, fostering cooperation and co-investment between upstream landholders and downstream beneficiaries, such as the city of Brisbane and its water supply authority (Sarker *et al.*, 2008).
   - Implement market-based instruments (MBIs), like payments for ecosystem services, to compensate landholders for setting aside land for riparian buffer strips and adopting practices that reduce soil erosion and nutrient flows (Sarker *et al.*, 2008). A managed fund with a 'broker' (e.g. SEQ Catchments) could facilitate these payments (Sarker *et al.*, 2008).
   - Rehabilitate whole reaches of rivers with riparian vegetation, focusing on areas with severe erosion, which also helps filter sediments and nutrients (Sarker *et al.*, 2008).
2. Community engagement and awareness
   - Develop programs to educate and raise community awareness about the importance of visual amenity and the impacts of pollution (Pollard *et al.*, 2004; Preston, 2006).
   - Regularly monitor and report sewage overflows to the public, along with notifications to warn potential swimmers of health risks (Pollard *et al.*, 2004).
   - Recognise and integrate the diverse values people hold towards waterways (e.g. aesthetic, emotional attachment, naturalistic) into management strategies and public communication (Ross *et al.*, 2019a, b).
   - Shift from a 'control' focused management approach to one that incorporates the positive dimensions of caring and collaboration (Ross *et al.*, 2019b).
   - Improve the connection between land and sea management to mirror the holistic perspective of Indigenous people regarding their coastal estates (Ross *et al.*, 2019b).
   - Expand monitoring and evaluation to include social, economic, and cultural benefits in addition to biophysical indicators (Ross *et al.*, 2019b).

5.16.6 Expert review

Prof Helen Ross (School of Agriculture and Food Sustainability, University of Queensland) has kindly provided an expert review of the Visual amenity value: Sedimentation Impact Statement.

5.17 Catchment Management and Regulation: Sedimentation Impact Statement

Brisbane River from above Photo credit: Gary Cranitch, © Queensland Museum

5.17.1 Summary

Regulations influencing sediment management in South East Queensland (SEQ) and the Moreton Bay catchment are structured as a shared responsibility between federal, state and local governments. This involves a suite of acts, regulations, codes, plans, policies, and guidelines to direct stakeholders involved in land management or land use change activities, including developers, businesses, landholders, agricultural practitioners, and suitably qualified and/or experienced professionals in erosion and sediment control.

There is some differentiation between sedimentation-related legislation and its application at the catchment-wide scale compared to the scale of development or construction sites. In general, overarching environmental legislation, along with planning policies and initiatives, applies at the catchment-wide scale. In comparison, specific erosion and sediment control (ESC) rules are applied to development and construction sites, set by the state government and enforced by local councils.

Catchment-wide scale

There is no explicit legislation regulating the causes of erosion (such as channel erosion) in rural parts of the catchment. Channel erosion is the dominant source of sediment (>90%) in SEQ waterways and a primary source of sediment for the Bay (Grinham *et al.*, 2024). At a catchment-wide scale, the non-statutory *SEQ Natural Resource Management Plan 2009-2031* has set a regional target for soil erosion that 'By 2031, the extent of erosion from hill slopes and gullies will be reduced by 50% from the 2008 baseline'. The Council of Mayors (SEQ) 'Resilient Rivers Initiative' (RRI) has also been established to better coordinate and address catchment-wide sedimentation issues (Council of Mayors (SEQ) *et al.,* 2015).

However, no net improvement in turbidity levels has occurred in the Caboolture, Brisbane, and Logan Rivers over the 18-year monitoring period from 2000 to 2018 (Saeck *et al.*, 2019a).

Development or construction site scale

At the development or construction site scale, local planning policies and regulations require developers to submit erosion and sediment control plans for land-disturbing activities, especially for large sites. These plans must demonstrate proactive strategies before ground-disturbing works begin, including minimising site disturbance. However, there has been limited success in reducing sediment loads entering Moreton Bay (Saeck *et al.*, 2019b).

At this scale, a major issue is the lack of compliance. Healthy Land & Water (2024b) estimates that only about 15% of construction sites are fully compliant with sediment control rules, less than half (40%) of sites are partially compliant, and around 50,000 dump trucks worth of sediments enter SEQ waterways each year. This has a significant impact on Moreton Bay and downstream marine environments. A lack of enforcement of existing sedimentation control requirements at construction sites has also been identified by councils and state government representatives as a key gap (Ecofutures, 2024).

5.17.2 Regulations governing sediment management in SEQ

Regulations governing sediment management in SEQ and the Moreton Bay catchment are structured as a shared responsibility between state and local governments. A summary of the legislation relevant to Moreton Bay, and the links to regulations, plans, policies and guidelines that sit below them, is described and summarised in Ecofutures' (2024) *A Blueprint for a Sustainable Moreton Bay (2025-2035)*—the TMBF Blueprint.

Both state and local policies frequently reference the *International Erosion Control Association Best Practice Erosion and Sediment Control* document (International Erosion Control Association, 2008) as an industry standard for designing, implementing and maintaining erosion sediment control measures (Queensland Government, 2020a, b; Queensland Government, 2021; Healthy Land & Water, 2024a).

The legislation and policy framework relevant to erosion and sediment control is briefly summarised below.

1. General legislative and policy framework:

<u>State legislation and role</u>

The Queensland Government sets the overarching rules and policy direction for erosion and sediment control (Council of Mayors (SEQ) *et al*., 2018). The *Environmental Protection Act 1994 (Qld)* (EP Act) is the primary legislation. The EP Act establishes a general environmental duty to prevent or minimise environmental harm and sets legal requirements for controlling sediment release and protecting water quality (Queensland Government, 1994).

The EP Act is underpinned by the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*, which defines environmental values and water quality objectives for Moreton Bay and its catchments that all developments must meet (Queensland Government, 2019b). This policy supports the *Planning Act 2016 (Qld)* (Planning Act), which regulates land use planning and development approvals, requiring sediment control as part of development conditions (Queensland Government, 2016).

The *State Planning Policy 2017* (SPP) articulates state interests in land use planning and development, with a focus on protecting and enhancing water quality (Queensland Government, 2017; Council of Mayors (SEQ) *et al*., 2018; Seqwater, 2024).

S*hapingSEQ 2023* is the Queensland Government's regional plan for SEQ. It serves as a statutory spatial growth strategy under the Planning Act, setting a regional framework for managing growth, land use, and development, and promoting the protection of water resource catchments (Queensland Government, 2023; Seqwater, 2024).

These instruments and policies have an effect at both the catchment and site levels.

Local government role

Local government planning schemes are crucial for implementing state policies, as they are required to integrate and align with the SPP and *Shaping SEQ 2023* (Queensland Government, 2023; Seqwater, 2024). Local councils are responsible for enforcing state rules and developing their own specific policies (Dennis, 2024; Brisbane City Council, 2014). Local government planning schemes and guidance are specifically relevant at the development or construction site level.

Matters such as environmental nuisance and water contamination are devolved to local governments for administration and enforcement within their respective regions (Queensland Government, 2020a, b). For instance, the Moreton Bay Regional Council's *Planning Scheme and Stormwater Management Policy* (Moreton Bay Regional Council, 2017) mandates the submission of Erosion and Sediment Control Plans that comply with technical specifications such as the *Pine Rivers Standard Specifications – C211* (Pine Rivers Shire Council, 2003). The Redland City Council manages waterways on both public and private land through a combination of legislative and non-legislative measures, including education programs (Redland City Council, 2021).

2. What the regulations require

The regulations governing sediment management in SEQ and the Moreton Bay catchment establish clear requirements for stakeholders involved in land-disturbing activities within the Moreton Bay catchment to prevent sediment loss into Moreton Bay. This includes developers, landholders, agricultural practitioners, and sediment managers (see below, 'Requirements for professionals in erosion and sediment control (ESC)', for more information on sediment managers).

These stakeholders are subject to a framework of regulations and policies designed to manage and reduce sediment delivery into waterways. The requirements are structured through a combination of state legislation, local government planning instruments, and technical guidelines.

The key requirements for stakeholders to manage sedimentation are summarised below.

General environmental duty

Stakeholders have a general environmental duty to prevent or minimise environmental harm. This includes preventing the unlawful deposit of earth buildup and other prescribed water contaminants into waterways, roadside gutters, or stormwater drainage, as stipulated by the EP Act (Queensland Government, 1994).

Compliance with local government requirements

Stakeholders and applicants undertaking land-disturbing activities must account for and comply with the relevant Council's specific requirements for erosion and sediment control. These requirements are usually detailed in local planning scheme policies, such as Section 7.11 of the *Infrastructure Design Planning Scheme Policy* in Schedule 6 of the *Brisbane City Plan 2014* (Brisbane City Council, 2024).

Erosion and sediment control plans
For land-disturbing activities, especially sites with expected soil disturbance exceeding 1000 m^2 (Brisbane City Council, 2024), all local governments in SEQ are expected to have, or are actively working towards, consistent implementation of erosion and sediment control (ESC) requirements and plans as part of their planning and development frameworks (Brisbane City Council, 2024; Queensland Government, 2020a, b; Queensland Government, 2023; Seqwater, 2024; Healthy Land & Water, 2024a). Erosion and sediment control plans must demonstrate proactive strategies before ground-disturbing works begin, including minimising site disturbance and protecting existing vegetation (Queensland Government 1994, 2019a, 2025; Pine Rivers Shire Council, 2003).

3. Requirements for professionals in erosion and sediment control (ESC)

Professionals involved in managing soil erosion and sediment control are expected to have at least two years of verifiable experience. They should understand soil properties (e.g. pH, sodic, dispersive, saline), be able to conduct soil sampling, interpret results, and design appropriate management strategies (Queensland Government, 2021; Healthy Land & Water, 2024a; Brisbane City Council, 2024). An understanding of best practice erosion, drainage, and sediment controls in Australia, including their correct installation, operation and maintenance, is also required. Tools like the Healthy Land & Water's *Erosion and Sediment Control (ESC) Toolkit* are available to support best practice (Healthy Land & Water, 2024a).

This multi-tiered regulatory environment managing sedimentation in SEQ is complex. The Blueprint points out that 'Currently, not all activities undertaken that have the risk of causing environmental harm require development approval and not all development approvals have adequate or specific provisions regulating the management of erosion and sediment controls' (EcoFutures, 2024).

5.17.3 Other catchment-wide (non-regulatory) sediment management

The Blueprint also identifies that there is 'no explicit legislation regulating the causes of erosion in the rural parts of the catchment', which is a primary source of sediment (EcoFutures, 2024).

In SEQ, Healthy Land & Water, a non-statutory Natural Resource Management (NRM) group, facilitates the development of the regional NRM Plan, which guides the community in managing regional priorities. Given the large contribution of sediment from diffuse sources that is currently largely unregulated in SEQ, NRM plans and Healthy Land & Water play a key role in mitigating catchment-wide sediment impacts on water quality.

Healthy Land & Water has multiple programs that address catchment-derived sediment, including: the *Sustainable Agriculture Program* that promotes farm management practices that include sediment management, land condition and soil health; the *Healthy Catchments Program* targeting water quality impacts with a focus on sediment reduction; and targeted riparian stabilisation and improvement activities in the Brisbane, Lockyer, Bremer, Logan and Caboolture catchments. These activities target high sediment-producing sub-catchments to maximise efficiency and outcomes. Healthy Land & Water is actively pursuing additional investment to scale up these activities and achieve a regional impact. The organisation is working closely with aligned organisations and programs, such as the RRI, to achieve this goal.

The RRI is a collaboration between local and state governments, water utilities and key non-government organisations to improve the health and resilience of SEQ's catchments, rivers and Moreton Bay. One of the four goals set out in the *South East Queensland Resilient Rivers Initiative: Regional Strategy 2015-2025* (Council of Mayors (SEQ) *et al.*, 2015) is to 'Keep soil on our land and out of our waterways'. The 2023 *South East Queensland City Deal* (*SEQ City Deal*) provides further investment in the RRI, as part of the 2023 *RRI*: *SEQ Waterways and Wetlands Investment Strategy* (Council of Mayors (SEQ), 2023). The *SEQ City Deal* commits $40 million over the next five years (until 2028) to fund works to improve the health and resilience of the region's rivers and waterways. However, the adequacy, timeliness, and efficacy of the investment needed to achieve impact at a scale that addresses regional priorities, including the health of internationally important wetlands in Moreton Bay, have yet to be assessed.

Queensland's *Fish Habitat Management Operational Policy (FHMOP 001)* (Couchman and Beumer, 2007), outlines some initiatives and policies aimed at managing processes that contribute to sedimentation and habitat loss, such as erosion and land filling. The policy's central initiative is the strict protection and management of marine plants (including mangroves, seagrass, and saltmarsh). However, revetment works for erosion protection are not supported unless there is substantiated accelerated erosion threatening infrastructure or buildings. Furthermore, aspects of sedimentation management, such as preventing further land-clearing or reducing nutrient and sediment flows into fish habitats, are only offered as suggested climate change offsets.

5.17.4 Current status of sedimentation in Moreton Bay

Land use change since European colonisation has had a significant impact on rates of erosion and sediment transport in the catchment. Ongoing pressures mean Moreton Bay and its catchments face substantial challenges regarding sediment management, despite existing efforts and legislation.

Moreton Bay has experienced a dramatic increase in fine sediment deposition (Lockington *et al.*, 2017; Saeck *et al.*, 2019a; Grinham *et al.*, 2024). A recent study found that nearly 100% of the once-sandy sea floor in Moreton Bay, where the Brisbane River meets the sea, is now covered in mud (Grinham *et al.*, 2024). Over the last 50 years, the surface area of clean sand within Moreton Bay has been reduced from 442 km^2 to

30 km^2 (Grinham *et al*., 2024). Muddy sediments now cover an estimated area of over 860 km^2, more than double what was recorded in 1970, and represent over 50% of the total surface sediment area (Lockington *et al*., 2017). This has led to a change in benthic habitat, with muddy bottom habitats increasing from approximately 30% in 1998 to 70% in 2011 (Saeck *et al*., 2019a).

It is hypothesised that the Bay is now receiving sediment at a rate that exceeds its natural capacity to move material offshore, suggesting that the adverse effects of sediment are likely to increase, and the need for managing sediment loads is urgent (Saeck *et al*., 2019a). The infilling of deeper channels with fine sediments has reduced the Bay's capacity to store sediments, leading to more frequent resuspension events and long-term changes in water clarity (Saeck *et al*., 2019a).

The primary sources of this sediment are:

1. Channel erosion

Research consistently supports that channel (gully and bank) erosion is the dominant source, accounting for over 90% of sediment in SEQ waterways (Leigh *et al*., 2013; Lockington *et al*., 2017; Saeck *et al*., 2019a). Channel erosion dominates the supply of sediment in the Lockyer (99%), Brisbane (99%), Stanley (67%), Kobble (74%), Emu (99%), Cressbrook (99%) and North Pine (99%) sub catchments (Olley *et al*., 2013). This is exacerbated by the loss of riparian vegetation, which can increase sediment export by up to 200 times compared to intact catchments (Olley *et al*., 2015; Olley *et al*., 2017; Saeck *et al*., 2019a).

2. Urbanisation and land clearing

The existing urban footprint and greenfield projects are responsible for approximately one-third of the fine sediment (Dennis, 2024). Since European settlement, extensive clearing, cultivation on floodplains, over-grazing, and urban development have led to significant increases in sediment export, with current rates estimated to be approximately 100 times greater than pre-European rates (Tibbetts *et al*., 1998; Lockington *et al*., 2017; Saeck *et al*., 2019a). Urban development poses a high risk of sediment export per hectare, with losses from recently cleared urban land during rainfall events potentially 1000 times greater than before disturbance (Saeck *et al*., 2019a).

3. Major flood events

These events significantly impact coastal receiving environments by facilitating direct smothering with sediment and nutrient loading (Lockington *et al*., 2017; Grinham *et al*., 2024). Over 20 million tonnes of sediment were deposited in Moreton Bay during the 2011 and 2013 flood events (Steven *et al*., 2014; Saeck *et al*., 2019a, b). Fine silt and clay fractions dominate the suspended particle size distribution during floods, suggesting that a large portion of the fine sediments in Moreton Bay are catchment-borne and delivered during these events (Steven *et al*., 2014; Lockington *et al*., 2017).

5.17.5 Management actions

The following section summarises management actions for developers, landholders, agricultural practitioners and ESC professionals.

Initiatives like *Water by Design*, led by Healthy Land & Water and commissioned by the Queensland Government, develop standard erosion and sediment control (ESC) decision support tools and courses to improve the consistency of implementation and enforcement across local governments in Queensland (Healthy Land & Water, 2024a). These tools provide a best practice approach for agricultural practitioners and landholders to manage erosion and sediment control.

Key management actions are listed below:

Catchment-wide scale

1. Focus on channel network stability
   Given that channel erosion is the dominant source of sediment (>90%) in SEQ waterways, management actions need to focus on stabilising the channel network (Gilby *et al*., 2016; Grinham *et al*., 2024; Saeck *et al*., 2019a). Measures include:
   i. **Maintaining existing remnant vegetation**: Existing catchment and riparian forest cover is crucial for protecting rivers. It traps sediments and nutrients, stabilises stream channels (Leigh *et al*., 2013), and reduces sedimentation and pollutant runoff (Simmonds *et al*., 2022). Conservation efforts should prioritise protecting areas with relatively good riparian cover and maintaining current levels of remnant vegetation (Leigh *et al*., 2013; Gilby *et al*., 2016; Redland City Council, 2021). Retention of natural and semi-natural terrestrial vegetation, particularly riparian vegetation, is essential for freshwater quality maintenance, including the reduction of sedimentation and pollutant runoff. Development guidelines also stipulate minimum separation distances for vegetation clearing from streams (e.g. 25m for stream order 1–3, 50m for stream order four or greater) to protect water sources (Seqwater, 2024).
   ii. **Revegetating bare banks:** This action helps to trap sediments, nutrients, and other contaminants from the surrounding catchment, buffering streams and other water bodies (Tibbetts *et al*., 1998; Redland City Council, 2021). The degradation of riparian forest has been a significant factor influencing channel stability, and more vigorous growth and recovery of vegetation in subtropical regions aids bank stability (Kemp *et al*., 2019).
   iii. **Promoting groundcover**: Hillslope erosion, a source of sediment, is best managed by promoting groundcover and maintaining soil structure (Olley *et al*., 2006). Sustainable land management practices emphasise maximising groundcover to reduce exposed soil and erosion and halt sediment flow into waterways (Tibbetts *et al*., 1998; Queensland Government, 2020b; Healthy Land & Water, 2024a). Targeted investment in riparian revegetation and increased ground cover in upper catchments is expected to boost infiltration and reduce sediment runoff (Saeck *et al*., 2019a).

iv. **Maintaining soil structure**: Changes to soil structure and density, such as those caused by European livestock grazing, can lead to increased runoff and erosion (Kemp *et al*., 2019), underscoring the importance of maintaining original soil structure.

v. **Preventing stock access to streams:** Channel erosion can be managed effectively by preventing European livestock from accessing streams (Olley *et al*., 2006). This can involve installing fencing to keep livestock out of creeks (Tibbetts *et al*., 1998; Nasplezes *et al*., 2019).

vi. **Reducing runoff and slowing water movement:** Management should aim to increase infiltration and slow water movement throughout the catchment, which is contrary to historical practices of increasing drainage efficiency (Olley *et al*., 2006). This can be achieved by installing barriers, encouraging vegetation and spreading the flow both spatially and temporally (Olley *et al*., 2006).

Development or construction site scale

2. <u>Implement effective sediment control measures:</u>
   A sediment basin is usually required by a local council if the disturbed area exceeds 1 hectare, or if disturbed soils are dispersive, or if there is a high priority for turbidity control in the local waterway management plan (Brisbane City Council, 2024). The Council may also require a sediment basin, even for disturbed areas less than 1 hectare, depending on the soil type or site location (Brisbane City Council, 2024). Sediment basins must be designed, implemented, and maintained to meet specific performance criteria. They must achieve at least 80% hydrological effectiveness (treating 80% of the average annual runoff volume of the contributing catchment) to discharge water with 50 mg/L total suspended solids or less, and a pH in the range of 6.5 – 8.5 (Healthy land & water, 2024a).

   Use of sediment traps, sediment fences, diversion drains, and stabilisation of disturbed areas is required to minimise loss of sediment from the site (Queensland Government, 2020b; Pine Rivers Shire Council, 2003; Healthy Land & Water, 2024a).

3. <u>Undertake ongoing maintenance and monitoring</u>
   Controls must be installed *before* works commence and remain in place, with regular maintenance and monitoring mandated throughout construction until the site is permanently stabilised against erosion (Queensland Government, 1994).

5.17.6 Sediment management status and issues

ShapingSEQ (Queensland Government, 2023) includes a vision that 'SEQ's catchments will be the best managed in the world…'. It sets out strategies to 'Protect and sustainably manage the region's catchments…' (Strategy 5.1) and to 'Ensure urban land development and its construction avoids impacts on the natural hydrological function, quality and quantity of water in our waterways, aquifers, wetlands, estuaries, Moreton Bay and oceans…' (Strategy 5.2).

While there has been progress in reducing nitrogen and phosphorus loads, there has been limited success in reducing the sediment load entering Moreton Bay (Saeck *et al.*, 2019a). For example, turbidity in the Caboolture, Brisbane, and Logan Rivers showed no net improvement between 2000 and 2018 (Saeck *et al.*, 2019a). Proof-of-concept work by Healthy Land & Water demonstrated that a 50 per cent reduction in sediment at a sub-catchment scale was possible using a suite of sediment reduction strategies. However, the investment needed to implement these strategies across all catchments in SEQ has yet to be secured.

Compared to point source pollution (such as sewage treatment plants), there has been underinvestment in mitigating diffuse source pollution and complex riparian remediation works (Grinham *et al.*, 2024).

Modelling suggests that applying all currently available management techniques (full investment scenario) across urban and rural areas of the whole catchment could lead to substantial reductions in sediment loads compared to a business-as-usual scenario (Saeck *et al.*, 2019a). However, this also highlights that without these comprehensive actions, sediment loads will continue to be a significant problem.

'A lack of enforcement of construction sites' has also been identified by councils and state government representatives as a key gap (Ecofutures, 2024). A recent audit by Healthy Land & Water found that only 15% of development sites were substantially compliant with erosion sediment control measures (Dennis, 2024). This indicates a significant gap between intended measures and on-ground implementation

5.17.7 Recommendations

To better manage sediment loads into Moreton Bay, key experts recommend a multi-faceted approach focusing on reducing overall sediment input and improving land management practices across the catchments. Key recommendations include:

Catchment-wide scale

1. Achieve a 50% reduction in sediment loads to maintain the Bay's current condition and improve ecosystem health (e.g. Olley *et al.*, 2006; Leigh *et al.*, 2013).
2. Stabilise the channel network by protecting and replanting streambank vegetation and undertaking riparian and in-stream rehabilitation (Gilby *et al.*, 2016; Grinham *et al.*, 2024; Saeck *et al.*, 2019a; Council of Mayors (SEQ), 2018). This includes rehabilitating 6,350 km of riparian land (Gilby *et al.*, 2016) and focusing on areas like the Upper Lockyer Catchment (Saeck *et al.*, 2019b).

   Channel erosion management actions need to focus on, and prioritise:

   a. Improving riparian vegetation condition and extent by:
      i. Maintaining existing remnant vegetation
      ii. Addressing threatening processes to native vegetation, such as weed impacts
      iii. Targeted stabilisation of actively eroding channels where appropriate

   iv. Supporting regeneration of complex channel bank and overbank vegetation communities
   v. Managing stock access to streams

b. Improving the surrounding catchment condition by:
   vi. Achieving improvements in land condition (ground cover and species mix) and soil health
   vii. Addressing key sediment sources, including actively eroding gullies
   viii. Planning farming activities to minimise erosion risk, including tillage minimisation; row direction; crop stage during high-risk periods; cover cropping and interrow management; and overland flow planning.

3. Implement best management practices (see item 2, above) throughout the catchment to increase water infiltration and slow its movement, maximise groundcover, reduce exposed soil and erosion, and halt sediment flow into waterways (Leigh *et al*., 2013; Olley *et al*., 2006; Saeck *et al*., 2019a).

Development or construction site scale

4. Improve management of stormwater and construction sites by innovative stormwater management designs (Gilby *et al*., 2016, 15; Saeck *et al*., 2019a). For exposed areas larger than 2,500 m^2, sediment controls must be designed for 80% hydrological effectiveness and treat runoff to 50 mg/L total suspended solids or less, with a pH in the range of 6.5–8.5 (Healthy land & water, 2024a; SPP, 2017). High efficiency sediment basins are considered the most effective way to meet these standards (Healthy Land & Water, 2024a; Council of Mayors (SEQ), 2018). These controls must be properly operated and maintained, with accumulated sediment removed without offsite conveyance, and any coagulants/flocculants used must be carefully managed to prevent harm to receiving waters (Queensland Government, 2021).

5.17.8 Expert review

Mr Ross Bigwood (Healthy Land & Water Catchments) kindly provided an expert review of the Catchment Management and Regulation: Sedimentation Impact Statement.

6. Discussion

Sedimentation poses a significant and increasing threat to the ecological systems of Moreton Bay, primarily driven by extensive land clearing and development in its large catchment since European settlement (Saeck *et al.*, 2019b). Current sediment export rates are estimated to be approximately 100 times (and may be up to 1000 times) greater than pre-European levels (Saeck *et al.*, 2019b), stemming dominantly from channel and gully erosion upstream (Kemp *et al.*, 2019; Grinham *et al.*, 2024).

Flood events are the dominant mechanism delivering vast amounts of sediment to the Bay (Saeck *et al.*, 2019b). Recent major flood events, such as those in January 2011, January 2013, and February 2022, have deposited millions of tonnes of sediment, leading to widespread fine sediment deposition across the entire Bay (Grinham *et al.*, 2024). This has resulted in a 'dramatic increase' in mud distribution, doubling mud cover between 1970 and 2015 (Saeck *et al.*, 2019b), and decreasing the area of clean sand substrate from 442 km^2 to 30 km^2 over 50 years (Grinham *et al.*, 2024).

6.1 Mechanisms of Sedimentation Impacts on Ecological Values

There are two primary mechanisms by which sedimentation impacts the ecological values in Moreton Bay: (i) physical degradation and habitat loss, and (ii) internal nutrient eutrophication. These mechanisms are discussed below.

6.1.1 Physical degradation and habitat loss

The influx of fine sediments results in severe physical and biological degradation across the Bay (Grinham *et al.*, 2024). In particular, the benthic zone is dramatically altered: over the last 50 years, the surface area of clean sand in the Bay has been reduced by approximately 93% (from 442 km^2 to 30 km^2). Benthic communities in over 98% of the Bay's benthic habitats have been altered and impacted (Coates-Marnane *et al.*, 2020; Grinham *et al.*, 2024). The extent of muddy bottom habitats in subtidal regions has roughly doubled since the 1970s (Coates-Marnane *et al.*, 2020).

Sediments suspended in the water column (suspended sediments) reduce water clarity (turbidity), restrict sunlight penetration, and ultimately smother and inhibit the reproduction and growth of key benthic communities such as seagrass and corals (Saeck *et al.*, 2019b). This reduced light availability causes benthic primary production to decline, leading to a larger ecological shift from benthic to pelagic productivity (Saeck *et al.*, 2019b; Coates-Marnane *et al.*, 2020).

6.1.2 Internal nutrient eutrophication

Fine sediments that settle to seabed form deposited mud. The deposited mud acts as a substantial, long-term source of nutrients (Saeck *et al.*, 2019b; Lu *et al.*, 2025). Ammonium, the primary dissolved inorganic nitrogen species, exists in the sediment porewater at concentrations typically more than three orders of magnitude higher than in the overlying water column (Grinham *et al.*, 2024). Frequent tidal and wind-driven resuspension of these muddy sediments releases this ammonium pool (Saeck *et al*., 2019b). This sediment-derived flux is highly significant, estimated at 17,700 tonnes of ammonium per year, which is 180 times higher than annual point source discharges from sewage plants (Grinham *et al*., 2024). These nutrients have led to an increase in bloom-forming marine diatoms and a decline in dominant diatoms since the mid-20th century (Coates-Marnane *et al*., 2020; Lu *et al*., 2025) and contribute to the ongoing decline in water quality (Douglas *et al*., 2003).

6.2 Current Condition

Table 34 provides a summary of the qualitative assessments of the status and trend in condition for the 15 key Moreton Bay values, including an assessment of the contribution of sedimentation to the current condition and condition trend.

Of the 13 ecological values assessed, four are currently in 'poor' condition (benthic macrofauna, epibenthic bivalves, saltmarshes and sea turtles) (Table 34). Another six are in 'fair' condition. Only mangroves and marine mammals remain in 'good' condition. Some ecological groups have been substantially impacted by factors outside of the Bay, such as shorebirds, which are under the most threat from habitat degradation along their international flyways. At the same time, others have been heavily harvested (e.g. epibenthic bivalves) or mined (hard corals) in the past. However, a range of ecological groups are in 'poor' or 'fair' condition due mainly to the relatively recent impacts of sedimentation (benthic macrofauna, hard corals, phytoplankton, saltmarshes and seagrasses). The visual amenity of the bay is also considered to currently be in 'fair' condition, mainly due to the impacts of sedimentation. No values were assessed as being in 'excellent' condition.

Of the 16 culturally important Moreton Bay values to Traditional Custodians, six are considered to be in 'good' condition, four in 'fair' or 'variable' condition and six in 'poor' condition (see Traditional Custodian Values: Sedimentation Impact Statement). Of those in 'poor' condition, the degradation of seagrasses can be attributed to sedimentation impacts, while sedimentation may also be partly or largely attributed to adverse impacts for oyster and shellfish reefs, sea turtles and beche-de-mer (see relevant sedimentation impact statements).

6.3 Condition Trend

The condition trend for the ecological values is more concerning than their current condition. Ten of the 13 ecological values assessed are considered to be in a 'declining' trend. Only mangroves, phytoplankton and marine mammals are assigned a 'stable' trend in their condition. Visual amenity also has a 'declining' condition trend.

The contribution of sedimentation to the condition trend of all 15 values (including fisheries and visual amenity) is substantial. For the 11 values with a 'declining' condition trend, the contribution of sedimentation is considered to be either 'major' (six values) or 'moderate' (six values), including visual amenity

Table 34. Qualitative assessment of the overall status and trend in condition for 16 key Moreton Bay values, including an assessment of the contribution of sedimentation to the current condition and condition trend. Traditional Custodian values have been expanded and presented in a separate table in Section 5.1: Traditional Custodian Values: Sedimentation Impact Statement.

Value	Current condition	Condition trend	Contribution of sedimentation to trend
1. Traditional Custodian values	*See table section 5.1*		
2. Seagrass	Fair*	Declining	Major
3. Mangroves	Good	Stable	Moderate
4. Saltmarsh	Poor	Declining	Major
5. Phytoplankton	Fair	Stable	Moderate
6. Zooplankton	Variable	Declining	Moderate
7. Benthic macrofauna	Poor	Declining	Major
8. Hard corals	Fair	Declining	Moderate
9. Epibenthic bivalves (shellfish reefs)	Poor	Declining	Major
10. Sharks and rays	Fair	Declining	Unknown
11. Teleost fish	Variable	Declining	Major
12. Sea turtles	Poor	Declining	Moderate
13. Shorebirds	Fair	Declining	Minor
14. Marine mammals	Good	Stable	Moderate
15. Fisheries	Fair	Stable	Unknown
16. Visual amenity	Fair	Declining	Major

* depending on the region in the Bay, as per the Healthy Land & Water report card (Healthy Land & Water, 2023).

This indicates that sedimentation is playing a major role in the deterioration of ecological communities and the visual amenity of the Bay (see relevant sedimentation impact statements).

The condition trend of the 16 culturally important Moreton Bay values to Traditional Custodians is assessed as 'stable' for eight and 'declining' for the other eight values (see Table 9). Of those that are 'declining', the trend for at least three values can be substantially attributed to sedimentation (oyster and shellfish reefs, seagrass and coral reefs) and partly attributed to another three values (sea turtles, finfish and beche-de-mer) (see relevant sedimentation impact statements).

6.4 Decline of Moreton Bay Values

The decline in Moreton Bay ecological, cultural, socio-economic and amenity values due to the direct or indirect impacts of sedimentation is of considerable concern, given the decades of previous environmental impacts and the prediction of large-scale perturbations to the marine environment (Ecofutures, 2024). The impacts of climate change (such as a warming climate and rising sea levels) are likely to increase sedimentation issues in the Bay (Grinham *et al.*, 2024).

Power and Callaghan (2016) have demonstrated a statistically significant, increasing trend in the frequency of major floods in coastal catchments spanning from Brisbane (SE Qld) to Eden (NSW), since the late 19th century. Climate change is also predicted to drive an increase in the frequency of extreme rainfall events and associated inflows from catchments to receiving waters along Australia's eastern seaboard, including for south-east Queensland (Gibbes *et al.*, 2014; Dowdy *et al.*, 2015). Without large reductions in sediment retention in the Moreton Bay catchment, future large floods will exacerbate the current impacts of sedimentation on the Bay's ecological values. Furthermore, the impacts of increasing plastic pollution and recreational fishing effort are likely to put additional pressure on the populations of many taxa.

If sedimentation into the Bay can be substantially reduced, it would reduce smothering of benthic communities and improve water clarity. This would lead to increased resilience and survival of photosynthetic communities (e.g., phytoplankton, seagrasses, algae, and hard corals), and reduce the frequency of toxic algal blooms. Furthermore, there would be a range of beneficial ecological cascading effects for other species (e.g. zooplankton, fishes, marine mammals and sea turtles) that rely on those communities more directly impacted by sedimentation. Most fisheries and other socio-economic interests would also benefit from healthier and more abundant ecological communities.

Given that the Bay is functioning as a sink for terrestrial sediment inputs and hypothesised to be receiving sediment at a rate that far exceeds its natural capacity to move material offshore, the adverse effects – such as more frequent resuspension events and long-term water clarity issues - are likely to increase (Saeck *et al.*, 2019b). Continued population growth (projected to reach 4.8 million by 2036) will place the system under more pressure (Saunders *et al.*, 2019; Saeck *et al.*, 2019b).

6.4.1 Harmful algal blooms

The frequency, intensity and geographical distribution of harmful algal blooms have increased globally (Hallegraeff *et al*., 2003), causing major negative ecological, economic and social impacts in coastal areas. Risks to Moreton Bay values associated with harmful algal blooms are also likely to increase in the Bay as a result of elevated nitrogen from sediment ammonium flux that is released from flood-derived muddy sediments (Grinham *et al*., 2024). An increased occurrence of the blue-green algae (*Lyngbya*) has been noted as a significant change in the Moreton Bay ecosystem (Richards, 2019) and is attributed to elevated nitrogen from sediment flux (Grinham *et al*., 2024). Past algal blooms have been implicated in fish kills and localised anoxia in the Bay (Saeck *et al*., 2019b), and Richards (2019) classifies Moreton Bay as being in poor health due to these blooms.

With increasing frequency of nutrient-laden sedimentation into the Bay, harmful algal blooms will likely increase in frequency and size in Moreton Bay (Saeck *et* al., 2019a; Grinham *et al*., 2024) potentially leading to larger, more catastrophic impacts on the Bay's ecological systems than previously seen.

6.5 Sedimentation Impacts in Other Regions

There are other examples of where flood-based sedimentation has degraded coastal marine ecological systems. For example, the Mary River catchment, located approximately 250 km north of Moreton Bay, has undergone extensive land clearance, grazing, and farming since European colonisation around 1840 (Butler *et al*., 2013), resulting in the exposure of large amounts of sediment. In January 2011, heavy rain and flooding delivered elevated levels of sediment, turbidity and nutrients into Hervey Bay for approximately 14 weeks following the event. This event led to a 40% reduction in coral cover post-flood, with significant mortality reaching up to 89% at four of six reefs (Butler *et al*., 2013). Similar examples in Australia have been described, such as those on the Great Barrier Reef (Adame *et al*., 2012), in south-eastern Australia (Kemp *et al*., 2019), and in Port Phillip Bay (Grinham *et al*., 2024).

Many international examples of sedimentation impacts on marine ecological systems have also been described. Albert *et al*. (2014) demonstrated how revegetation of logging areas in the Solomon Islands improved water quality, increased the biomass of marine herbivores and increased coral cover, with the changes indicative of improving reef health. Similar examples have been described for New Zealand (Talbot *et al*., 2018) and the USA (Talbot *et al*., 2018), as well as other regions.

7. Recommendations and Information Gaps

7.1 High-level Recommendations

The high-level recommendations presented below have been consistently identified in many of the studies underpinning the sedimentation impact statements, focusing on catchment control, governance, and long-term planning.

7.1.1 Goal setting and sediment load reduction

A core mandate is the urgent reduction of overall diffuse sediment and nutrient loads entering Moreton Bay from its catchments. The explicit, quantifiable regional management target should be to achieve a 50% reduction in sediment loads to maintain the Bay's current condition and improve ecosystem health.

7.1.2 Comprehensive catchment land management

Management actions must prioritise the stabilisation and rehabilitation of land and channel networks, including:

a) Riparian and channel restoration: Protect, enhance, and replant streambank (riparian) vegetation, including maintaining existing remnant vegetation and rehabilitating degraded stream networks.

b) Addressing erosion sources: Focus on addressing key sediment sources, including actively eroding gullies.

c) Best management practices: Implement best land management practices throughout the catchment to increase water infiltration, maximise groundcover, reduce exposed soil, and halt sediment flow. This includes improving farming practices, such as tillage minimisation, cover cropping, and planning activities to minimise erosion risk during high-risk periods.

7.1.3 Urban and development site runoff control

Improved control of sediment and pollutant runoff from urbanised areas and development sites, including:

a) Stormwater management: Implement innovative stormwater management practices and intelligent design in urban water runoff systems and new developments to reduce sediment and nutrient discharge.

b) Erosion and sediment controls: For exposed areas larger than 2,500 m^2, sediment controls must be designed for 80% hydrological effectiveness and treat runoff to 50 mg/L total suspended solids or less. High-efficiency sediment basins are considered the most effective way to meet these standards.

7.1.4 Integrated management and monitoring

A multi-faceted, adaptive management approach spanning the land and sea is required, including:

a) Integrated/land-to-sea framework: Adopt integrated land-to-sea management strategies through collaborative efforts. This approach should reflect a holistic perspective, similar to the way Indigenous people view their coastal estates, rather than a sectoral approach.

b) Adaptive monitoring: As regular monitoring and assessment are vital to inform management decisions, implement persistent, continuous monitoring of ecological values in the Bay and continually adapt management strategies.

c) Pollutant mitigation: Develop strategies to reduce the discharge of sediments and associated pollutants into estuarine and coastal waters. This includes improving pollutant management strategies to better understand and reduce the impacts of major weather events like floods.

7.1.5 Traditional Custodian involvement

Actively weave Traditional Knowledge and traditional science with western science to inform policy development. Strengthen Indigenous governance and management leadership, supporting organisations like the Quandamooka Yoolooburrabee Aboriginal Corporation. Continue to progress the Quandamooka submission for inclusion on Australia's World Heritage Tentative list.

7.1.6 Improved governance

Adopt a common-pool resource approach for water quality management, fostering cooperation between upstream landholders and downstream beneficiaries. Implement market-based instruments, such as payments for ecosystem services, to compensate landholders for practices that reduce erosion and nutrient runoff.

7.2 Recommendations for Specific Ecological Values

The following recommendations are gleaned from published information and targeted toward unique challenges or opportunities particular to the selected values that are the focus of this report. These recommendations highlight the lack of monitoring and information about many ecological values that are under substantial pressure from sedimentation, as well as other pressures, including rising temperatures and sea levels, organic forms of nutrients and carbon, microplastics, and pollutants.

7.2.1 Habitat restoration and protection

Seagrasses: Tailor management efforts to specific regions, using Species Distribution Models (SDMs) to identify local limiting factors. Mitigate direct physical effects by addressing high wave action through methods such as breakwaters or gabions. Stabilise sediment in areas prone to resuspension using methods such as hessian bags or shell armour.

Mangroves: Implement active sediment management, which may include manually removing excess sediment or trapping and adding sediment where rates are too low. When planting, select native mangrove species tolerant of specific sedimentation rates.

Saltmarshes: Restore natural hydrological patterns to improve water flow and tidal exchange. Implement strong legislative protection and planning measures to allow for the landward migration of saltmarshes by establishing buffer zones. Minimise human disturbance by controlling access to prevent physical damage like trampling.

Benthic macrofauna: Set ecologically relevant limits for sedimentation, moving beyond current sediment quality guidelines, which may not adequately protect coastal ecosystems.

Epibenthic bivalves: Restore shellfish reef habitats using clear, quantifiable goals and adaptive management based on robust, ongoing monitoring. View oyster reefs as part of a more expansive, connected seascape.

Teleost fish: Prioritise managing and restoring estuarine habitats closer to the mouth of estuaries, as these are frequent transition zones and are likely to recover quickly from disturbances. Maximise the extent of natural habitats across estuaries to mediate the effects of floods.

7.2.2 Specialised spatial planning and ecological controls

Mangroves, shorebirds: Manage mangrove encroachment into shorebird habitats (saltmarshes). Prioritise the conservation of the seaward fringe mangrove zone as it plays a crucial role in sediment retention.

Coral, seagrasses: Foster healthy populations of herbivorous fish (e.g. protecting herbivores or designating no-take fishing areas) to protect reefs against macroalgae overgrowth and limit algal loads on seagrass.

Coral, fish, sharks and rays: Use well-designed and managed marine reserves to enhance ecosystem resilience. Strategically place reserves in resilient areas or those less impacted by flood impacts and riverine runoff.

Shorebirds: Strategically plan for and manage artificial roost sites (e.g. those created from dredge material) to secure high-tide roosting habitat. Implement erosion control and active management of water levels in roosts.

Sea turtles, mammals: For activities like dredging, undertake careful planning, avoid sensitive areas, and use environmental windows during critical times to minimise impacts. Implement and enforce Moreton Bay Marine Park green zones and mandatory ‘go slow’ areas for vessels.

7.2.3 Monitoring, research and chemical focus

Phytoplankton: Enhance nitrogen management, as the sediment itself carries and releases nitrogen that fuels phytoplankton growth.

Phytoplankton, seagrasses: Improve monitoring for a broader suite of parameters, including organic forms of nutrients and carbon, to understand their impact on plant growth responses and refine water quality models.

Zooplankton: Increase research on the seasonality of zooplankton in relation to wet season inputs. Sample smaller zooplankton, particularly microzooplankton, more thoroughly. Consider using zooplankton as ecosystem indicators for environmental change, eutrophication, and pollution.

Benthic macrofauna: Monitor the health and structure of subtidal and demersal benthic macrofauna communities to assess changes in response to variations in their habitat, including parameters such as substrate structure, turbidity and temperature.

Epibenthic bivalves (shellfish reefs): Monitor the health and community structure of shellfish reefs to assess changes in response to variations in their habitat, including parameters such as substrate structure, turbidity, temperature and sea level rise.

Hard corals: Further research is needed to disentangle the impacts on, and responses of, corals to sediments and nutrients, including different sediment types, the role of sediment shading during heatwaves, and the impacts of microplastics.

Sea turtles: Reduce marine debris at its source. Evaluate spatial relationships between dioxin exposure and the health status of Green turtles to identify ‘hotspots’. Increase biomonitoring of trace elements and other chemicals.

Mammals: Monitor the health of dugong and dolphin populations and individuals (e.g. through contaminant exposure) to screen for and mitigate emerging health-related problems linked to habitat deterioration.

8. Conclusions

Substantial shifts in climate and population are expected to occur in the Moreton Bay region by 2050. By 2046, South-east Queensland is expected to have a population of around six million people, an increase of 2.2 million from its current 3.8 million (Queensland Government, 2023). This growth is likely to be coupled with further development of land for housing and agricultural production within the Bay's catchment areas. Without major changes to the management of exposed sediments, the risk of further very large sediment loads being flushed into the Bay remains high and ongoing.

Climate change projections include an increased frequency of severe storms and flooding in eastern Australia. Floods that occur in south-east Queensland will mobilise any exposed sediment in the catchment and deliver additional muddy sediments throughout much of Moreton Bay. Along with the volume of exposed sediment in the catchment, the frequency and size of future floods will determine the size of future sediment loads into the Bay. If major flooding events continue as frequently as in recent decades (e.g. since 2011), the Bay will be unable to remove the unusually high sediment loads in timeframes that allow habitats to recover in the short term. The consequences are likely to be further degradation of benthic habitats, such as coral reefs, shellfish reefs, deeper benthic communities and seagrass beds. Ecological groups that rely on these communities and habitats, such as fish, sharks, rays, sea turtles and marine mammals, may also suffer substantial population degradation. The high concentrations of nutrients that will also be delivered into the Bay, along with sediment, may create conditions for larger, more frequent algal blooms, further impacting ecological values and amenity. Increased sea water temperatures may also exacerbate this threat.

While Moreton Bay has recovered to some extent from past, larger, and less frequent floods, the projected increase in the frequency of more extreme floods, along with large, exposed sediment loads in the catchment, will create conditions that greatly restrict the recovery of ecological values in Moreton Bay. Mitigating sediment and nutrient runoff through improved catchment management is therefore crucial for enhancing the recovery and persistence of these values, as well as reducing greenhouse gas emissions to mitigate the frequency of large flooding events in the long term.

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Appendix A - References, citation style and naming conventions

References

The use of published, cited information sources (the references) is a key component of this project. References provide the foundation for developing a credible 'evidence pack' of key knowledge regarding the impacts of sedimentation on Moreton Bay.

A total of 285 published or publicly available references have been reviewed and cited as evidence for this report. A summary analysis of the references used for this report is provided in Appendix B - Summary analysis of references

Peer reviewed papers provided the majority (58%) of references for this report. Other published reports or articles comprised 18% of references. Published books or book chapters comprised 15%. Together, peer reviewed papers, published reports and books or book chapters accounted for almost all (91%) of the references cited in this report.

Over 90% (93%) of sources used were published within the last 25 years (from 2000 onwards). More than half the references cited (58%) were published in the last 10 years (2015 onwards) and 28% were published in the last 5 years (2020 and later). Only 6% of references were published prior to 2000.

Forty-five percent (45%) of all references focused specifically on Moreton Bay. Around 58% of references addressed Moreton Bay and/or its catchments as either the focus for, or part of, the study. Sources also included other relevant publications with a Queensland focus (12%), an Australian focus (6%) or an international focus (22%).

Citation style

The Harvard citation style has been used throughout the report, including for in-text citations and the full reference list (see References).

All personal communications (pers. comm.) noted in the report were provided in 2025.

The 'Red List' from *International Union for Conservation of Nature and Natural Resources* (IUCN Red List) has been used to provide information on the conservation status of some species (e.g. sea turtles, sharks and rays, shorebirds, marine mammals). Citations for the status of each IUCN Red List species mentioned in this report have not been included, as they are readily available from the IUCN Red List website at https://www.iucnredlist.org.

Naming conventions

The scientific name for each species is italicised and provided in sentence case (only the first word and any proper nouns capitalised), as per standard conventions for scientific writing. Common names for species are also generally presented in sentence case. This naming convention aligns with CSIRO, the *Australian Faunal Directory* and government agencies and has been applied to all ecological values for consistency, except for shorebirds. Shorebird names use title case for the common name (each word of the common name capitalised), in line with *BirdLife Australia* (https://birdlife.org.au/) and ornithological conventions more broadly.

Appendix B - Summary analysis of references

This appendix provides a summary analysis of the references used in the report. The analysis is based on information logged in the knowledge register. The knowledge register is an Excel database of all references used in the report and has been provided to TMBF as a separate project output (see Appendix).

A total of 285 references (refs) were used in this report: this figure is the basis of calculations for '% of total refs' in the tables below.

Table B1. Overall count of the number of references (refs) cited in each Impact statement (or value)

Impact statement (Value)	No. of refs	% of total refs
Traditional Custodian values	16	6%
Seagrass	23	8%
Mangroves	32	11%
Saltmarsh	27	9%
Phytoplankton	12	4%
Zooplankton	24	8%
Benthic macrofauna	22	8%
Hard corals	31	11%
Epibenthic bivalves	28	10%
Sharks and rays	20	7%
Teleost Fish	27	9%
Sea turtles	41	14%
Shorebirds	19	7%
Marine mammals	35	12%
Fisheries	16	6%
Visual amenity	7	2%
Sources of sedimentation	28	10%
Catchment management and regulation	42	15%
Other report sections	6	2%

Table B2. Type of reference

Reference (ref) type	No. of refs	% of total refs
Peer reviewed & published paper	164	58%
Published book/book chapter	42	15%
Published report/article	52	18%
Media/social media article	2	1%
Thesis	7	2%
Website	6	2%
Conference paper	2	1%
Other	10	4%
TOTAL	**285**	**100%**

	No. of refs	% of total refs
Sum of published papers, book chapters & reports	258	91%

Table B3. Currency of references (refs) - based on generalised eras

Year of reference (ref)	No. of refs	% of total refs
<2000	18	6%
>2000	264	93%
<2015	106	37%
>2015	166	589%
>2020	80	28%

Table B4. Currency of references (refs) – based on specific timeframes

Year of reference (ref)	No. of refs	% of total refs
<2000	18	6%
2000 - 2015	101	35%
2016 - 2020	86	30%
2021 - 2025	80	28%
TOTAL	**285**	**100%**

Table B5. Focus area of study/studies for references (refs)

Sites/areas of focus for the reference (ref)	No. of refs	% of total refs
Moreton Bay	129	45%
Moreton Bay catchment/land	19	7%
Moreton Bay and other Queensland sites/areas	11	4%
Moreton Bay and other Australian sites/areas	7	2%
Other Queensland sites/areas (not incl. Moreton Bay)	33	12%
Other Australian sites/areas (not incl. Moreton Bay)	17	6%
Other international sites/areas (not incl. Moreton Bay)	63	22%
Other Australian and international sites/areas	6	2%
TOTAL	**285**	**100%**

	No. of refs	% of total refs
Sum of references with Moreton Bay and/or its catchment included as a part, or the focus, of the study	166	58%

Appendix C

Knowledge register

The 'Register of Knowledge Sources' (knowledge register) was developed to collate and log key information for all references used in this report.

The knowledge register is a searchable Excel database and is provided as a separate project product for TMBF and can be added to or amended by TMBF, as required.

The database:

- categorises each reference based on the relevant key value/s or impact statement/s relevant to the reference (see Key Values section and Sedimentation Impact Statements sections)
- includes basic search and analysis functions regarding the references (such as number of references, types of references and lists of references for each key value or impact statement). See Data fields

The knowledge register database is based on one unique entry or row for each reference. For each reference (the row) there are multiple data fields (the columns) including:

- short version of author name/s and year for easy searching (e.g. Gilby *et al.*, 2024).
- year of publication.
- full citation with each author's full name, publication date, publication title, journal or book title, publisher and doi.
    - This information is taken directly from the References section and uses the Harvard citation style.
- type of reference (e.g. Peer reviewed & published paper).
- focus area of the study/studies (e.g. Moreton Bay; other Queensland sites/areas (not including Moreton Bay)).
- title for easy searching of topics/key words.
- 12 fields/columns to capture and categorise the 'Value' (or values) relevant to the reference.
    - In general, each 'Value' represents an impact statement (see Chapter 5 Impact statements).
    - Although some of the impact statements are not technically values (such as the 'Sources of sedimentation' and 'Catchment management and regulation' impact statements), the 'Value' fields also allow for information on these impact statements to be collated and analysed.

- 'Search Term' field. This allows for a specific value or impact statement to be inserted and matched to any relevant references, via the 'Match' field.
- 'Match' field. This field applies a basic search function allowing a search across all value fields to find and list any reference that matches the search term ('IF' is "Match" function).

Table C1 summarises key information on the knowledge register's data fields. All data fields can be sorted and searched according to user requirements.

The database also incorporates several automated basic search and analysis functions, including count functions to list and determine the number of:

- references overall (TOTAL Refs).
- references for a specific search term/value (see Table A1, above).
- reference types (e.g. Peer reviewed & published paper; Published book/book chapter; etc.) (see Table A2, above).
- references within a general timeframe (e.g. before 2000; after 2000; before 2015; after 2015; and after 2020) and the associated percentage of TOTAL Refs (see Table A3, above).
- references within a specific timeframe (e.g. 2000-2015; 2016-2020; and 2021-2025) the associated percentage of TOTAL Refs (see Table A4, above).
- references focused on specific sites/areas (e.g. Moreton Bay; Moreton Bay and other Queensland areas; etc.) (see Table A5, above).

Table C1. Field names and content used in the Knowledge Register (database).

Field name	Content	Field type
Short ref/ Author	Short version of author name/s and year	Text field
Year	Year of publication	Date field (YYYY)
Citation/ Reference	Full citation for the reference using the Harvard citation style	Text field
Ref Type	Type of reference: • Peer reviewed & published paper • Published book/book chapter • Published report/article • Media/social media article • Thesis • Website • Conference paper • Other	Drop down list
Study area focus	Focus area of the study/studies: • Moreton Bay • Moreton Bay catchment/land • Moreton Bay and other Queensland sites/areas • Moreton Bay and other Australian sites/areas • Other Queensland sites/areas (not incl. Moreton Bay) • Other Australian sites/areas (not incl. Moreton Bay) • Other international sites/areas (not incl. Moreton Bay) • Other Australian and international sites/areas	Drop down list
Title	Title of publication	Text field
Value_1 to Value_12	12 fields for entering the relevant value/s (or impact statement/s) • Traditional Custodian values • Seagrasses • Mangroves • Saltmarshes • Phytoplankton • Zooplankton	Drop down list

Field name	Content	Field type
	• Benthic macrofauna • Hard corals • Epibenthic bivalves • Sharks and rays • Teleost Fish • Sea turtles • Marine mammals • Fisheries • Visual amenity • Sources of sedimentation • Catchment management and regulation • Other report sections	
Search term	User to enter specific Value (see above) to search for and match	Text field (use Value)
Match	Function to list all references that match the search term	Calculated field. Select 'Match' in search field.

This report was commissioned by The Moreton Bay Foundation (TMBF) to develop a summary 'evidence pack' of key knowledge regarding the impacts of sedimentation on the coastal and marine ecosystems of Moreton Bay and the values they support. It stemmed from the TMBF-commissioned ***Blueprint for a Sustainable Moreton Bay for People and Nature (2025-2035)***, which identifies catchment-derived sediment as one of the main threats to the ecological and other values of the Bay.

The Moreton Bay Foundation

DBC David Brewer Consulting

The Moreton Bay Foundation and David Brewer Consulting acknowledge the Quandamooka, Kabi Kabi/Gubi Gubi and Kombumerri peoples, the Traditional Custodians of Moreton Bay, Quandamooka, who manage Moreton Bay as their sea country under Aboriginal customary law encompassed by this plan. We also acknowledge the Traditional Custodians of the catchment areas adjacent to Moreton Bay include the Jinibara, Mulinjarlie, Jagera, Yuggerra and Ugarapul people. The Traditional Custodians of this region maintain an unbroken connection with the area and we recognise the cultural, spiritual, social, and economic significance that these lands and waters hold to these people. We pay our respects to past, present, and future Traditional Custodians and Elders, and to their commitment to the continuation of cultural, spiritual, and educational practices of Aboriginal and Torres Strait Islander peoples.

Cover Images:
Sediment river outflow, Photo credit: A. Grinham
Eastern Curlew, Photo credit: C. Walker
Corals in Moreton Bay, Photo credit: K. Walters

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