Marine Biodiversity Index

Methods for integrating marine indicators

Port Phillip Bay

August 2022

VICTORIA State Government | Environment, Land, Water and Planning

Photo credit

Katrina Richards, DELWP

Authors

Dr Tessa Mazor: Marine Spatial Analyst, Biodiversity Division, DELWP, tessa.mazor@delwp.vic.gov.au
Ms Laura Town-Hopkinson: Biodiversity Division, DELWP, laura.town-hopkinson@delwp.vic.gov.au
Mr Lawrance Ferns: Marine Knowledge Manager, Biodiversity Division, DELWP, lawrance.ferns@delwp.vic.gov.au
Ms Rhiannon Holden: Marine Spatial Analyst, Biodiversity Division, DELWP, rhiannon.holden@delwp.vic.gov.au
Dr Kate Watermeyer: Marine Spatial Analyst, Biodiversity Division, DELWP, kate.watermeyer@delwp.vic.gov.au
Ms Regan East: Marine Biodiversity Policy Officer, Biodiversity Division, DELWP, regan.east@delwp.vic.gov.au

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Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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Marine Knowledge | Biodiveristy Protection and Information

Contents

List of acronyms

BQR	Biological Quality Ratio
CPUE	Catch Per Unit Effort
CM	Confidence Metric
DRI	Dolphin Research Institute
EMP	Port Phillip Bay Environmental Management Plan 2017 – 2027
FFG Act	Flora and Fauna Guarantee Act 1988
GAM	Generalised Additive Modelling
GES	Good Environmental Status
HELCOM	Helsinki Commission, protection of Baltic marine environment
IUCN	International Union for Conservation of Nature
MERI	Monitoring, Evaluation, Reporting and Improvement strategy
MBI	Marine Biodiversity Index
OSPAR	Oslo/Paris convention for the Protection of the Marine Environment of the North-East Atlantic
PPB	Port Phillip Bay
RLS	Reef Life Survey
SRMP	Victorian Subtidal Reef Monitoring Program
UNCLOS	United Nations Convention on the Law of the Sea
VBA	Victorian Biodiversity Atlas
VFA	Victoria Fisheries Authority

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Dr. Andre Chiaradia (Phillip Island Nature Parks), Flossy Sperring (Earthcare St Kilda), Dr. Richard Reina (Monash University), Dr. John Arnould (Deakin University), Michael Sams (Parks Victoria), Mark Norman (Parks Victoria), Dr. Jacqueline Pocklington (DELWP), Paul Reich (DELWP), Darren Cottam (EPA), Dr. Harry Gorfine (VFA), Dr. Simon Conron (VFA), Dr. Daniel Ierodiaconou (Deakin University), Dr Paul Carnell (Blue Carbon Lab Deakin University), Dr. Tim O'Hara (Museums Victoria), Prof. Stephen Swearer (University of Melbourne), Dr Kate Robb (Marine Mammal Foundation), Dr Sue Mason (Cetacean Science Connections), Mandy Watson (DELWP), Dr Greg Parry, Dr. Kasey Stamation (ARI), Dr. Rebecca McIntosh (Phillip Island Nature Parks), Mark Keenan (Melbourne Zoo's MRU), David Donnelly (DRI), Jeff Weir (DRI), Dr Matt Edmunds (Australian Marine Ecology), Dr Adrian Flynn (Fathom Pacific), Prof. Peter Macreadie (Blue Carbon Lab Deakin University), Dr. Steve Sinclair (ARI), Dr Steve Klose (Birdlife), Dr. Danny Rogers (DELWP ARI), Dr. Peter Menkhorstst (DELWP ARI), Dr. Alastair Hirst (EPA), Prof. Paul Boon (Victoria University), Dr. Tom Hurst (Melbourne Water), David Ball, Dr. Ruth Reef (Monash), Greg Woodward (DELWP), David Reid (DELWP), Dr. Mariela Soto-Berelov (RMIT), Dr. Tracey Regan (DELWP ARI), Dr. Josephine Machunter (DELWP ARI).

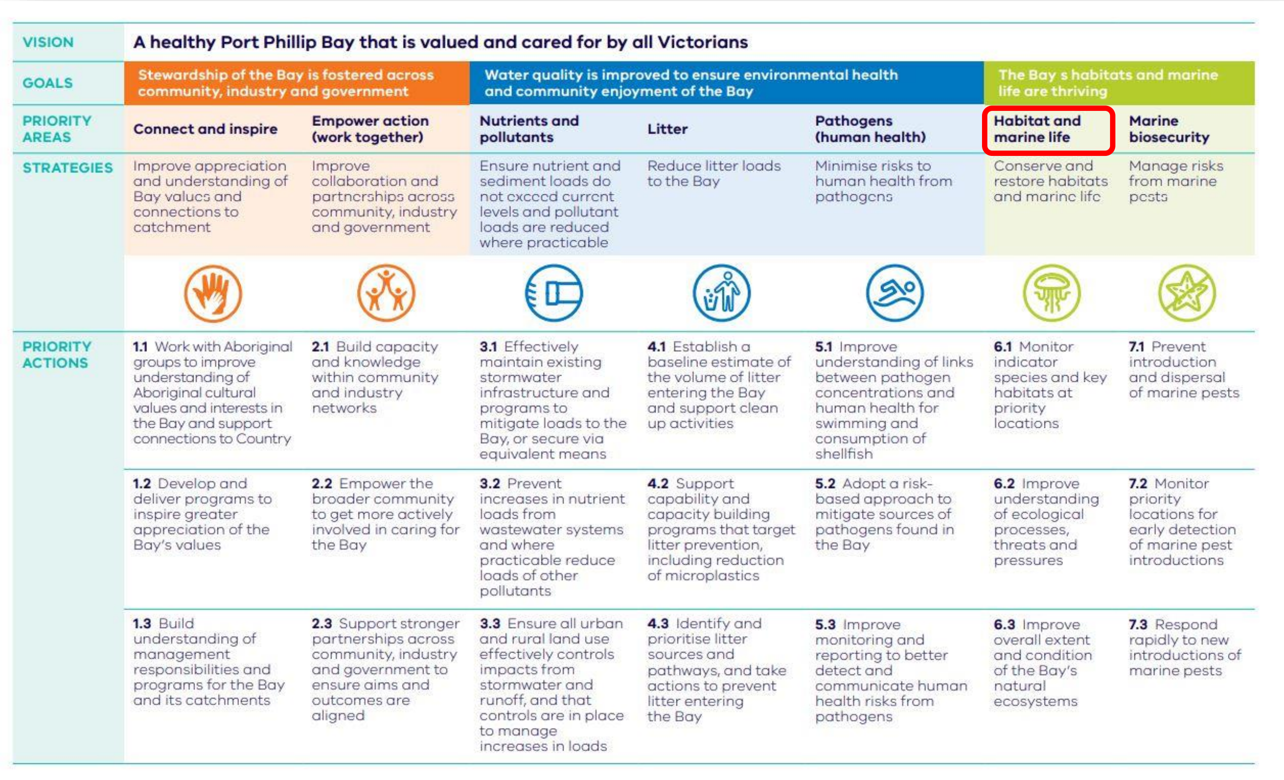
1. Purpose

This document has been created for the Port Phillip Bay (PPB) Environmental Management Plan 2017 – 2027 (EMP). It identifies an evaluation methodology for marine biodiversity that can be used for reporting and to drive continuous improvement in the monitoring and management of marine life. That said, the approach described is also relevant for other marine and coastal regions. The presented method is embedded within the Victoria's Marine and Coastal Knowledge Framework (MACKF), a recommended mechanism for addressing knowledge gaps, reducing uncertainties, and forming the future evidence base for assessing management interventions and environmental outcomes in PPB and Western Port. The method provides clear linkages between the MACKF's core pillars of 'Outputs' and 'Applications'; whereby data and information products are synthesised to support management and planning decisions, evaluation, and reporting purposes. The marine biodiversity reporting method also supports Victoria's Biodiversity 2037 plan, specifically by improving the information needed in achieving the goal of 'Victoria's natural environment is healthy' and the state-wide target to provide 'a net improvement in the outlook across all species by 2037'.

2. Introduction

The EMP is authorised under the *Marine and Coastal Act* (MACA) 2018 and the State Environment Protection Policy (Waters) 2018. The MACA, section 55 (1) specifies environmental management plans must be reviewed within five years of making the plan.

The EMP's Monitoring, Evaluation, Reporting and Improvement strategy (MERI) will guide the five-yearly evaluation through an assessment of the effectiveness and efficiency of the EMP's strategies (Figure 1). As part of this, the EMP MERI will assess the effectiveness of the EMP in delivering on its overarching goal of 'The Bay's habitats and marine life are thriving', and Priority Area of 'Habitat and marine life'.



VISION	A healthy Port Phillip Bay that is valued and cared for by all Victorians						
GOALS	Stewardship of the Bay is fostered across community, industry and government		Water quality is improved to ensure environmental health and community enjoyment of the Bay			The Bay s habitats and marine life are thriving	
PRIORITY AREAS	Connect and inspire	Empower action (work together)	Nutrients and pollutants	Litter	Pathogens (human health)	Habitat and marine life	Marine biosecurity
STRATEGIES	Improve appreciation and understanding of Bay values and connections to catchment	Improve collaboration and partnerships across community, industry and government	Ensure nutrient and sediment loads do not exceed current levels and pollutant loads are reduced where practicable	Reduce litter loads to the Bay	Minimise risks to human health from pathogens	Conserve and restore habitats and marine life	Manage risks from marine pests
PRIORITY ACTIONS	**1.1** Work with Aboriginal groups to improve understanding of Aboriginal cultural values and interests in the Bay and support connections to Country	**2.1** Build capacity and knowledge within community and industry networks	**3.1** Effectively maintain existing stormwater infrastructure and programs to mitigate loads to the Bay, or secure via equivalent means	**4.1** Establish a baseline estimate of the volume of litter entering the Bay and support clean up activities	**5.1** Improve understanding of links between pathogen concentrations and human health for swimming and consumption of shellfish	**6.1** Monitor indicator species and key habitats at priority locations	**7.1** Prevent introduction and dispersal of marine pests
	1.2 Develop and deliver programs to inspire greater appreciation of the Bay's values	**2.2** Empower the broader community to get more actively involved in caring for the Bay	**3.2** Prevent increases in nutrient loads from wastewater systems and where practicable reduce loads of other pollutants	**4.2** Support capability and capacity building programs that target litter prevention, including reduction of microplastics	**5.2** Adopt a risk-based approach to mitigate sources of pathogens found in the Bay	**6.2** Improve understanding of ecological processes, threats and pressures	**7.2** Monitor priority locations for early detection of marine pest introductions
	1.3 Build understanding of management responsibilities and programs for the Bay and its catchments	**2.3** Support stronger partnerships across community, industry and government to ensure aims and outcomes are aligned	**3.3** Ensure all urban and rural land use effectively controls impacts from stormwater and runoff, and that controls are in place to manage increases in loads	**4.3** Identify and prioritise litter sources and pathways, and take actions to prevent litter entering the Bay	**5.3** Improve monitoring and reporting to better detect and communicate human health risks from pathogens	**6.3** Improve overall extent and condition of the Bay's natural ecosystems	**7.3** Respond rapidly to new introductions of marine pests

Figure 1. The placement of the habitat and marine life priority area (red box) under the broader goal of 'The Bay's habitats and marine life are thriving' and within the broader EMP framework.

There are currently 191 activities listed in the EMP's Delivery Plan. Of these 25 activities are delivering the habitat and marine life goal.

Indexes, or composite indicators, enable simplified reporting on complex information for broad audiences (McIntosh et al 2019), and are used worldwide for reporting on environmental condition and management actions (Logan 2020). The Marine Biodiversity Index (MBI) is a composite indicator designed to evaluate the health and condition of PPB's habitats and marine life, and to monitor and measure outcomes of conservation actions.

3. Integrated indicators approach

The MBI method is adapted from international approaches such as the Baltic Sea's integrated indicators approach (The Helsinki Convention; HELCOM 2018a), the Joint Nature Conservation Committee's (JNCC) Good Environmental Status (GES) and the OSPAR (Oslo/Paris convention for the Protection of the Marine Environment of the North-East Atlantic) common indicators approach. These approaches report on marine ecosystem components supporting the delivery of key international obligations to protect the marine environment under the United Nations Convention on the Law of the Sea (UNCLOS), the United Nations Sustainable Development Goal 14 (conserve and sustainably use the ocean, seas, and marine resources for sustainable development), and the United Nations Convention on Biological Diversity.

The MBI approach enables data and results from independent indicators to be integrated into a holistic assessment (Figure 2). Following the HELCOM biodiversity assessment (HELCOM 2018a; 2018b), integrated assessments were performed separately for PPB's seven key ecosystem components. Assessment biota were selected to represent key ecosystem components, and to align with indicators reported in the Commissioner for Environmental Sustainability State of the Bays report (State of the Bays 2016), HELCOM's biodiversity assessment (HELCOM 2018a; 2018b), as well as the EMP priority action 6.1 to monitor indicator species and key habitats. The MBI index aligns with the European GES Descriptor 1 (Biodiversity), and as well as Descriptor 3 (The population of commercial fish species is healthy; ecosystem component 'Fish').

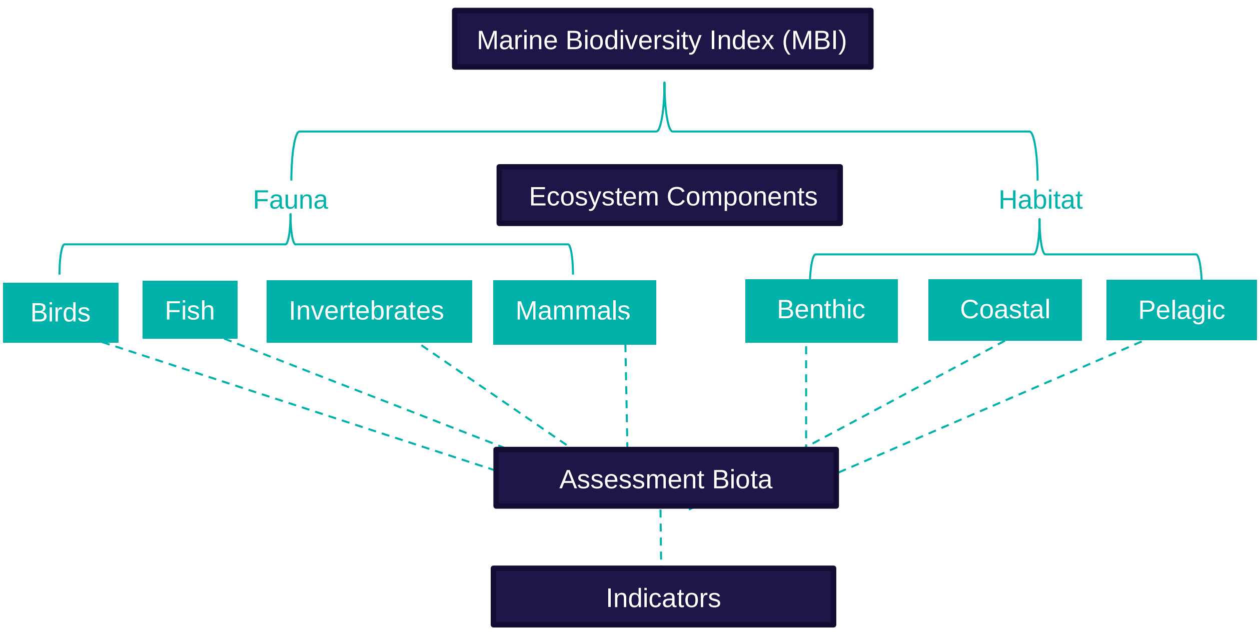


Figure 2. Marine Biodiversity Index (MBI) structure

Expert working groups have been established for each ecosystem component to provide data, exchange scientific knowledge, and assist in the development of threshold values. Table 1 provides an overview of the nested approach and the assessment biota and indicators applied to each ecosystem component. The integrated approach enables inclusion of different indicators, with the primary understanding that marine biota is often measured in different ways, includes different types of data, scales, and units. Furthermore, new indicators may be developed in the future and robust methods to incorporate these dynamics must be included into consistent biodiversity reporting methods. The nested approach (following HELCOM's BEAT 3.0 Tool; HELCOM 2018b) normalises the scores for indicators so they can be combined into a Biological Quality Ratio (BQR; described below) which provides a common scale. To enable accumulation of indicators in a hierarchical manner (Figure 2), weights are given to each indicator and a weighted average is calculated. The structure of weights is balanced to ensure that all ecosystem elements at the same structural level (such as ecosystem component level or taxa group level) are considered equally, irrespective of the number of indicators applied.

Table 1. Breakdown of Marine Ecosystem Components into Assessment Biota and Indicators as per (Figure 2).

Marine Ecosystem Component	Assessment Biota (Taxa group/species)	Indicators
Birds	• Shorebirds • Waterbirds • Little Penguin • Australasian Gannet	• Living Planet Index • Population trends in abundance • Breeding success
Fish	• King George Whiting • Southern Sand flathead • Snapper	Commercial stock assessment (VFA): • Biomass – catch per unit effort (CPUE)
Invertebrates	• Urchins • Abalone • Spider Crab • Reef invertebrates	• Species abundance – mean density (number per m^2) • Species diversity (richness and abundance)
Mammals	• Common Dolphin • Burrunan Dolphin • Whales • Seals	• Population trends in abundance • Reported emergencies (entanglements, mortalities) and sightings
Benthic habitats	• Subtidal biotopes (see section for list)	• Marine condition • Habitat hectares • Species diversity (richness and abundance)
Coastal habitats	Intertidal biotopes: • Seagrass beds • Salt marshes • Mangroves • Reefs	• Marine condition • Habitat hectares • Change in habitat extent
Pelagic habitats	• Zooplankton • Chlorophyll-a • Harmful algal blooms	• Zooplankton/phytoplankton abundance • Chlorophyll-a conditions • Harmful algal bloom events

3.1 Status categories

The MBI is based on five categories of status as defined in Table 2. The progression of MBI status from 'Very Poor' through to 'Very Good' broadly represents increasing health, condition and resilience of habitats and marine life. These status categories align with other reported indexes and evaluations of the EMP goals

(Figure 1). Status is defined by different methods (integrated or individual) according to the hierarchical level of biodiversity reported. For individual indicators these status categories are based on quantitative threshold values which utilise scientific knowledge such as a historic baseline reference, threshold concentration levels, or baselines derived from multi-year data trends. All thresholds and their values are determined in consultation with an Expert Working Group of regional marine ecologists and stakeholder groups. Threshold values are specific to each indicator and thus their application may take the form of maximum, minimum or a range of values and there can also be variation in the threshold values (quantitative values) as well as the approach.

The integrated indicators approach (following HELCOM's BEAT 3.0 tool; HELCOM 2018b) normalises indicator scores to a common assessment scale between 0 and 1, referred to as the BQR. A BQR of value 1 represents the highest attainable value, with five equal-distance categories (Table 2) and a threshold value of 0.6 representing a 'Good' integrated status. The normalisation process requires a minimum and maximum value to be defined for every indicator and calculates the distance to the threshold value, to enable different indicators to be comparable.

The below equations are applied to calculate the BQR:

1) applied when the observed indicator value is <u>below</u> the threshold value equation:

$$\text{BQR} = 0.6 * (\text{Observed value} - \text{Minimum value}) / (\text{Threshold value} - \text{Minimum value})$$

2) applied when the observed indicator value is <u>above</u> the threshold value equation (2):

$$\text{BQR} = 1 * (\text{Observed value} - \text{Threshold value}) / (\text{Maximum value} - \text{Threshold value})$$

The normalisation process can also be applied to other types of indicators where a minimum and maximum are not defined, such as conditional indicators and for trend-based indicators following methods by HELCOM (2018a; 2018b).

Table 2. MBI Status categories and description categories based on both individual and integrated indicators

Status Categories	Description of Categories	
	Integrated Indicators Biodiversity Quality Ratio BQR	**Individual Indicators** Definition to Define Status
Very Good	0.8 – 1.0	Maximum value
Good	0.6 – 0.8	At baseline/threshold defined by Expert Working Group
Fair	0.4 – 0.6	Below baseline/threshold (%) defined by Expert Working Group
Poor	0.2 – 0.4	Below baseline/threshold (%) defined by Expert Working Group
Very Poor	0.0 – 0.2	Minimum value
Data Deficient	Not Assessed due to not enough data available to define a status	

3.2 Confidence assessment

A parallel confidence assessment is integrated into the approach to evaluate the underlying data that the indicators are derived from. Confidence of each indicator is measured in four ways to include accuracy (ConfA), temporal coverage (ConfT), spatial representation (ConfS) and methodological quality (ConfM) as outlined in Table 3. Confidence metrics are defined by Expert Working Groups, where confidence metric components are categorised as high, intermediate, or low, and thereafter assigned categorical values (1, 0.5 and 0, respectively).

Table 3. Confidence Metric (CM) components and their classification within the high, intermediate, and low categories.

Confidence Metric (CM) components		High (value = 1)	Intermediate (value = 0.5)	Low (value = 0)
ConfA	Confidence in the assessment based on **accuracy** of indicator result (accuracy in relation to threshold)	Indicator assessment with accuracy ≥90 %	Indicator assessment with accuracy 70 – 90 %	Indicator assessment with accuracy <70 %
ConfT	Confidence in the assessment based on **temporal coverage**	Monitoring data available for all years of assessment period (2000 – 2021)	Monitoring data available for more than half of the assessment period years	Monitoring data available for less than half of the assessment period years
ConfS	Confidence in the assessment based on **spatial representation**	Data represents ≥80 % spatial coverage of the assessment unit	Data represents 60 – 80% of spatial variation across assessment unit	Data represents <60 % of spatial variation across the assessment unit
ConfM	Confidence in the assessment based on **methodological quality**	Monitoring methods and data is consistent and of high scientific quality	Monitoring methods and data is of mixed methods and sources with moderate scientific quality	Monitoring methods and data (not quality assured) is low quality

Confidence Metric (CM) components are then combined into an overall Confidence Metric (CM):

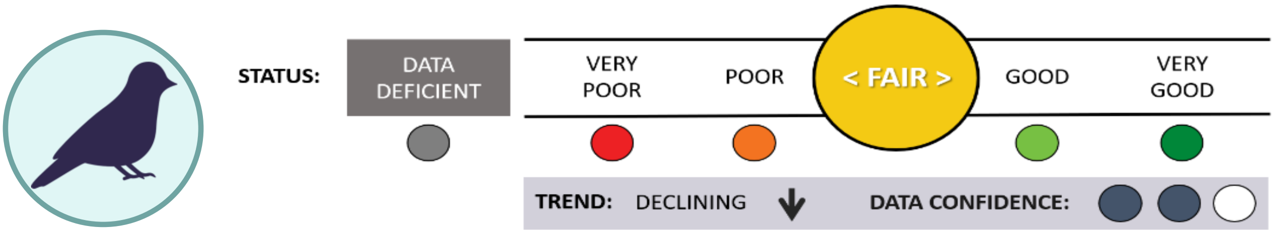
Confidence Metric (CM) = (0.25*ConfA) + (0.25*ConfT) + (0.25*ConfS) + (0.25*ConfM)

An overall CM is calculated for each indicator by equally weighting the confidence metric components and summing these to produce a value between 0 and 1. Confidence status is defined by the CM value as per Table 4. The confidence assessment follows the same nested approach using weights for integration across assessment biota and ecosystem components. Moreover, a CM value is obtained when grouping at different levels of biodiversity reporting (Figure 2).

Table 4. Confidence Status as determine by the Confidence Metric (CM) value.

Confidence Status	CM Value
High	> 0.75
Intermediate	0.5 – 0.75
Low	< 0.5

4. Birds



Assessment Biota	• Migratory shorebirds • Resident shorebirds • Waterbirds • Seabirds • Little penguin (*Eudyptula minor)*, • Australasian Gannet (*Morus serrator)*)
Data Sources	Birdlife, Earthcare St Kilda, Deakin University
Consulted Stakeholders and Experts	Dr Steve Klose (Birdlife), Dr. Danny Rogers (ARI), Dr. Peter Menkhorstst, Flossy Sperring (Earthcare St Kilda), Dr. Richard Reina (Monash University), Dr. Andre Chiaradia (Phillip Island Nature Parks), Dr. John Arnould (Deakin University)

The status of birds in PPB in 2020–2021 was Fair and the trend is declining. Birds are grouped into taxa groups of shorebirds, waterbirds and seabirds following Birdlife categories (Birdlife 2018). These groups are further divided into migratory and resident shorebirds, and seabirds focus on two iconic species for PPB the Little Penguin and the Australasian Gannet. This status is informed by available time-series data indicating the status of 39 species of shorebirds, 47 species of waterbirds, Australasian Gannets, and incorporates Little Penguins from 2000 onwards. The confidence score for this data is Medium

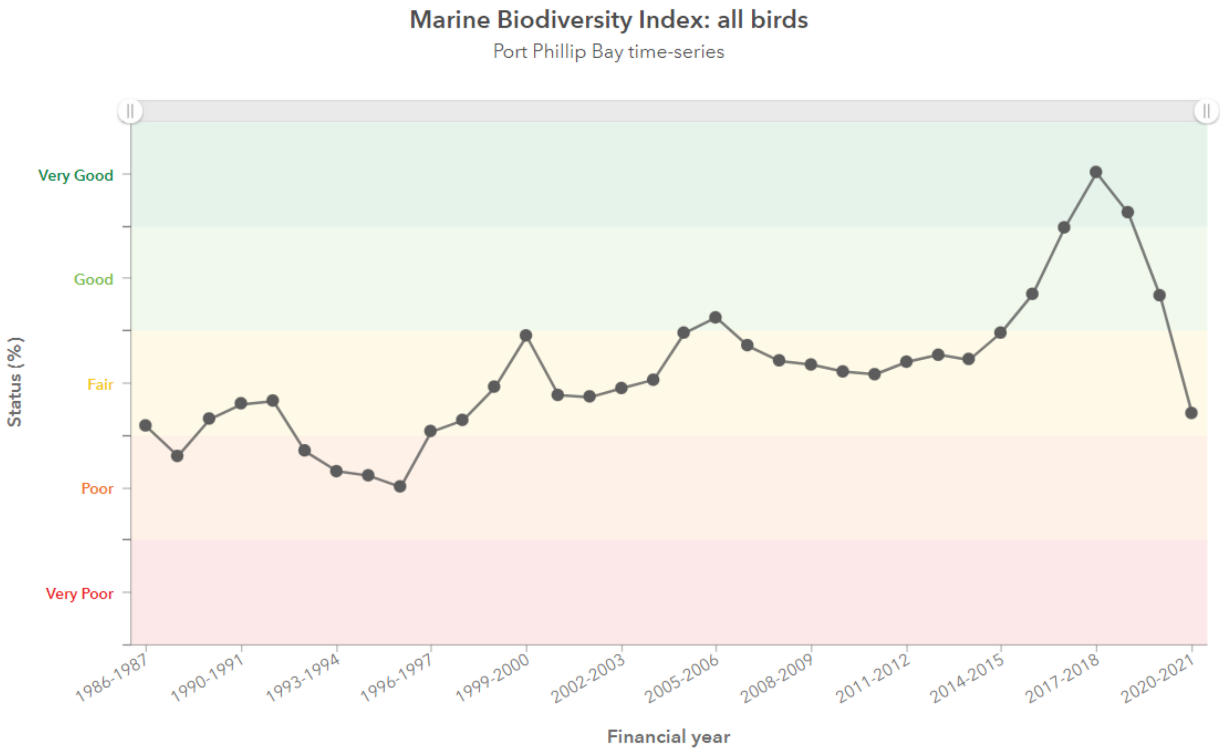


Figure 3. Marine Biodiversity Index (MBI) across all birds (39 species of shorebirds, 47 species of waterbirds, Australasian Gannets, and incorporates Little Penguins) applying the BQR and nested framework in Figure 4.

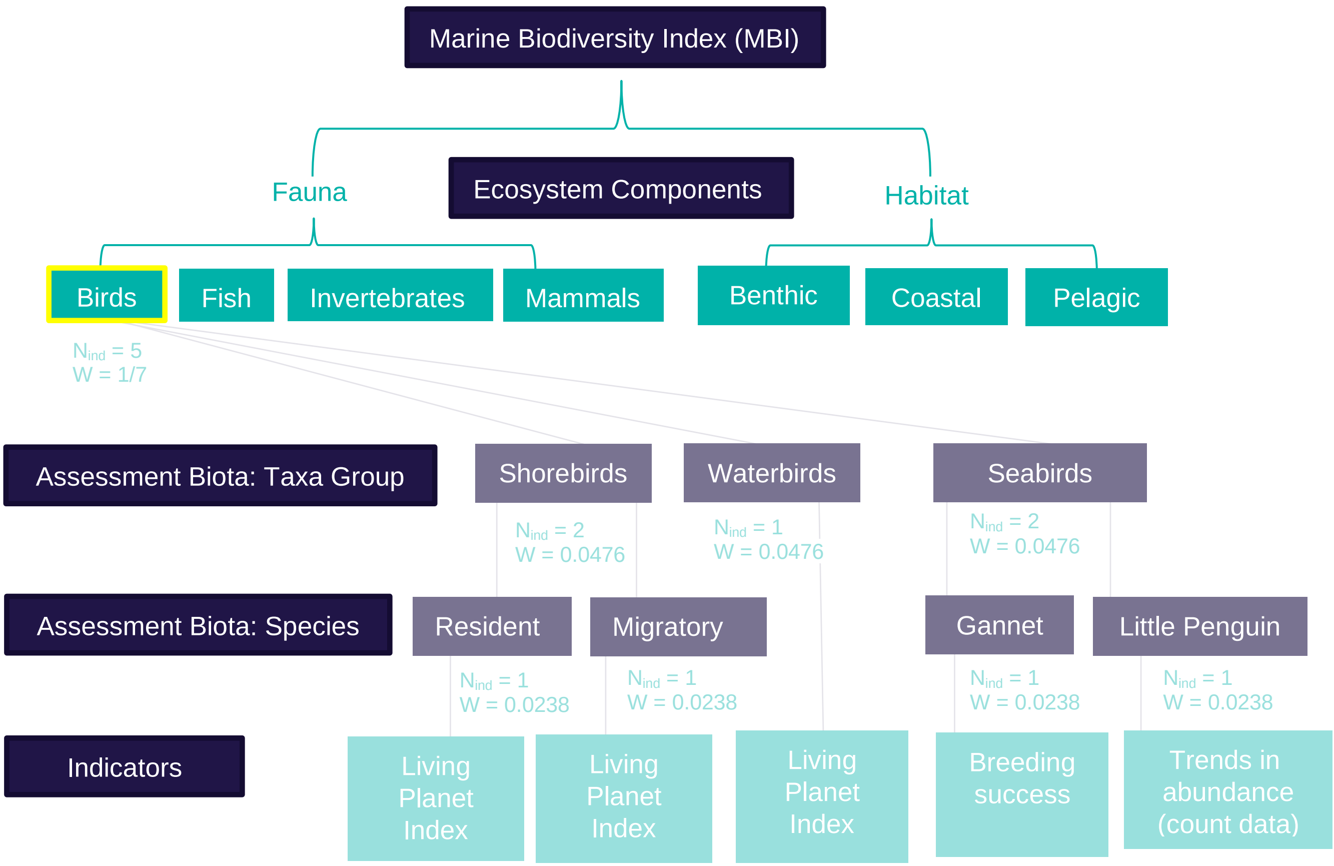
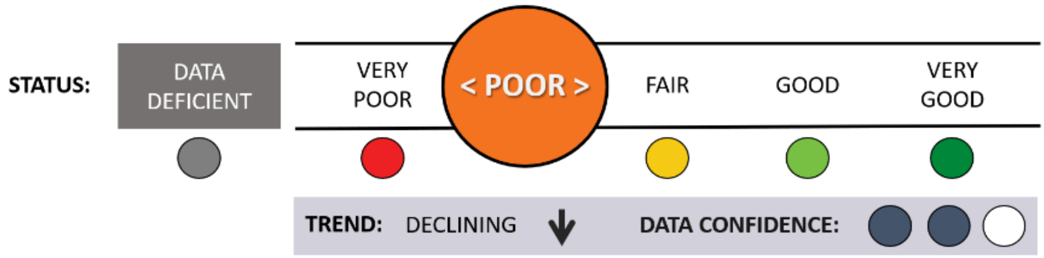


Figure 4. Nested structure of Bird Ecosystem Component. N_{ind} is the number of indicators used to measure the taxa group or species, and W is the weight applied in the overall nested structure.

4.1 Migratory shorebirds



Species	28 species (BirdLife Australia 2021) see Table A1 for species list, following Ramsar conservation listings**.** Of these four species are listed under the FFG Act 1988, and under the International Union for Conservation of Nature (IUCN) Red List two species are Endangered and seven are Near Threatened.
Indicator	The Living Planet Index method (Collen et al. 2009), also adopted by the Threatened Species Index for Australian birds (Bayraktarov et al. 2020) calculates the geometric mean of trends for each species within a Generalised Additive Modelling (GAM) framework. Species that had counts for less than six years within the time frame (1987–2021) were excluded from the analysis, along with sites with less than two years of monitoring data (Bayraktarov et al. 2020). A baseline with an average taken between years 1987–2000 was used.

Data Source	Shorebirds were assessed using data from the National Shorebird Monitoring database provided by Birdlife Australia. Sightings across PPB covering 1,826 sites from standardised surveys (shorebirds count, area and radius searches; Birdlife 2021). Data was divided into migratory and resident shorebird species, following Ramsar conservation listings.

The status of migratory shorebirds in PPB in 2020–2021 was Poor and the trend is declining. This status is informed by available time–series data indicating abundance. The confidence score for this data is Medium. Abundance changes in migratory shorebirds are good indicators to determine the state of the marine environment particularly in coastal environments where they maintain trophic equilibrium in complex and productive environments. These birds forage select prey with diverse traits (body size, bill shape, leg length), at various depths and habitats such as nearshore, offshore, estuaries, wetlands and coastal habitat types.

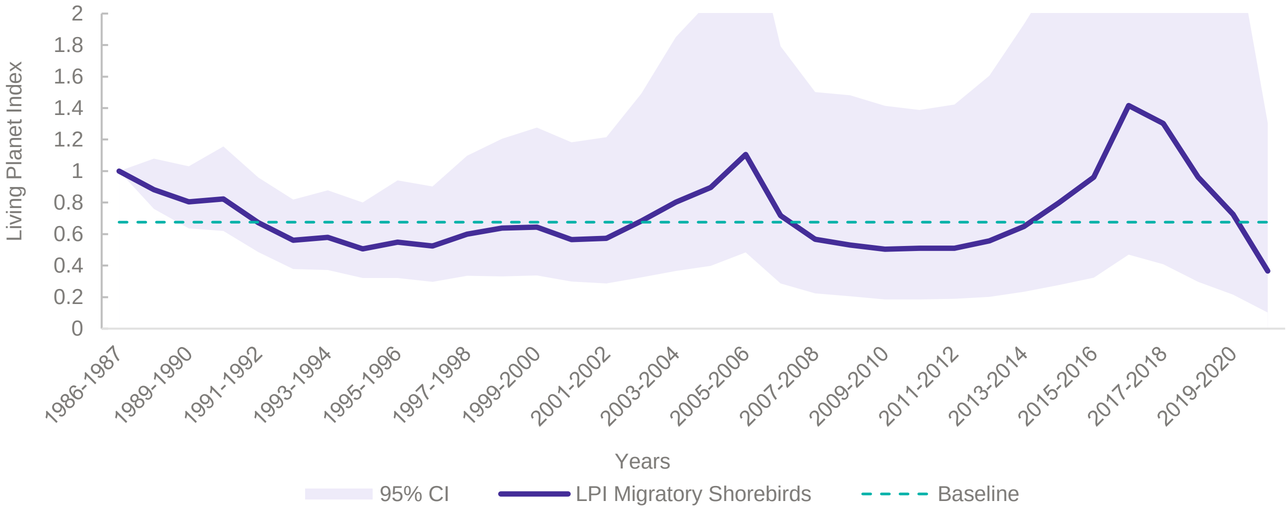


Figure 5. Living Planet Index trend for 28 migratory shorebirds across PPB. (Data: BirdLife Australia 2021).

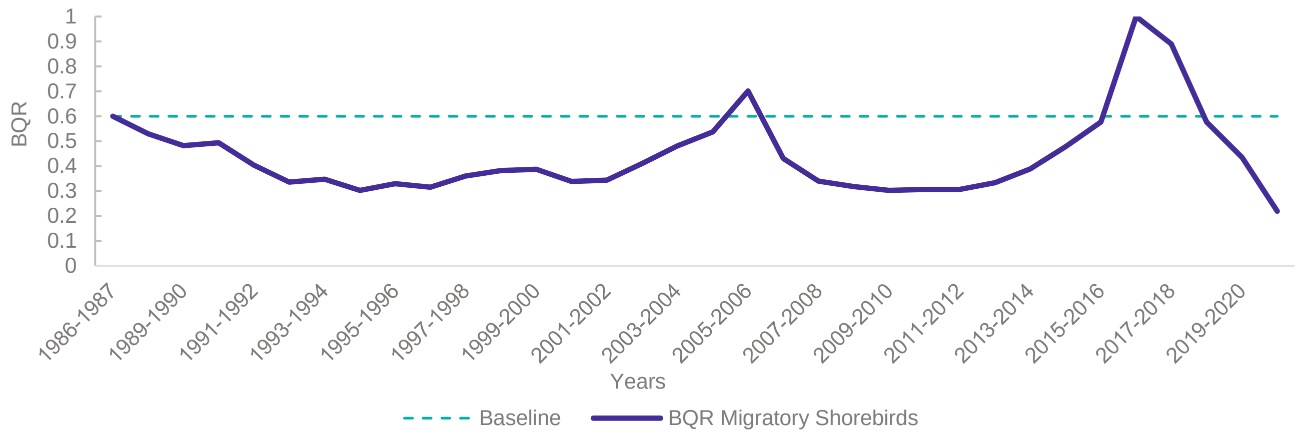
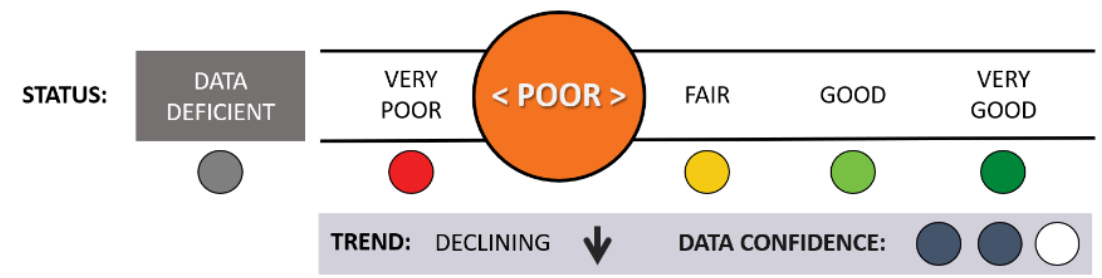


Figure 6. BQR for indicators (Figure 5) of 28 migratory shorebirds across PPB (Data: BirdLife Australia 2021).

4.2 Resident shorebirds



Species	11 species sighted across the PPB catchment (BirdLife Australia 2021), see Table A2 for species list. Of these, one species is listed under the FFG Act 1988, and under the IUCN red list one species is Vulnerable.
Indicator	Living Planet Index method (Collen et al. 2009), also adopted by the Threatened Species Index for Australian birds (Bayraktarov et al. 2020) calculates the geometric mean of trends for each species within a Generalised Additive Modelling (GAM) framework. Species that had counts for less than six years within the time frame (1987–2021) were excluded from the analysis, along with sites with less than two years of monitoring data (Bayraktarov et al. 2020). A baseline with an average taken between years 1987-2000 was used.
Data Source	Shorebirds were assessed using data from the National Shorebird Monitoring database provided by Birdlife Australia. Sightings across PPB covering 1,826 sites from standardised surveys (shorebirds count, area and radius searches; Birdlife 2021). Data was divided into migratory and resident shorebird species, following Ramsar conservation listings.

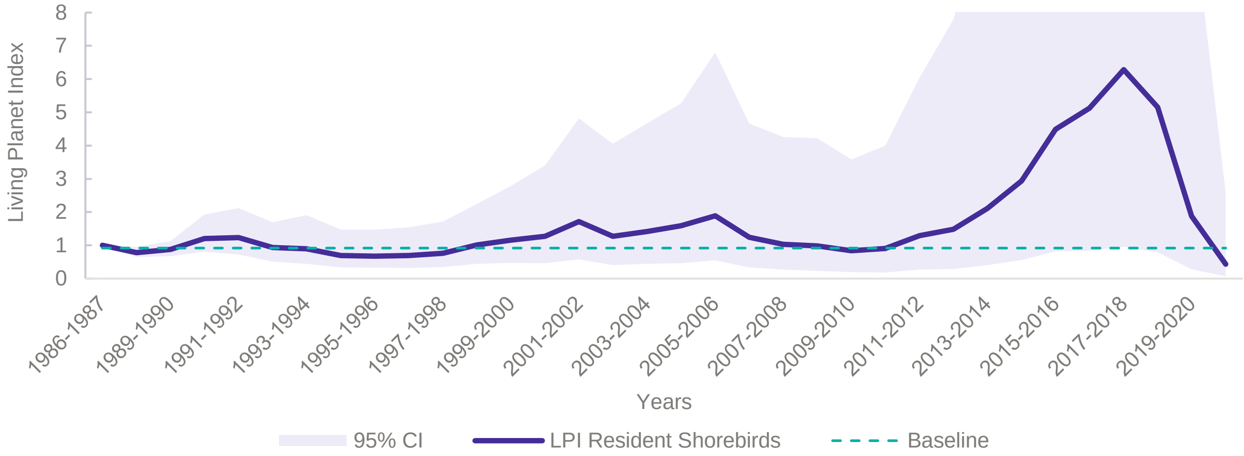


Figure 7. Living Planet Index trend for 11 resident shorebirds across PPB. (Data: BirdLife Australia 2021).

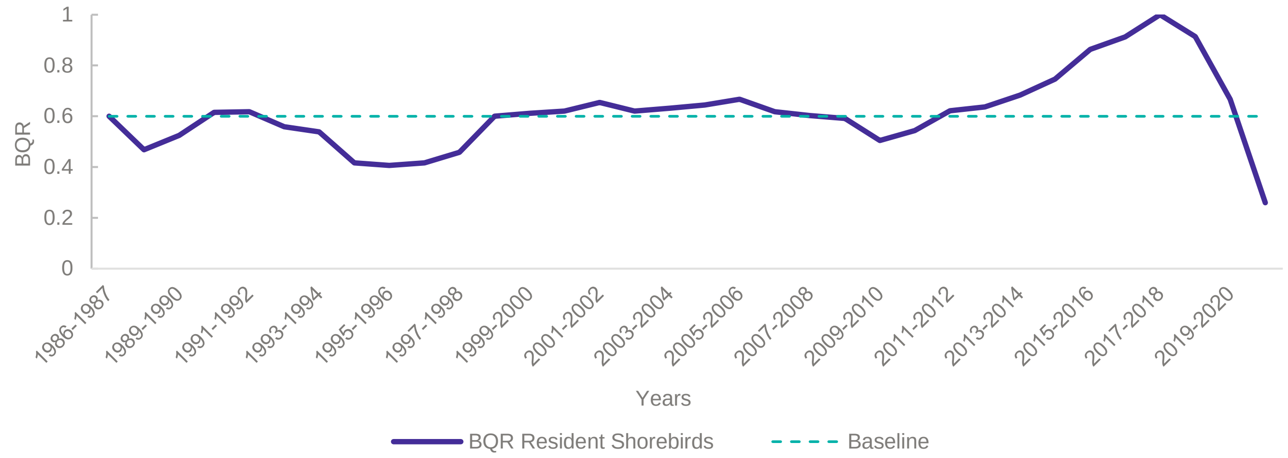
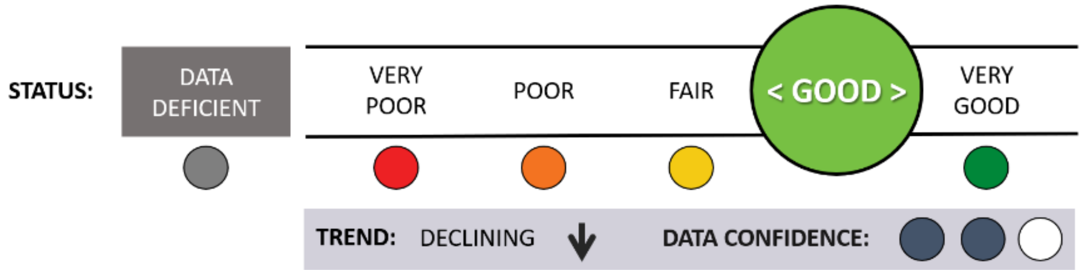


Figure 8. BQR for indicators (Figure 7) of 11 resident shorebirds across PPB. (Data: BirdLife Australia 2021).

4.3 Waterbirds



Species	11 species sighted across the PPB catchment (BirdLife Australia 2021), see Table A2 for species list. Of these, one species is listed under the FFG Act 1988, and under the IUCN red list one species is Vulnerable.
Indicator	Living Planet Index method (Collen et al. 2009), also adopted by the Threatened Species Index for Australian birds (Bayraktarov et al. 2020) calculates the geometric mean of trends for each species within a Generalised Additive Modelling (GAM) framework. Species that had counts for less than six years within the time frame (1987-2021) were excluded from the analysis, along with sites with less than two years of monitoring data (Bayraktarov et al. 2020). A baseline with an average taken between years 1987-2000 was used.
Data Source	Waterbirds were assessed using data from the National Shorebird Monitoring database provided by Birdlife Australia (Birdlife 2021). This data was collected by volunteers and Birdlife Australia across hundreds of roosting and feeding sites along coastal Australia.

The status of waterbirds in PPB is Good and the trend is declining. This status is informed by available time-series data indicating abundance. The confidence score for this data is Medium. Abundance changes in waterbirds are good indicators to determine the state of the marine environment particularly in coastal environments, where they maintain trophic equilibrium in complex and productive environments. These birds forage select prey with diverse traits (body size, bill shape, leg length), at various depths and habitats such as nearshore, offshore, estuaries, wetlands and habitat types.

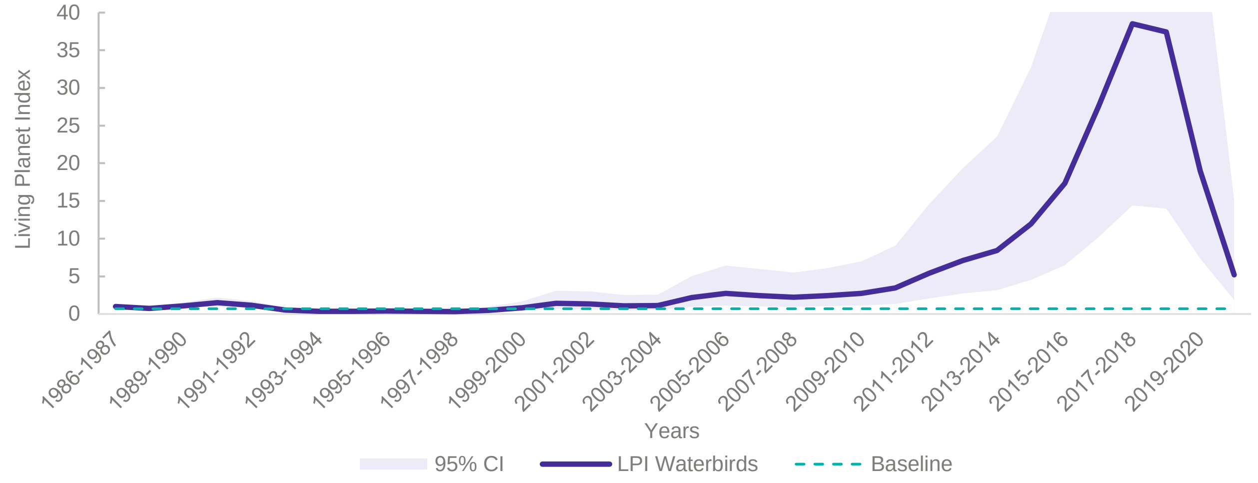


Figure 9. Living Planet Index trend for 47 waterbirds across PPB. (Data: BirdLife Australia 2021).

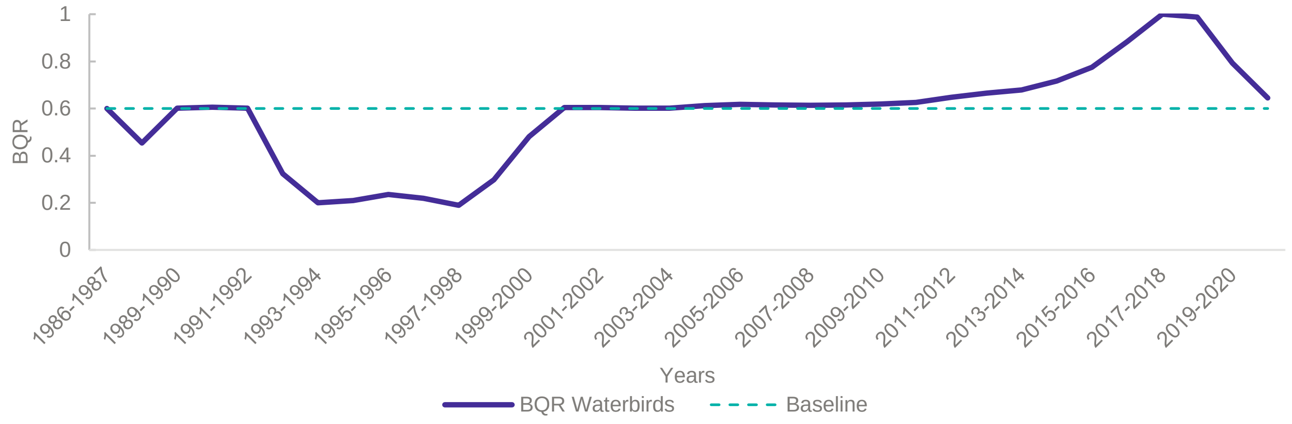
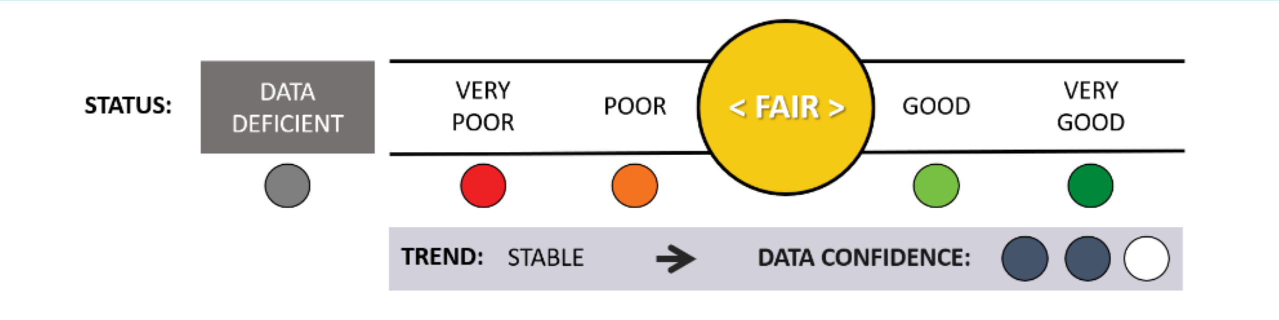


Figure 10. BQR for indicators (Figure 9) of 47 waterbirds across PPB. (Data: BirdLife Australia 2021).

4.4 Australasian Gannet



Species	Australasian Gannet (*Morus serrator)*
Indicator	Data provided by Arnould (2020) represents the number of near-fledging Australasian Gannet chicks (a measure of reproductive success) banded as part of a long-term monitoring program (Pyk et al., 2013) and are used as an indicator of population health. The data is provided for 1986 – 2020. The baseline is calculated from the average value across 1995–2020 for the Australasian Gannet colony at Pope's Eye
Data Source	Data provided by Arnould (2020)

The status of the Australasian Gannet (*Morus serrator*) in PPB in 2020–2021 was Fair and the trend is stable. This status is informed by available time-series data indicating abundance. The confidence score for this data is Medium. Australasian Gannets and other seabirds are important indicators of marine ecosystems due to their cause-effect association with microclimate and habitats and their ability to be detected easily unlike other marine fauna. Seven Australasian Gannet breeding colonies (total of ~ 500 breeding pairs) are found in PPB, Victoria (Bunce et al. 2002). The largest colony is Pope's Eye established on an artificial structure in the late 1970s to early 1980s (Norman and Menkhorst 1995), comprised of up to 180 breeding pairs (Gibbs et al. 2000; Norman and Menkhorst 1995; Pyk et al. 2007; Pyk et al., 2013). Gannets breed annually between July (start of nest building) and early April (last chicks fledge).

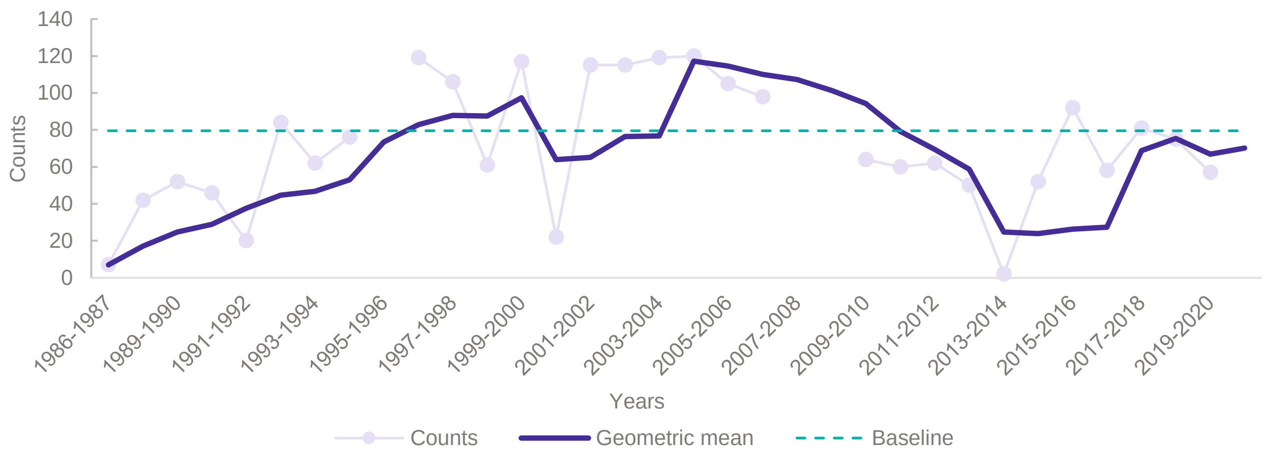


Figure 11. Trend from Surveyed abundance of Australasian Gannets banded chicks at Pope's Eye. (Data: Arnould 2020).

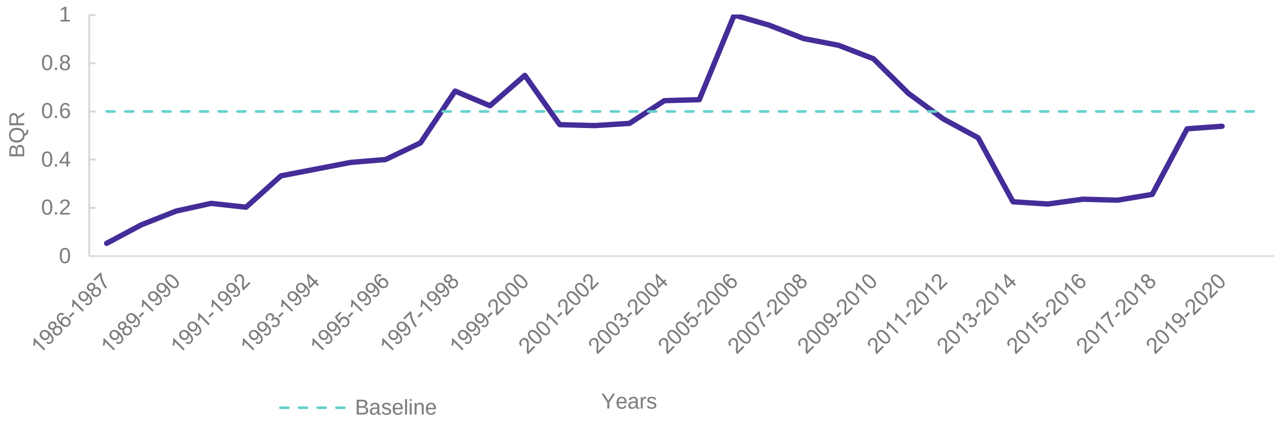
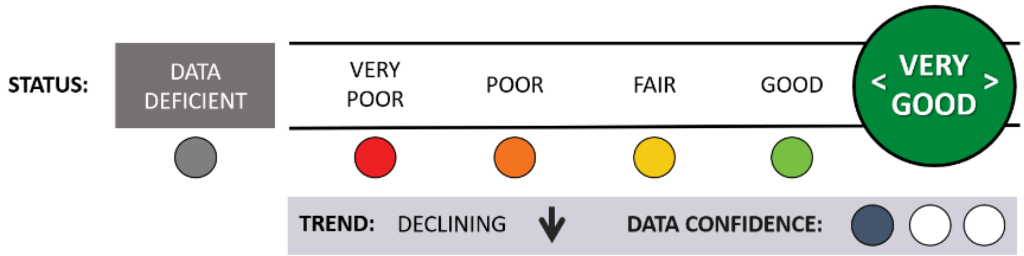


Figure 12. BQR for indicators (Figure 11) of Australasian Gannets banded chicks at Pope's Eye. (Data: Arnould 2020).

4.5 Little Penguin



Species	Little penguins (*Eudyptula minor*)
Indicator	The best current trend information on the PPB St Kilda penguin population is count data collected by Earthcare St Kilda (Sperring 2021) from 2001 – 2021, however total population abundance information is lacking. The trend of count data (standardised by survey effort) and the moving average (geometric mean) across four years was used to provide quantitative evidence to infer the population status. The baseline is calculated from average value across all years.
Data Source	Data provided by Earthcare St Kilda (Sperring 2021)

The status of the Little Penguin (Eudyptula minor) in PPB in 2020–2021 was Very Good though the trend is declining. This status is informed by available time-series data indicating abundance. The confidence score for this data is Low. Little Penguins are top order predators and their role in the marine ecosystem food web serves as a valuable indicator, where changes in their population, diet, foraging range and success relate to changes in marine health. Importantly, the Little Penguin is recognised as a tourism asset and an iconic species for the PPB region. Available Little Penguin data was provided by Earthcare St Kilda, a non-profit volunteer group that operate citizen-science surveys. In PPB the construction of the St Kilda Breakwater in 1956 for the Melbourne Olympics incidentally provided habitat to support the Little Penguin colony, currently estimated at 1,400 individuals and ~400 breeding penguins (Preston et al. 2008). The much larger Little Penguin colony at Phillip Island (70 km to the southeast), was estimated in 2011 to support 30,000 – 35,000 breeding penguins (Sutherland and Dann 2014), with penguins foraging inside PPB during laying and incubation stages, overlapping their foraging grounds with the St Kilda penguins which spend their entire life cycle in the bay (Figure 1: Chiaradia et al. 2012).

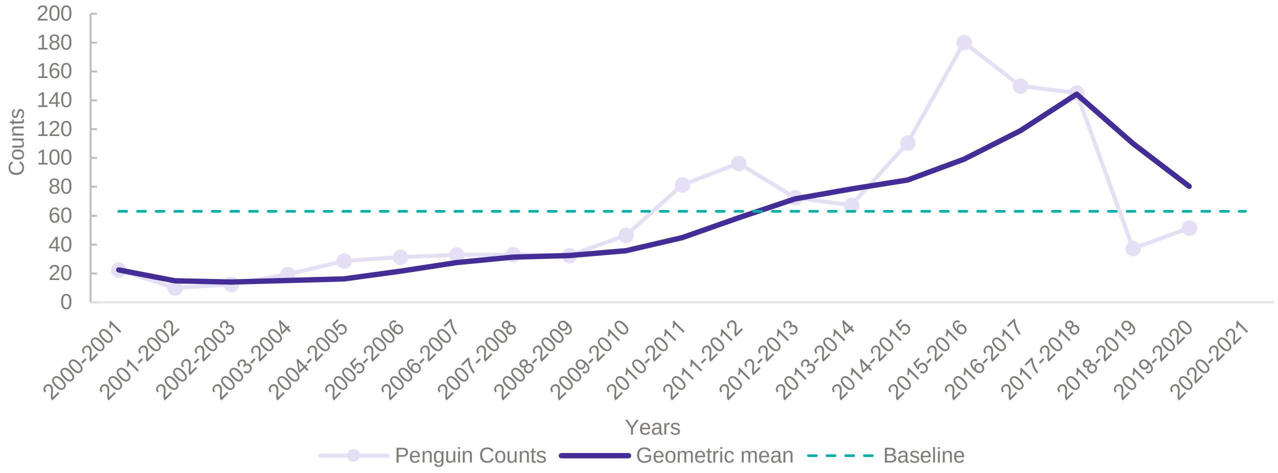


Figure 13. Little Penguin trend from survey counts. (Data: Earthcare St Kilda; Sperring 2021).

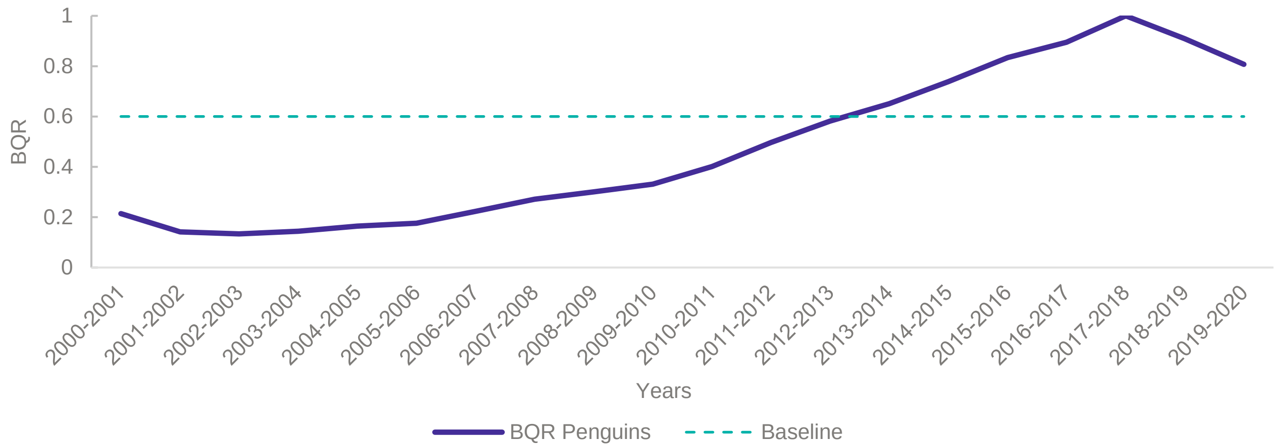


Figure 14. BQR for indicators (Figure 13) of Little Penguin. (Data: Earthcare St Kilda; Sperring 2021).

5. Fish

Assessment Biota	• King George Whiting • Snapper • Southern Sand Flathead
Data Sources	VFA
Consulted Stakeholders and Experts	VFA; Dr. Harry Gorfine, Dr. Simon Conron, Dr Justin Bell

The status of all fish assessed in PPB in 2020–2021 was Good and the trend is improving. This status is informed by available time-series data of Southern Sand Flathead, King George Whiting and Snapper. The confidence score for this data is High. Coastal fish communities are good indicators of the ecological state of coastal ecosystems (HELCOM 2018b). For PPB fish communities are of high ecological and socio-economic importance, for ecosystem function, recreational and commercial fisheries. This assessment incorporates the Biomass CPUE indicators used by the VFA (Conron et al. 2020) to assess the three key fishery species in PPB.

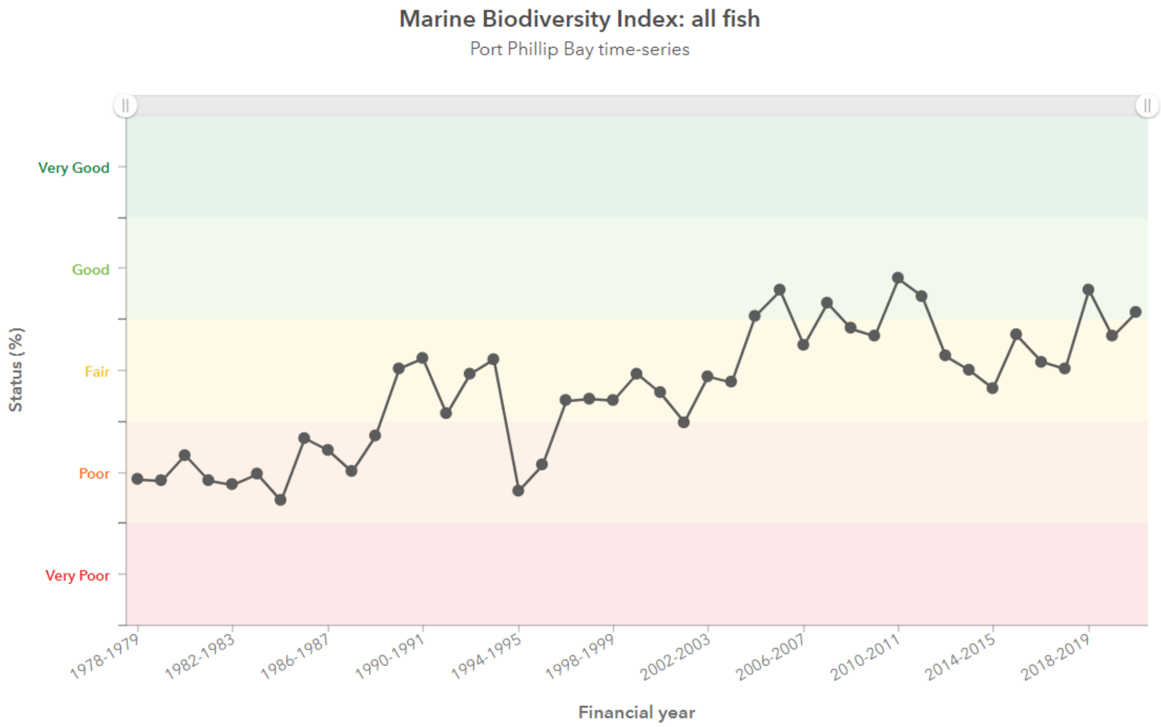


Figure 15. Marine Biodiversity Index (MBI) across all fish (King George Whiting, Snapper and Southern Sand Flathead) applying the BQR and nested framework in Figure 16.

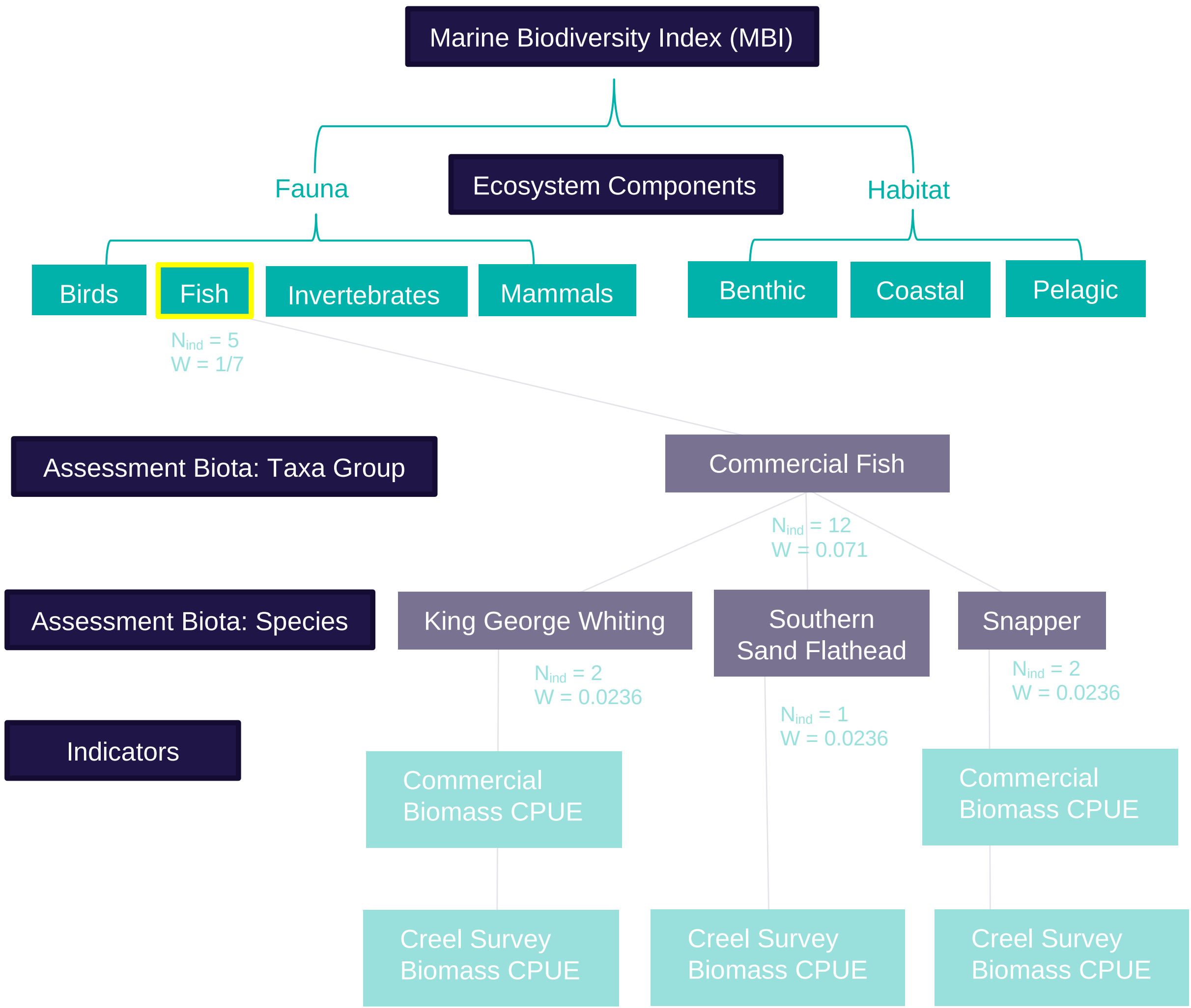
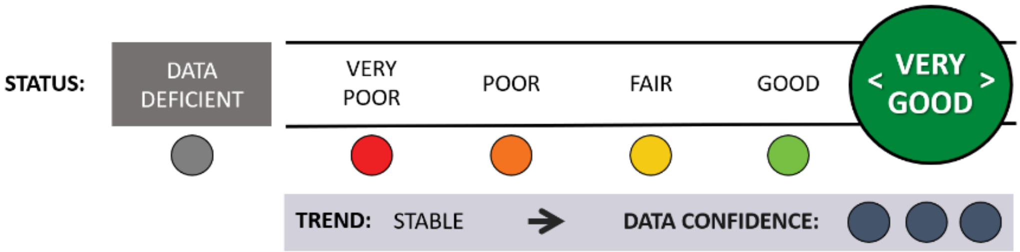


Figure 13. Nested structure of Fish Ecosystem Component. N_{ind} is the number of indicators used to measure the taxa group or species, and W is the weight applied in the overall nested structure.

5.1 King George Whiting



Species	King George Whiting (*Sillaginodes punctatus*).
Indicator	The VFA use Biomass – nominal and standardised CPUE for commercial and recreational fisheries. CPUE reference levels represent the estimated biomass above which a stock is sustainably fished or, alternatively, below which represents unsustainable fishing, and the stock is at risk of overfishing. The limit reference point (or minimum value) is the level below which the stock biomass is considered at risk of recruitment collapse by overfishing and where management interventions are needed. Commercial: Nominal CPUE for haul seine in PPB (Note: nominal CPUE is used because standardisation has minor influence on levels, trends and variability in seine net CPUE). The baseline was calculated by averaging years between 1985 – 2015 following VFA reporting (Conron et al. 2020). Recreational: Standardised CPUE for the recreational fishery from annual creel surveys in PPB. The baseline was calculated by averaging years between 1989 – 2015 following VFA reporting (Conron et al. 2020).
Data Sources	Data provided by VFA (Conron et al. 2020).

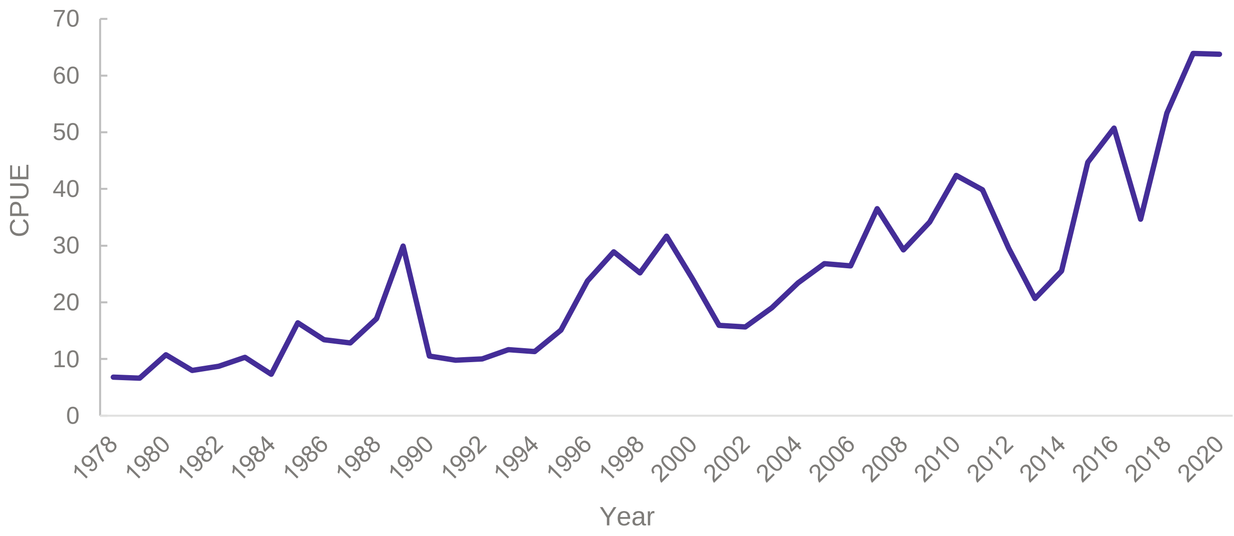


Figure 17. King George Whiting (*Sillaginodes punctatus*) nominal CPUE for haul seine in PPB. Data provided by VFA (Conron et al. 2020).

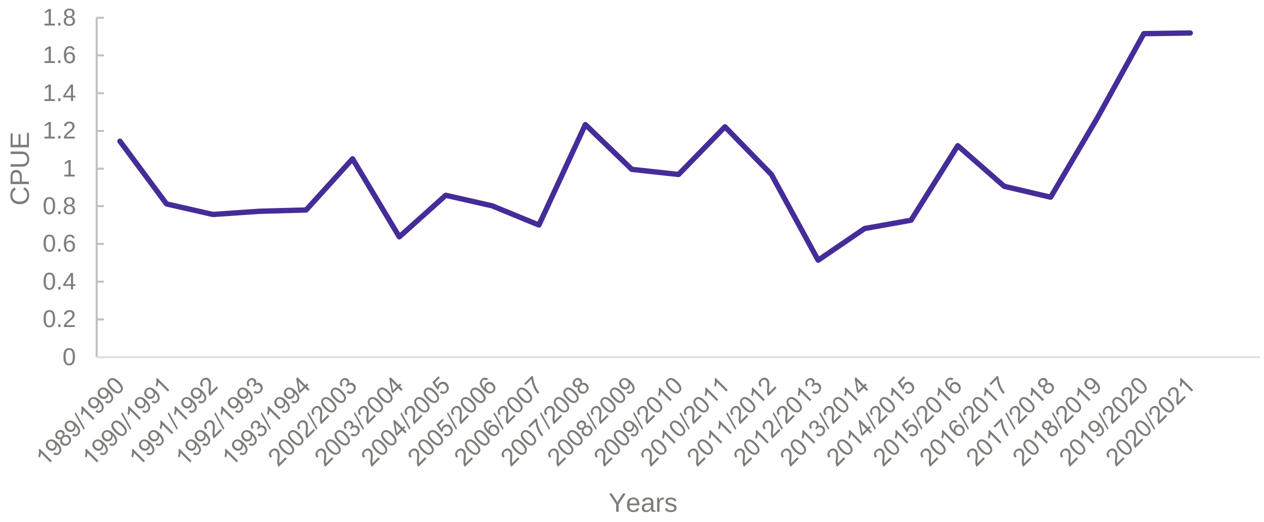


Figure 18. King George Whiting (*Sillaginodes punctatus*) standardised CPUE for the recreational fishery from annual creel surveys in PPB. Data provided by VFA (Conron et al. 2020).

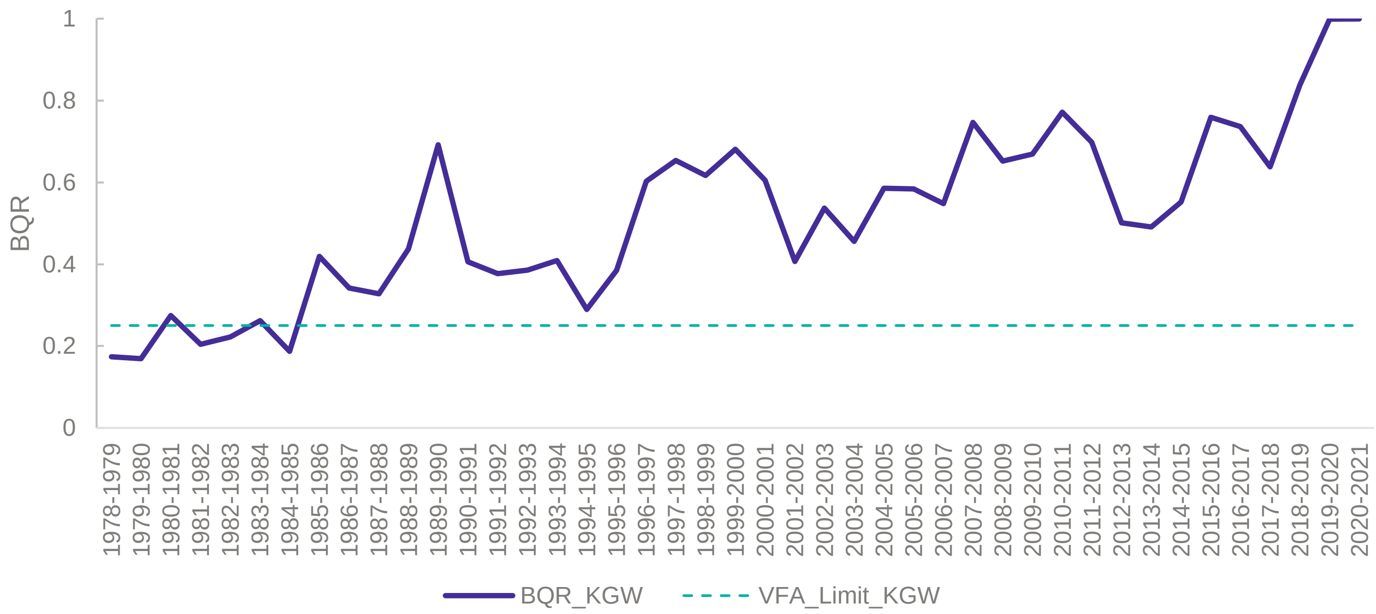
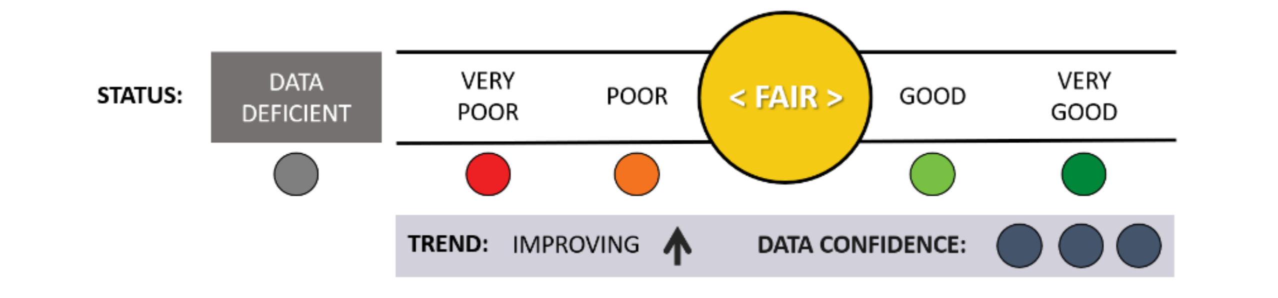


Figure 19. King George Whiting (*Sillaginodes punctatus*) BQR method applied to combine both indicators. Data provided by VFA (Conron et al. 2020). The VFA limit reference point (or minimum value) is the level below which the stock biomass is considered at risk of recruitment collapse by overfishing and where management interventions are needed.

5.2 Southern Sand Flathead



Species	Southern Sand Flathead (*Platycephalus bassensis*)
Indicator	The VFA use Biomass - nominal and standardised catch per unit effort (CPUE) for commercial and recreational fisheries. CPUE reference levels represent the estimated biomass above which a stock is sustainably fished or, alternatively, below which represents unsustainable fishing, and the stock is at risk of overfishing. The limit reference point (or minimum value) is the level below which the stock biomass is considered at risk of recruitment collapse by overfishing and where management interventions are needed.. Recreational: Standardised CPUE for the recreational fishery from annual creel surveys in PPB. The baseline was calculated by averaging years between 1989 – Current following VFA reporting (Conron et al. 2020).
Data Sources	Data provided by VFA (Conron et al. 2020).

The most important Victorian fishery for Southern Sand Flathead (*Platycephalus bassensis*) is in PPB. The majority of Victorian Southern Sand Flathead catch is taken by recreational anglers with only minor commercial harvesting. The PPB component of the Southern Sand Flathead stock is a predominantly self-replenishing sub-population with the primary spawning period occurring during October to March.

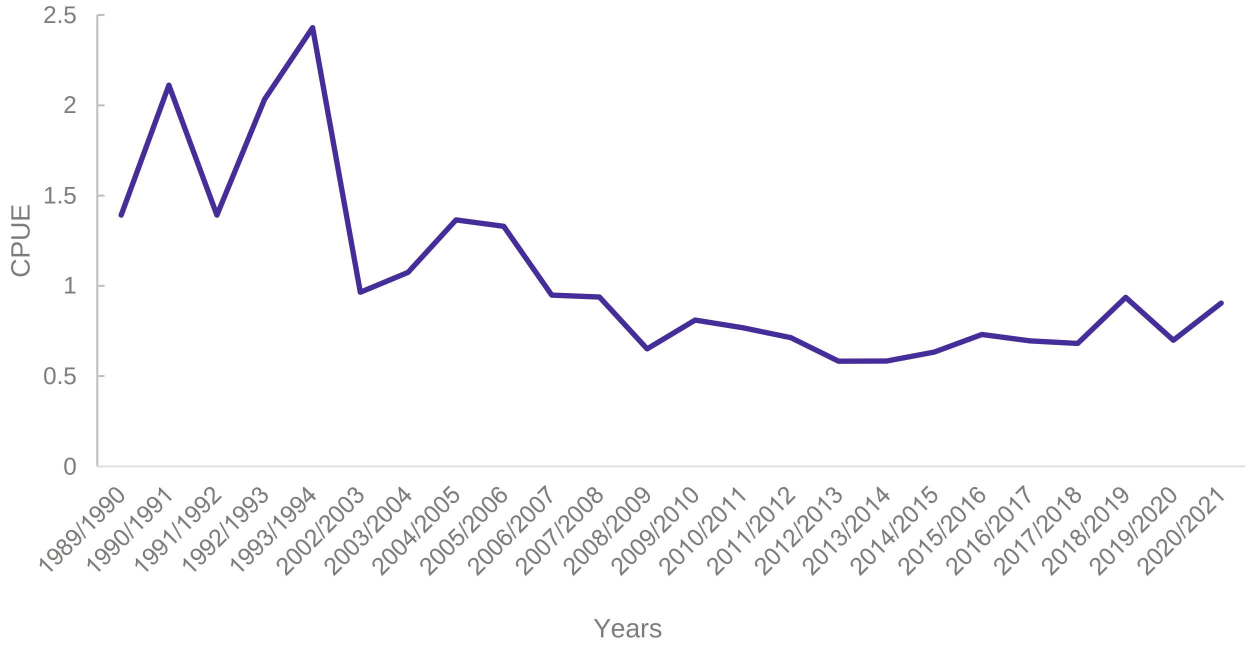


Figure 20. Southern Sand Flathead (*Platycephalus bassensis*). Standardised CPUE for the recreational fishery from annual creel surveys in PPB. Data provided by VFA (Conron et al. 2020).

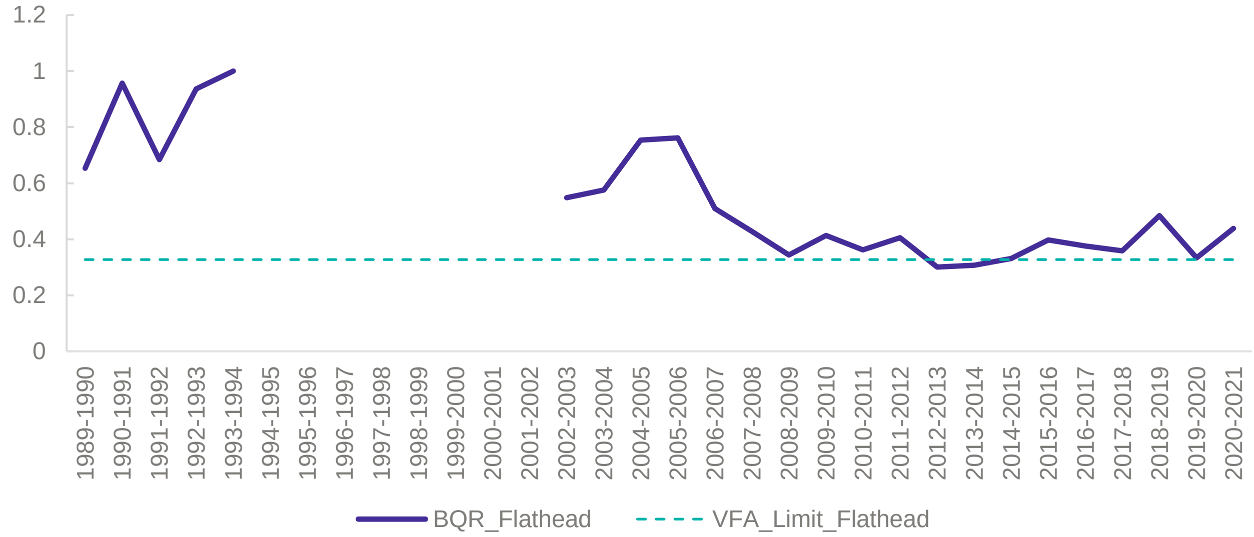
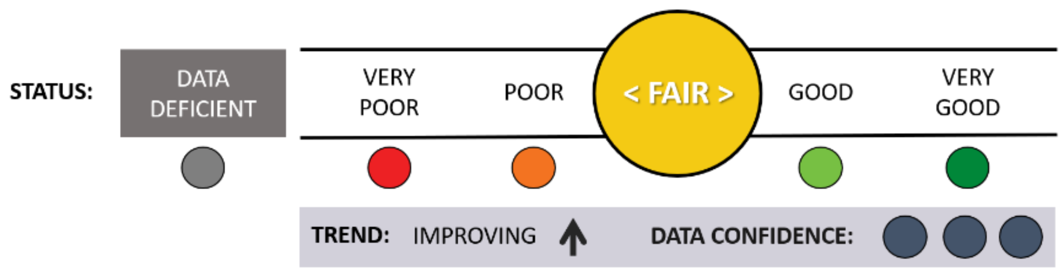


Figure 21. Southern Sand Flathead (*Platycephalus bassensis*) BQR method applied to indicator. Data provided by VFA (Conron et al. 2020). The VFA limit reference point (or minimum value) is the level below which the stock biomass is considered at risk of recruitment collapse by overfishing and where management interventions are needed.

5.3 Snapper



Species	Snapper (*Chrysophrys auratus*)
Indicator	The VFA use Biomass – nominal and standardised CPUE for commercial and recreational fisheries. CPUE reference levels represent the estimated biomass above which a stock is sustainably fished or, alternatively, below which represents unsustainable fishing, and the stock is at risk of overfishing. The limit reference point (or minimum value) is the level below which the stock biomass is considered at risk of recruitment collapse by overfishing and where management interventions are needed. Commercial: Standardised CPUE for long line in PPB. The baseline was calculated by averaging years between 2000–2015 following VFA reporting (Conron et al. 2020). Recreational: Standardised CPUE from annual creel surveys in PPB for adult (October-December) and juvenile/sub-adult (January–April) Snapper. The baseline was calculated by averaging years between 2002–2015 following VFA reporting (Conron et al. 2020).
Data Sources	Data provided by VFA (Conron et al. 2020).

Victoria's Snapper (*Chrysophrys auratus*) population is divided into a western and eastern stock, with the western stock covering the PPB region (VFA 2017). PPB is the main spawning area for western stock replenishment, with spawning occurring between November and January. PPB is Victoria's largest Snapper fishery, comprised of both commercial and recreational. The western stock fisheries account for most of the Victorian Snapper harvest and receive most of the assessment and management attention. Data provided by VFA (Conron et al. 2020).

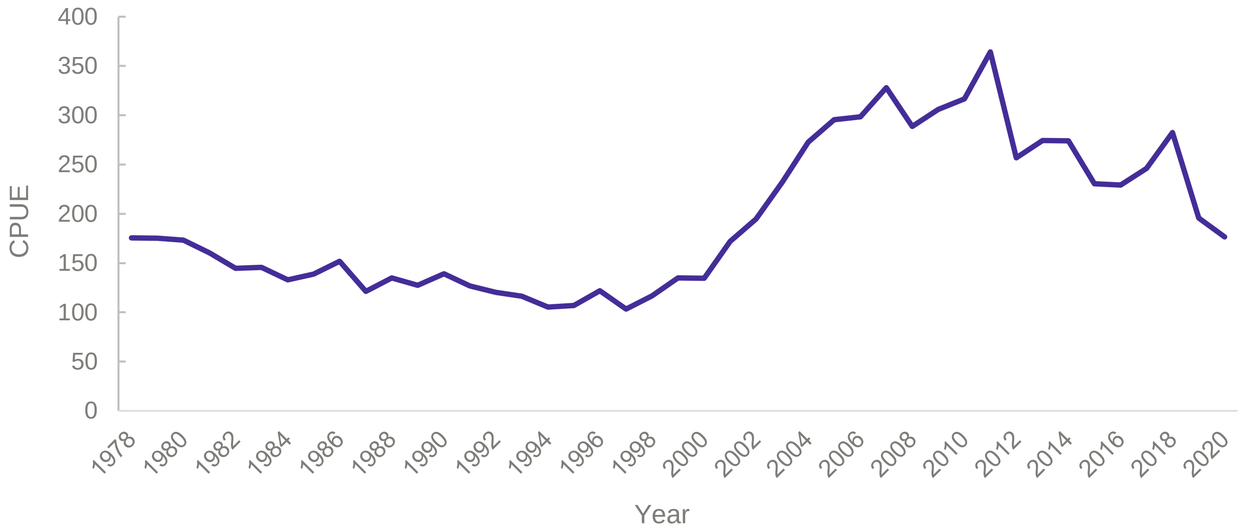


Figure 22. Victoria's Snapper (*Chrysophrys auratus*) standardised CPUE for long line in PPB. Data provided by VFA (Conron et al. 2020).

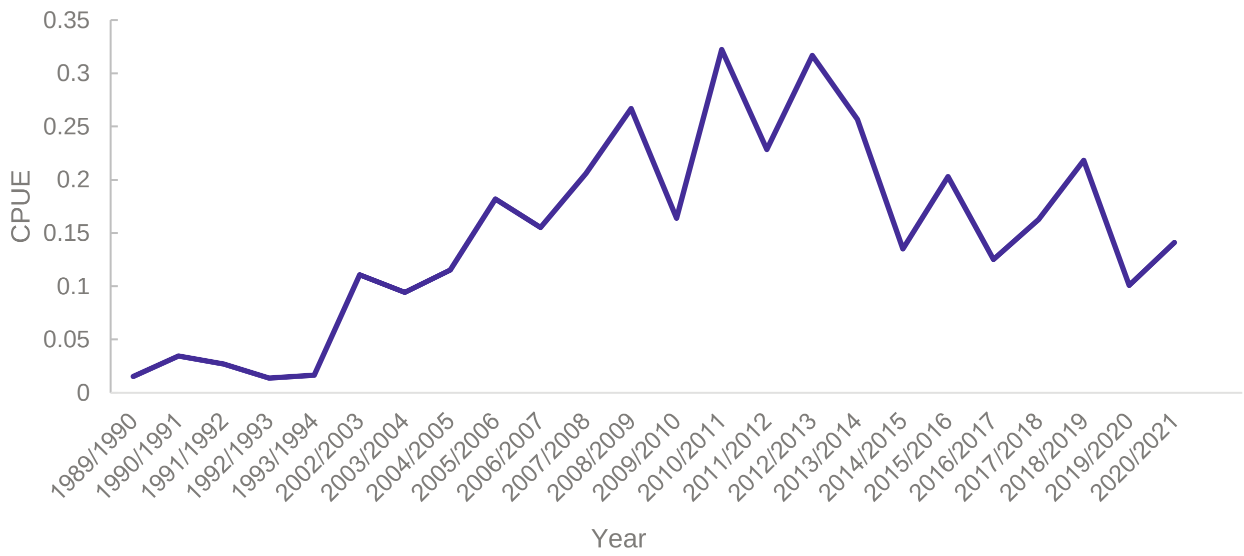


Figure 23. Victoria's Snapper (*Chrysophrys auratus*) standardised CPUE from annual creel surveys in PPB. Data provided by VFA (Conron et al. 2020).

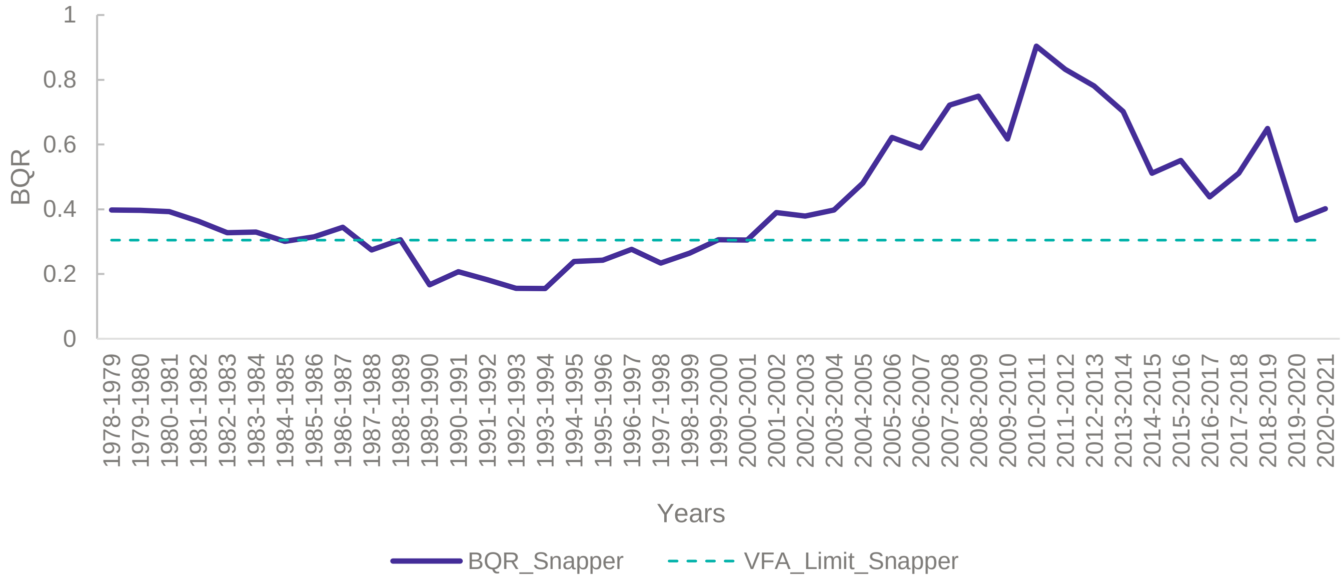
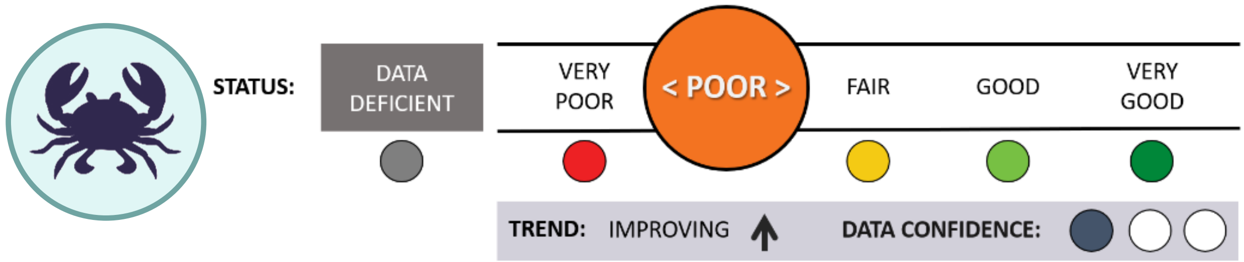


Figure 24. Victoria's Snapper (*Chrysophrys auratus*) BQR method applied to combine indicators. Data provided by VFA (Conron et al. 2020). The VFA limit reference point (or minimum value) is the level below which the stock biomass is considered at risk of recruitment collapse by overfishing and where management interventions are needed.

6. Invertebrates



Assessment Biota	• Spider Crab (*Leptomithrax gaimardii) – currently not included* • Sea urchins *(Heliocidaris)* • Reef invertebrates (on subtidal reefs) • Abalone
Data Sources	Reef Life Survey (RLS), Victorian Subtidal Reef Monitoring Program (SRMP), and VFA
Consulted Stakeholders and Experts	VFA, Dr Paul Carnell (Deakin University), Dr Tim O'Hara (Museums Victoria), Prof. Stephen Swearer (University of Melbourne), Dr John Arnould (Deakin University), Dr. Daniel Ierodiaconou (Deakin University)

The status of invertebrates in PPB in 2020–2021 was Poor and the trend is improving. This status is informed by available time-series data indicating the biodiversity status of urchins, abalone and reef invertebrates. Spider Crab data will be incorporated into the status in the future. The confidence score for this data is Low. Marine invertebrates are extremely important indicators of environmental change since they are sensitive to pollution and sudden changes to abiotic and biotic parameters in their environment (Borja et al. 2009; Smit et al. 2021)

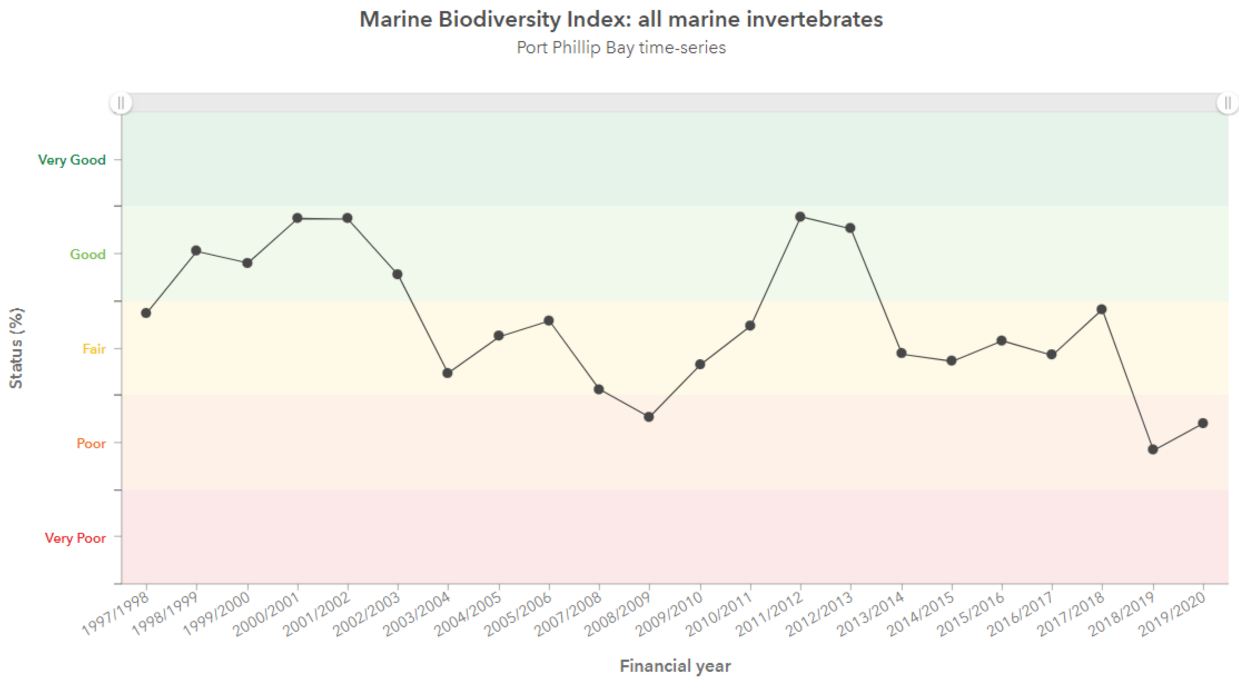


Figure 25. Marine Biodiversity Index (MBI) across all invertebrates (Abalone, Urchins and Reef Invertebrates) applying the BQR and nested framework in Figure 26.

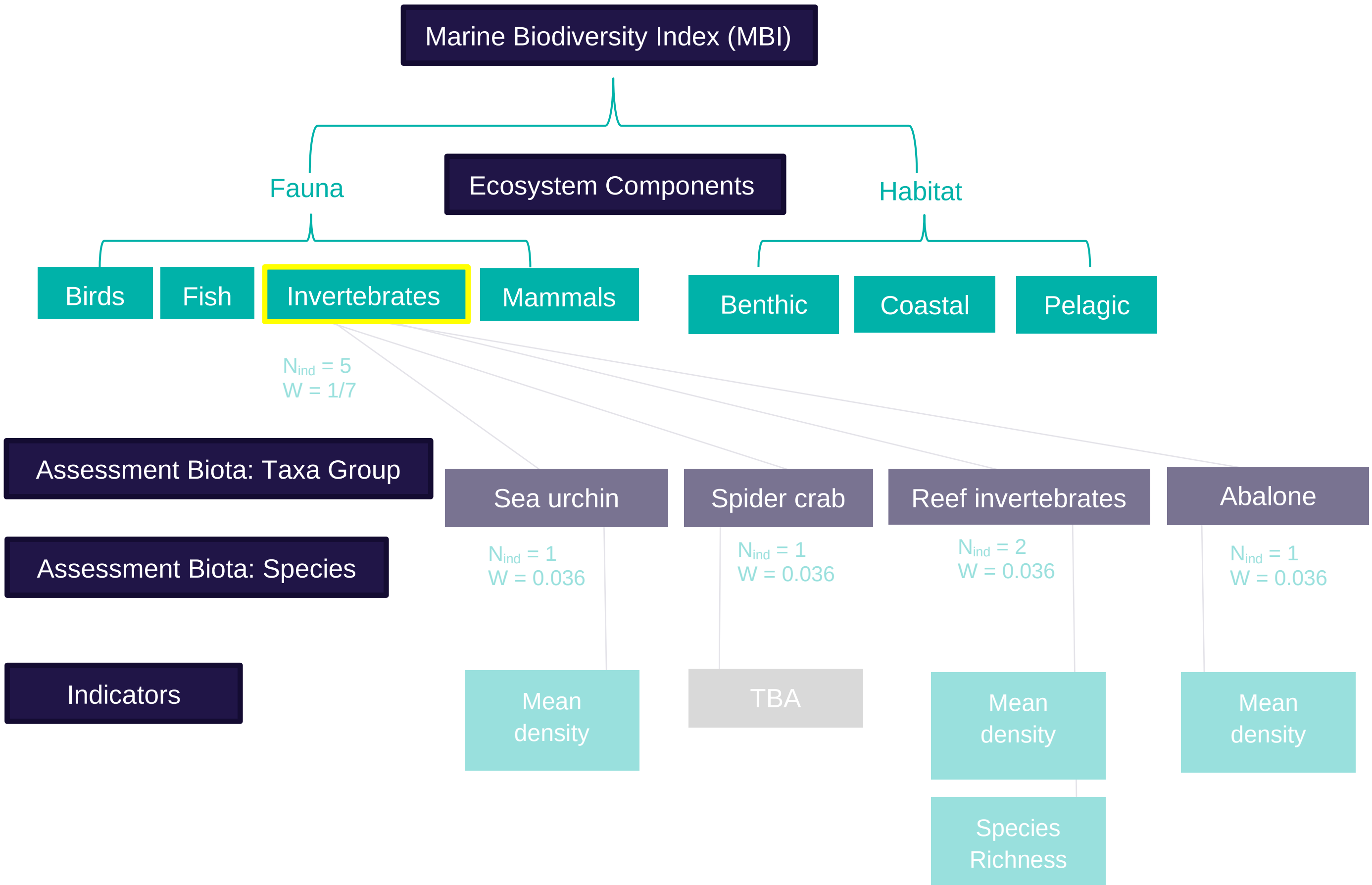
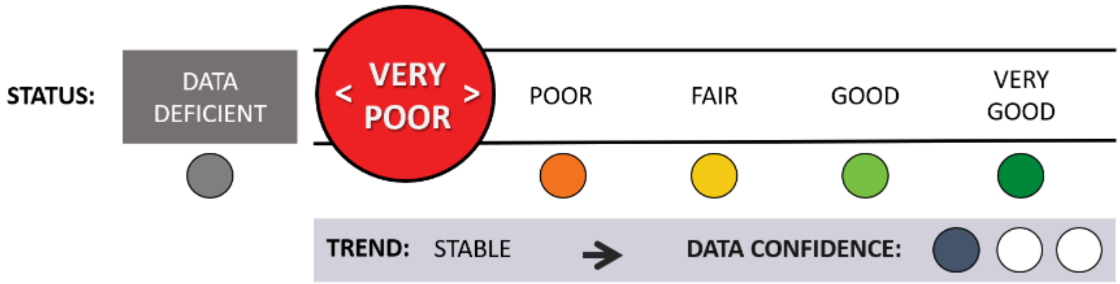


Figure 26. Nested structure of the Invertebrate Ecosystem Component. N_{ind} is the number of indicators used to measure the taxa group or species, and W is the weight applied in the overall nested structure.

6.1 Abalone



Species	Abalone (*Haliotis rubra, Haliotis laevigata, Haliotis scalaris*)
Indicator	Mean density (number per m^2), with the moving average (geometric mean) across 4 years. A baseline with an average taken across all years was used.
Data Sources	Reef Life Survey and the Victorian Subtidal Reef Monitoring Program

Abalone provides Victoria with one of its most valuable commercial fisheries. Abalone have a very high fecundity ranging in size and growth rates across species.

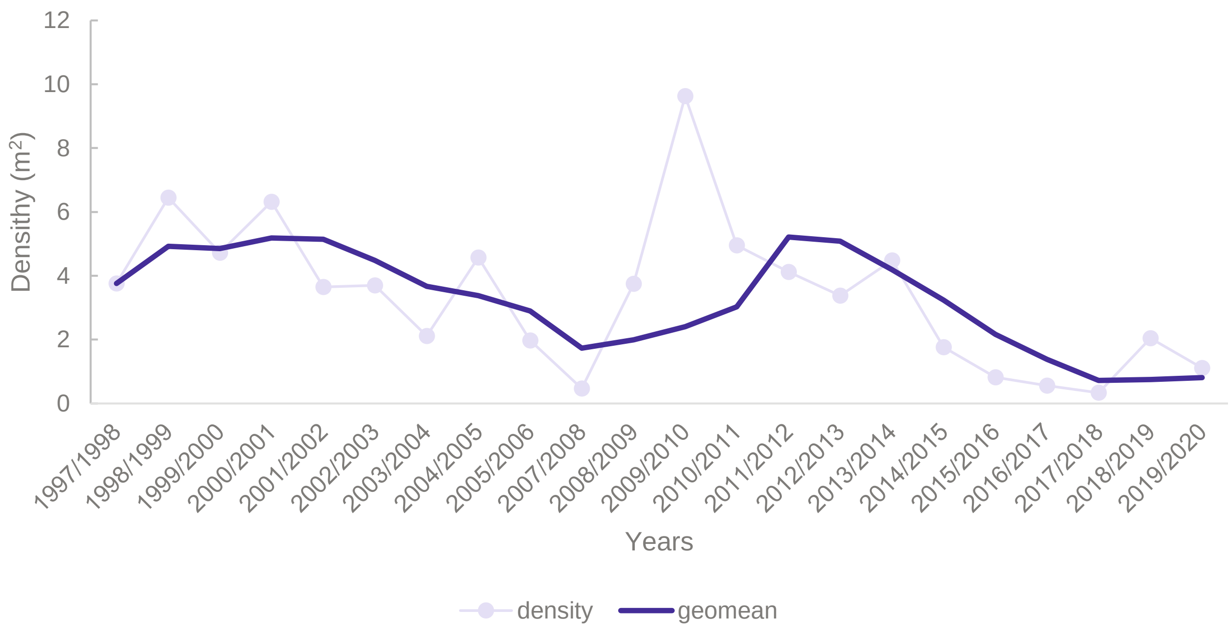


Figure 27. Density (m^2) of abalone species (*Haliotis rubra, Haliotis laevigata, Haliotis scalaris*), data from Reef Life Survey and the SRMP.

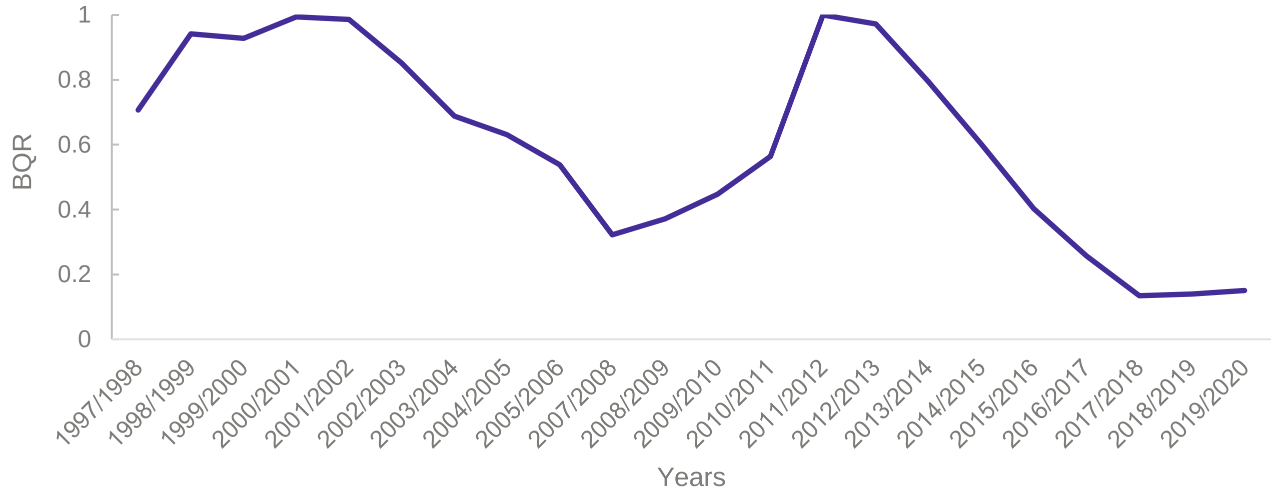
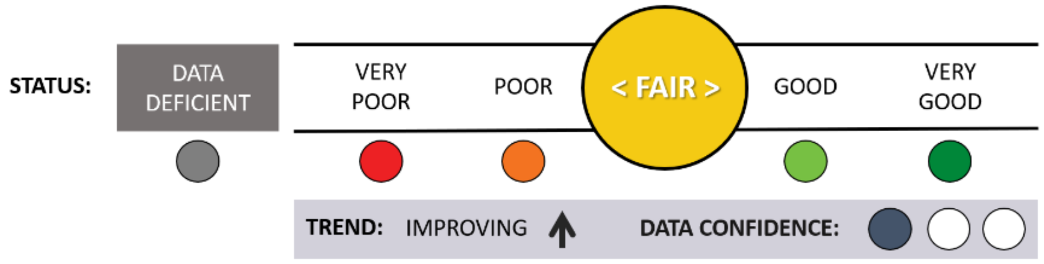


Figure 28. BQR method applied to abalone species (*Haliotis rubra, Haliotis laevigata, Haliotis scalaris*), data from Reef Life Survey and the SRMP.

6.2 Reef invertebrates



Species	Invertebrate species
Indicator	Mean density was calculated from count data across reef monitoring sites. Additionally, species richness was calculated using the Simpson Index and Shannon's Index for each year of data. A baseline with an average across all years was used.
Data Sources	Reef Life Survey and the Victorian Subtidal Reef Monitoring Program

Marine invertebrate species can influence the growth and survival of organisms that form reef habitat. Invertebrate size, abundance and species diversity are some of the key elements used to assess the overall condition of reef systems. Victorian SRMP and RLS datasets will be used to examine macro-invertebrates on subtidal reef habitats.

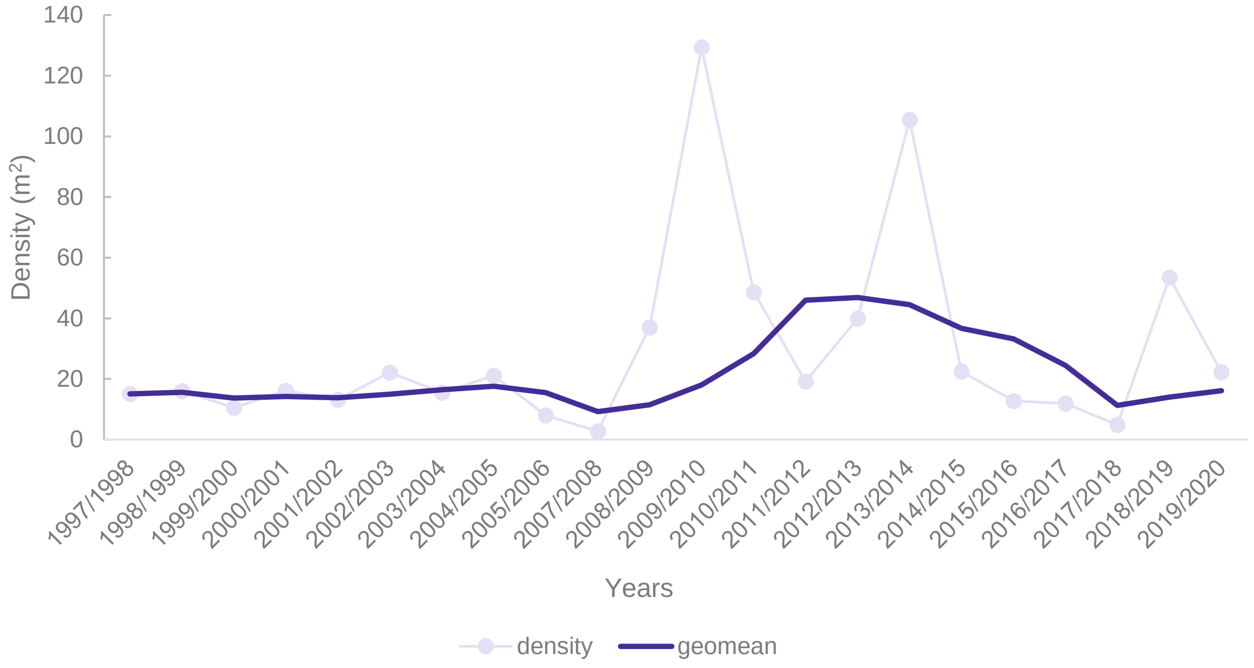


Figure 29. Density (m^2) of reef invertebrates from Reef Life Survey and the Victorian SRMP.

Figure 30. Diversity of reef invertebrates (Shannon index, and Simpson Index) from Reef Life Survey and the Victorian SRMP.

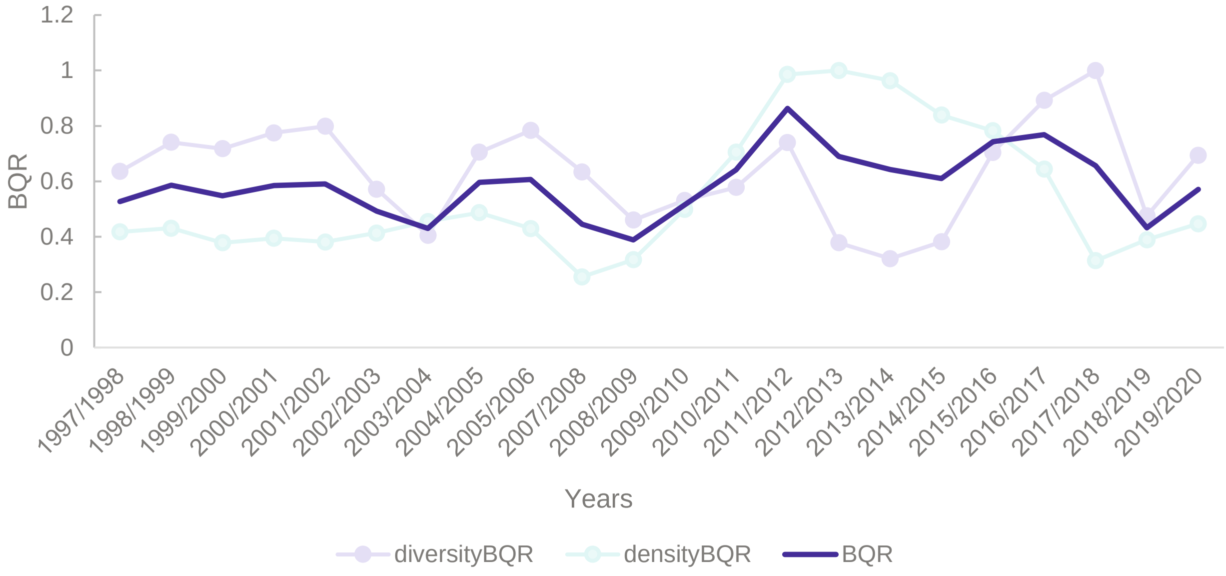
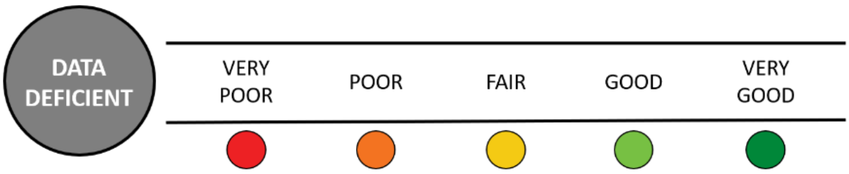


Figure 31. Diversity BQR, density BQR and combined BQR of reef invertebrates from Reef Life Survey and the Victorian SRMP.

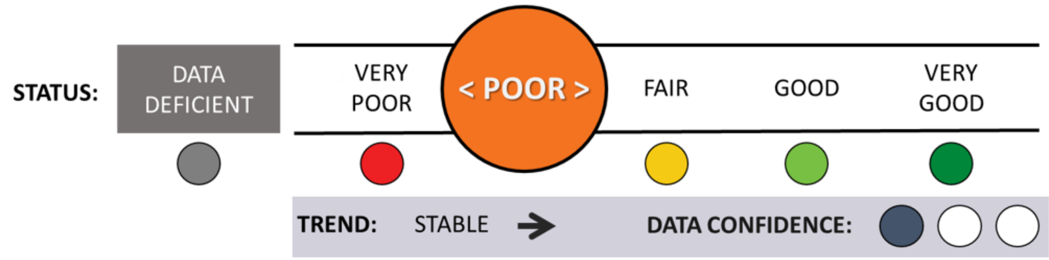
6.3 Spider Crab



Species	Giant Spider Crab (*Leptomithrax gaimardii*)
Indicator	TBD
Data Sources	TBD

Crabs are considered potentially good indicators of environmental habitat quality and of water conditions. There has been regular Giant Spider Crab *Leptomithrax gaimardii* aggregations each winter in areas of Blairgowrie and Rye piers. Giant spider Crabs are thought to move from deeper waters of Victoria's PPB and coastal waters into shallow water less than 5 meters deep as a part of an annual aggregation cycle.

6.4 Urchins



Species	Sea urchins *Heliocidaris* species Overabundant *Heliocidaris erythrogramma*
Indicator	Mean urchin density (number per m^2) measured by the number of sea urchins scored on reef surveys (Young et al. 2020). For *Heliocidaris* species a baseline of eight urchins per metre squared (Carnell and Keough 2020; Kriegisch et al. 2016) was used as a threshold to indicate a poor status. For other urchin species a baseline was calculated by average densities across all survey years.
Data Sources	Reef Life Survey and the Victorian Subtidal Reef Monitoring Program

Urchins play a unique role in being both beneficial and harmful to reefs depending on their abundance (Carnell and Keough 2020). Over the last 20 years PPB has seen an increase in reef areas becoming sea urchin barrens, where ecosystem function and species diversity is reduced (Carnell and Keough 2020). Urchin sampling programs include RLS, and the Victorian SRMP. Counts of urchin species, were used to calculate the density of urchins at each sampling location (urchins per m^2) based on the different sampling protocols for each survey method (Young et al. 2020). The overabundant urchin *Heliocidaris erythrogramma* was also assessed applying thresholds to indicate overabundance (Carnell and Keough 2020; Kriegisch et al. 2016).

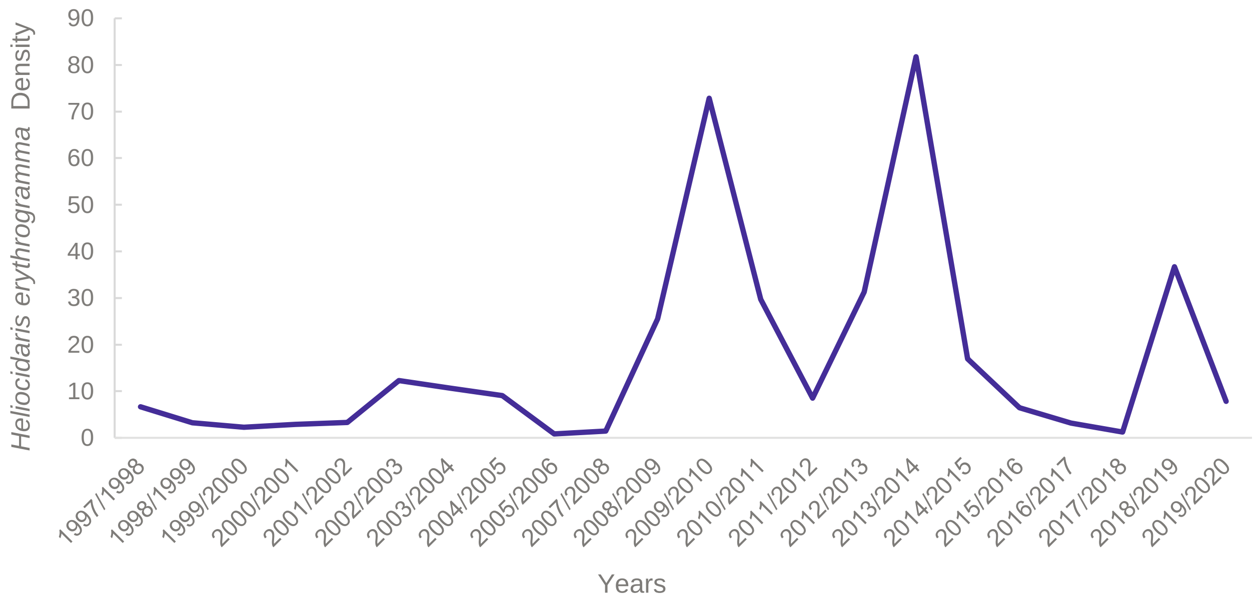


Figure 32. Density of Sea urchin *Heliocidaris erythrogramma,* data from Reef Life Survey and the SRMP.

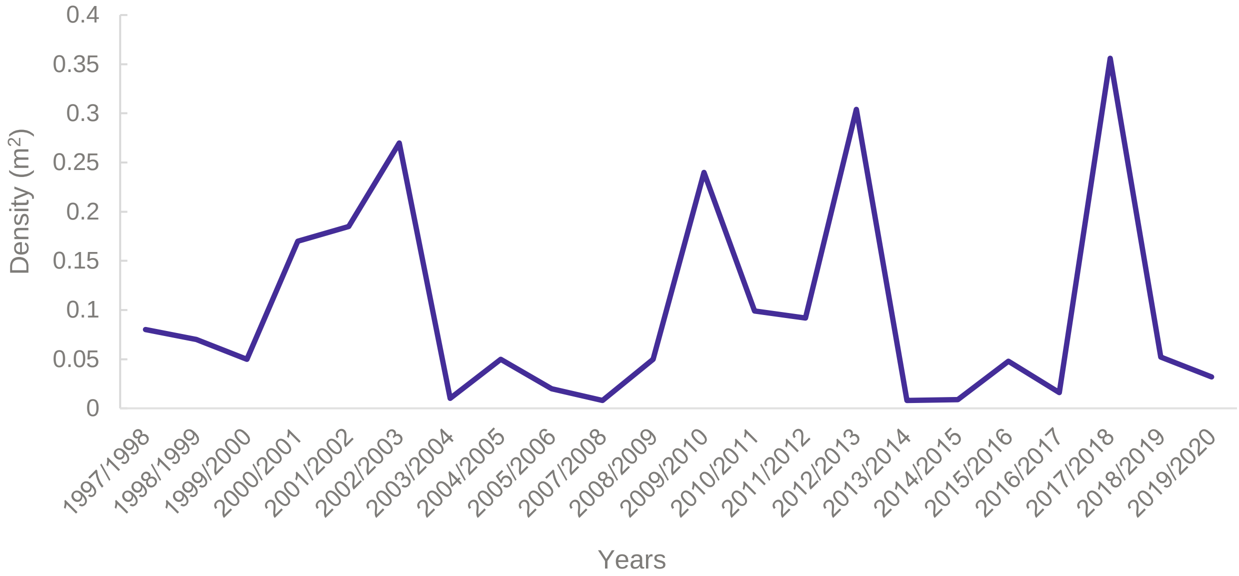


Figure 33. Density of sea urchins (excludeing *Heliocidaris erythrogramma*) data from Reef Life Survey and the SRMP.

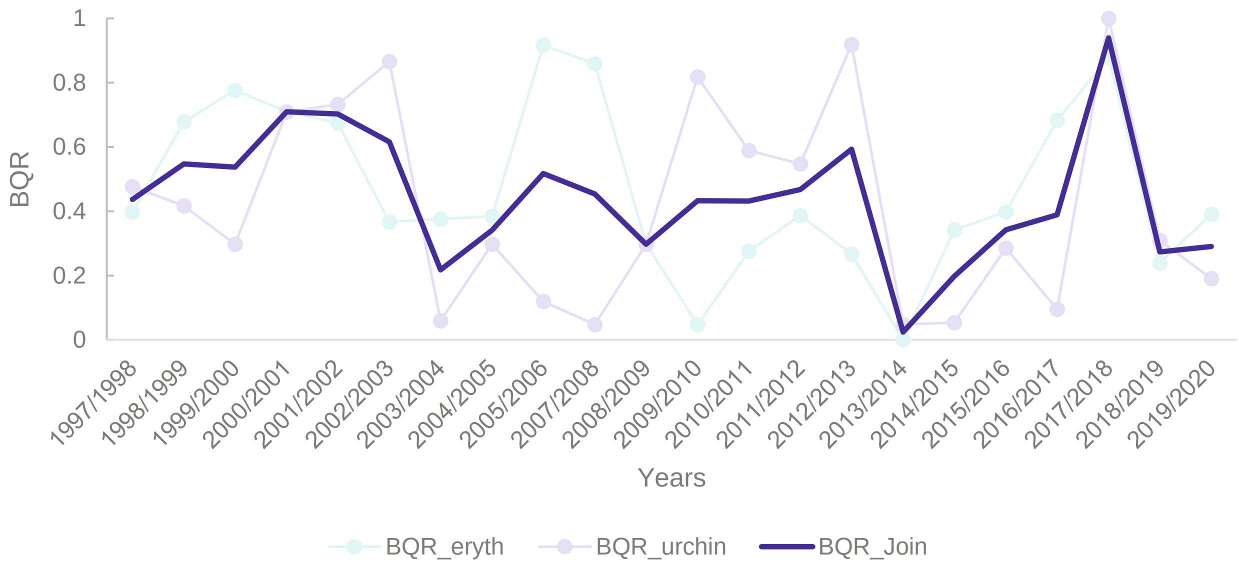
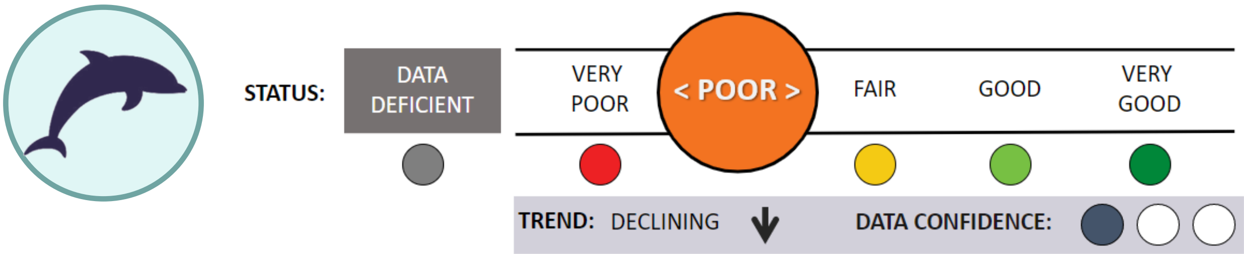


Figure 34. BQR of *Heliocidaris erythrogramma*, BQR of urchin species (excluding *Heliocidaris erythrogramma*) and BQR combined, data from Reef Life Survey and the SRMP.

7. Mammals



Assessment Biota	• Burrunan Dolphin • Common Dolphin • Seals • Whales
Data Sources	Victorian Biodiversity Atlas (VBA), Dolphin Research Institute (DRI), Zoos Victoria's Marine Response Unit, Marine Mammal Foundation, Cetacean Science Connections
Consulted Stakeholders and Experts	David Donnelly (DRI), Jeff Weir (DRI), Dr. Kate Robb (Marine Mammal Foundation), Dr Sue Mason (Cetacean Science Connections), Mandy Watson (DELWP), Dr. Kasey Stamation (ARI), Dr John Arnould (Deakin University), Dr. Rebecca McIntosh (Phillip Island Nature Parks), Mark Keenan (Melbourne Zoo's MRU), Dr. Michael Lynch (Melbourne Zoo's MRU).

The status of marine mammals in PPB in 2020–2021 was Poor and the trend is improving. This status is informed by available time-series data of dolphins, seals and whales. The confidence score for this data is Low. Marine mammals, being top predators of the marine ecosystem, are good indicators of the state of food webs, levels of hazardous substances and direct human disturbance (HELCOM 2018b).

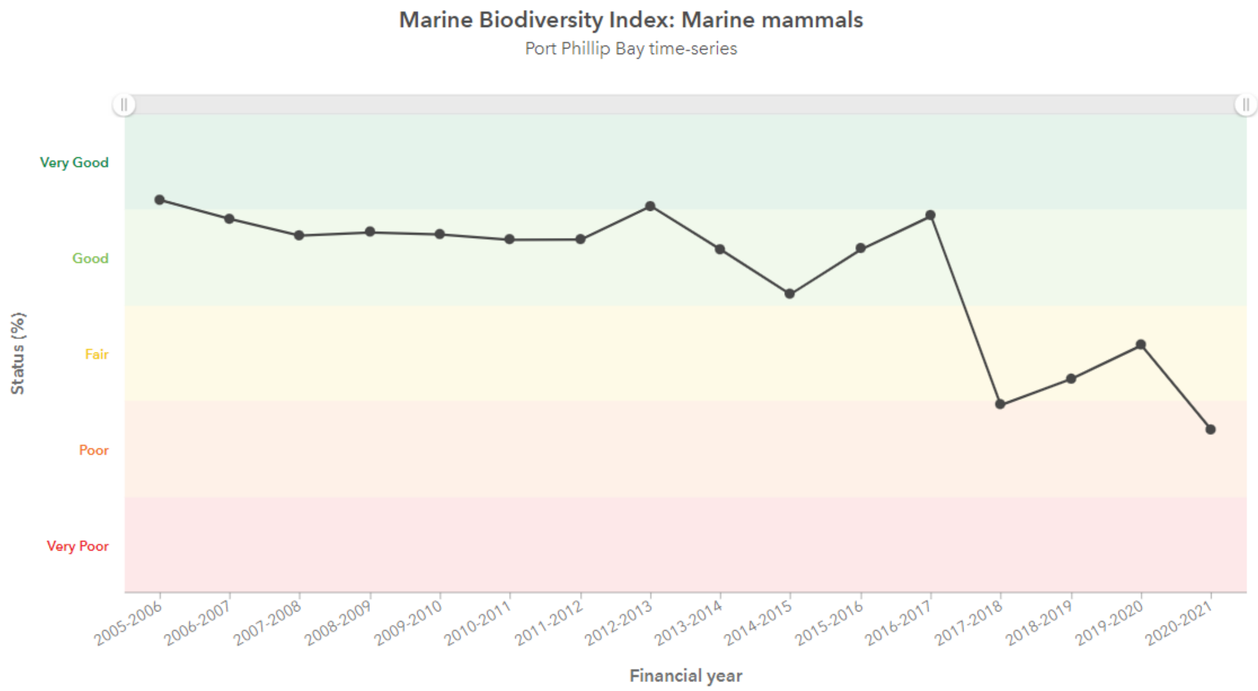


Figure 35. Marine Biodiversity Index (MBI) across all mammals (dolphins, seals and whales) applying the BQR and nested framework in Figure 36.

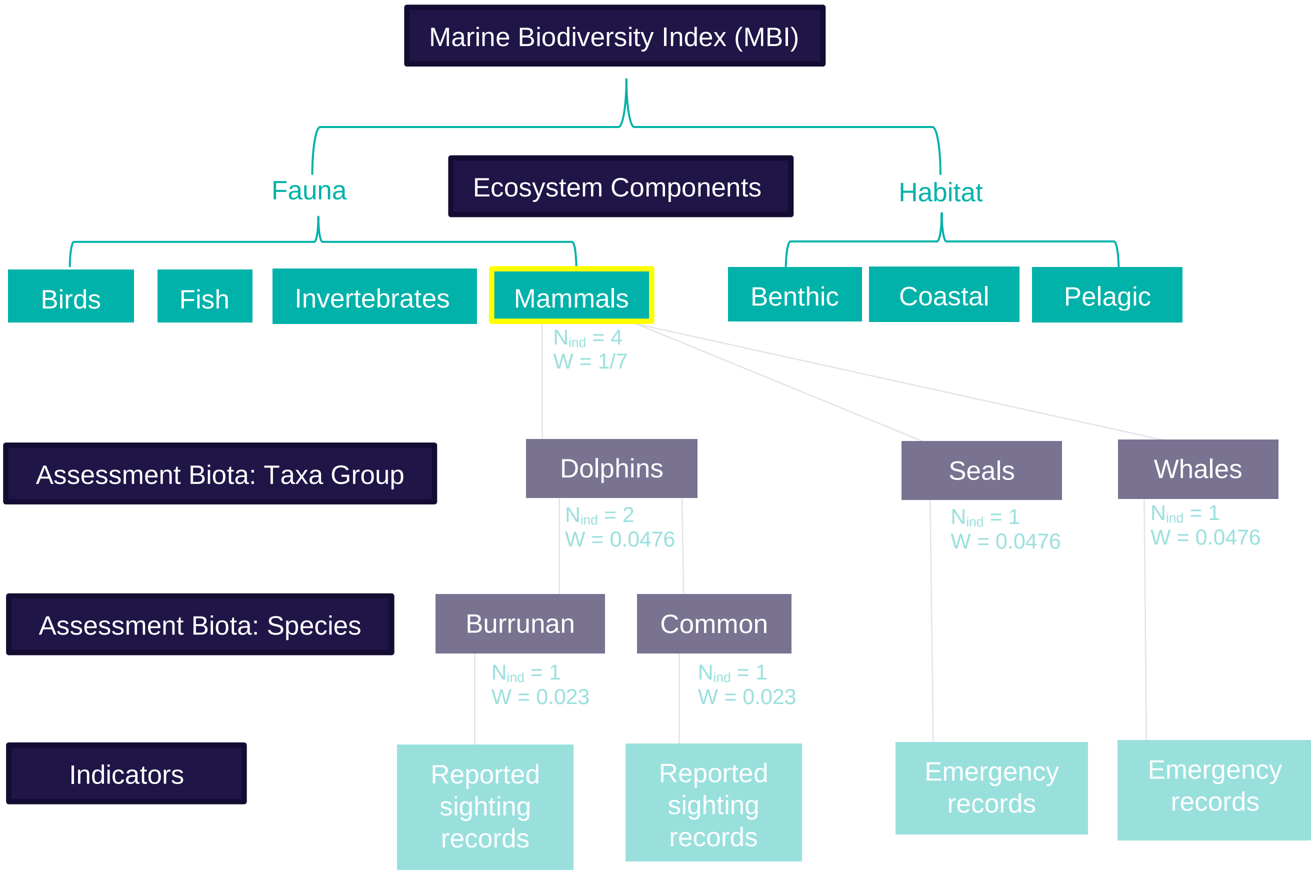
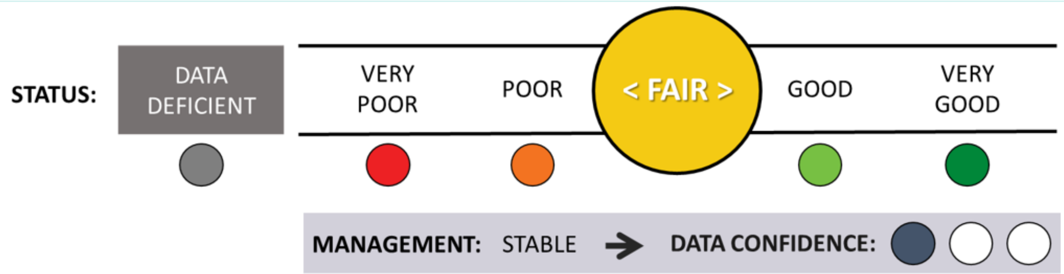


Figure 36. Nested structure of the Mammals Ecosystem Component. N_{ind} is the number of indicators used to measure the taxa group or species, and W is the weight applied in the overall nested structure.

7.1 Burrunan Dolphin



Species	Burrunan Dolphin (*Tursiops australis*)
Indicator	Sighting records from the year 2000, applying a moving average (geometric mean) across four years. The baseline was calculated from the average value across all years. Sampling effort was standardised for comparisons across years to be informative. Only VBA records from the year 2000 onwards were considered and only those entered as “Targeted Surveys” were included, moreover incidental records were excluded from the analysis.
Data Sources	Victorian Biodiversity Atlas (VBA), Marine Mammal Foundation

The Burrunan Dolphin (*Tursiops australis*) was first described as a new dolphin species in 2011 (Charlton-Robb et al. 2011) in PPB. The PPB population is considered to comprise of approximately 120 individuals

(Charlton-Robb et al. 2011). The Burrunan Dolphin is listed as threatened under the Victorian Flora and Fauna Guarantee Act 1988 (the FFG Act). Data was provided from records on the Victoria Biodiversity Atlas (VBA) from the Marine Mammal Foundation.

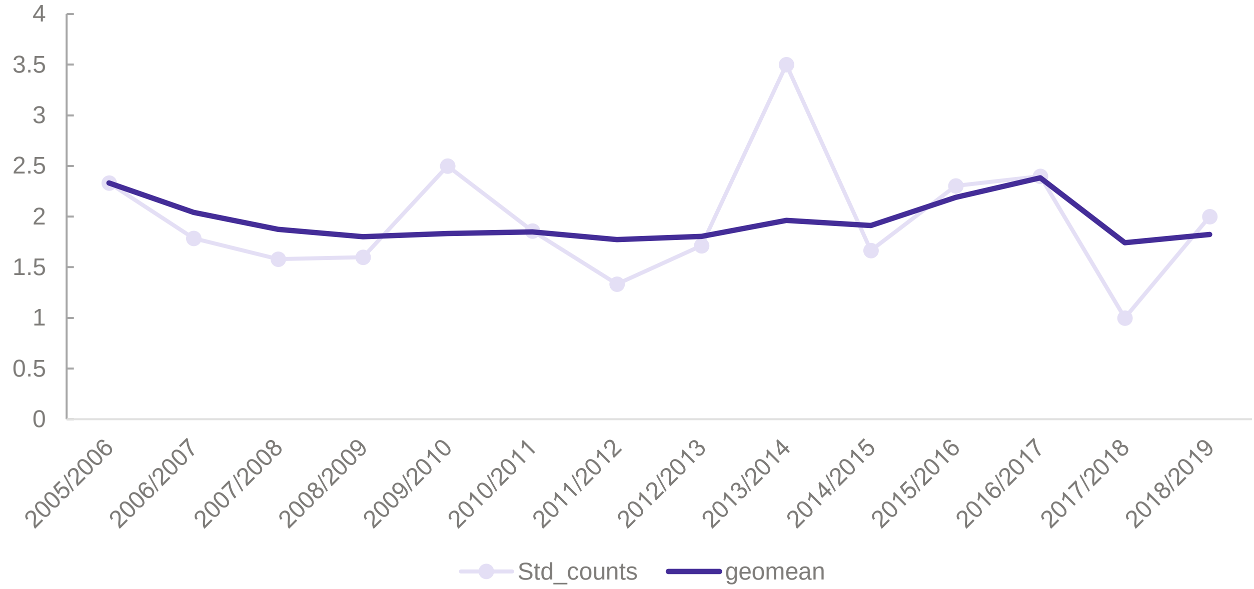


Figure 37. Burrunan Dolphin (*Tursiops australis*) standardised sightings (counts) by survey effort per financial year. The geometric mean was calculated (a moving average across four years). Data from VBA records.

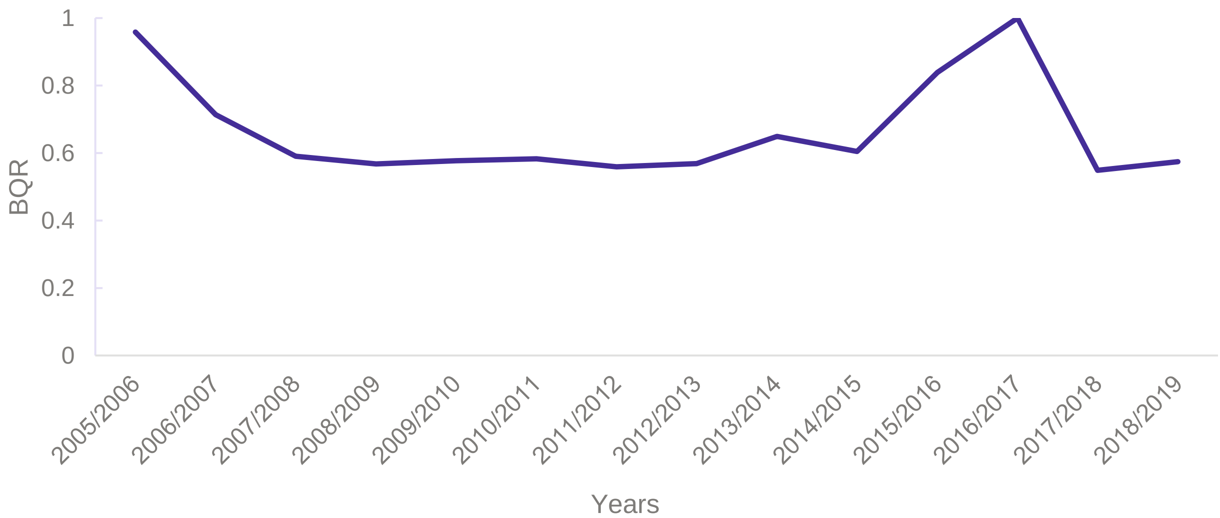
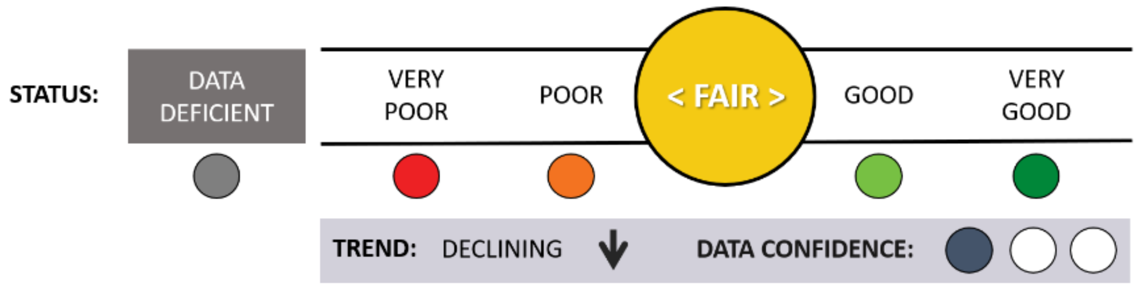


Figure 38. Burrunan Dolphin (*Tursiops australis*) BQR per financial year. Data from VBA records.

7.2 Common Dolphin



Species	Common Dolphin (*Delphinus delphis*)
Indicator	Sighting records from 2002, applying a moving average (geometric mean) across four years. The baseline is calculated from the average value across all years. Sampling effort was standardised for comparisons across years to be informative. Only VBA records from the year 2000 onwards were considered and only those entered as 'Targeted Surveys' were included, moreover incidental records were excluded from the analysis.
Data Sources	Victorian Biodiversity Atlas, Dolphin Research Institute.

A community of Common Dolphins (*Delphinus delphis*), a usually oceanic species, has established residency in south-eastern PPB between Mt Eliza and McCrae since 2005. The community comprises both resident and transient dolphins with more than 100 individuals currently in PPB, estimated by The Dolphin Research Institute. Anthropogenic pressures on these dolphins are evident through significant trauma to some animals, but they seem to recover well, showing resilience to the pressures of living in an "urban" environment. Although the graph below indicates a decline in common dolphin sightings in the last few years, it should be noted that survey effort was reduced due to the COVID19 pandemic. Efforts to provide more detailed and accurate reporting of the Common Dolphin is currently being undertaken and will be reflected in future reports.

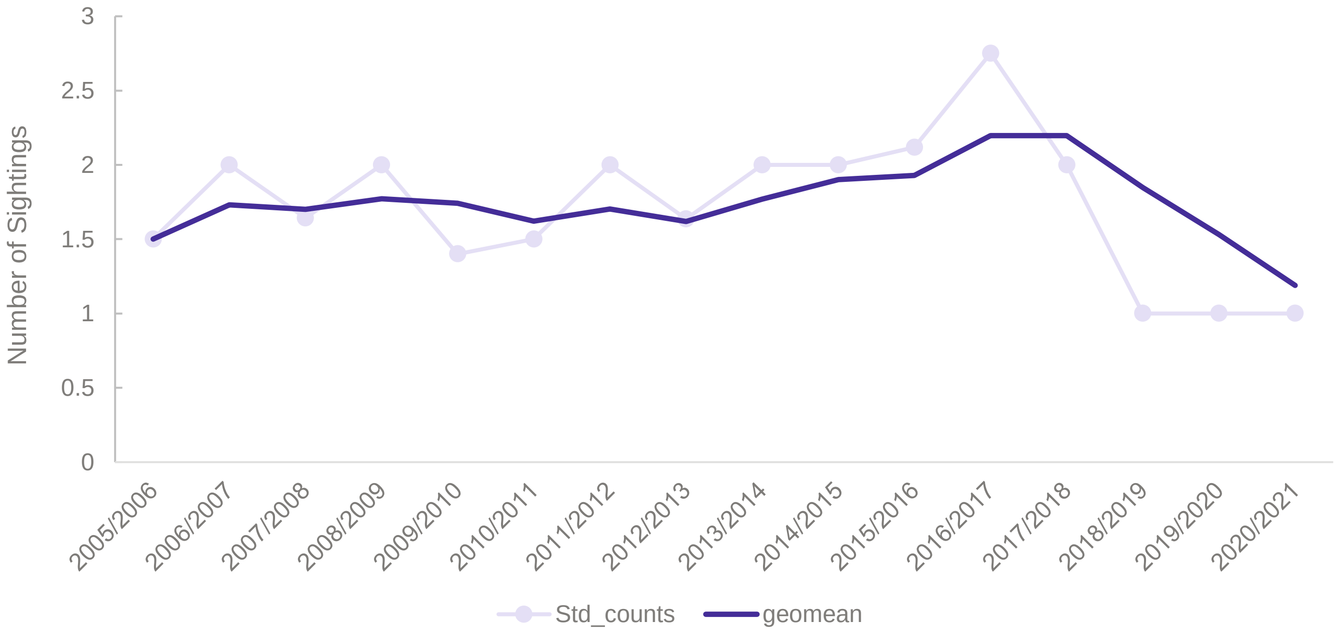


Figure 39. Common Dolphin (*Delphinus delphis*) standardised sightings (counts) by survey effort per financial year. The geometric mean was calculated (a moving average across four years). Data from VBA records.

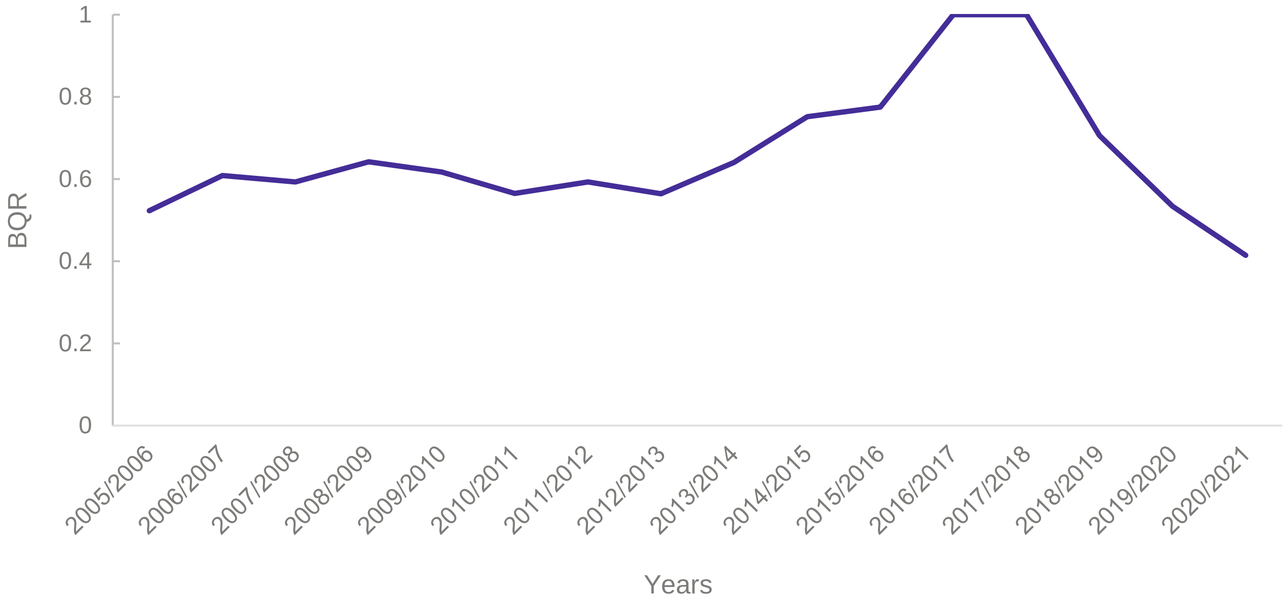
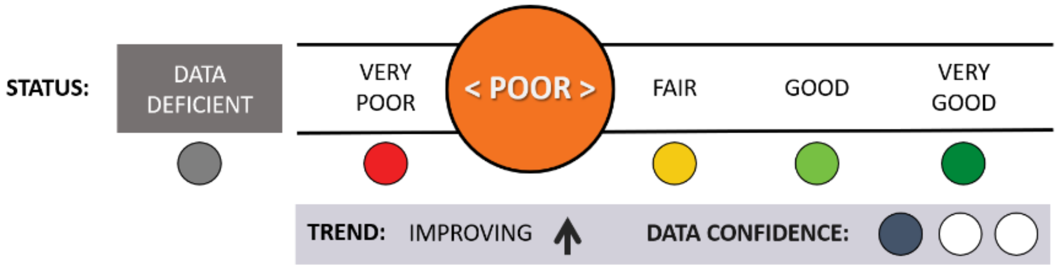


Figure 40. Common Dolphin (*Delphinus delphis*) BQR per financial year. Data from VBA records.

7.3 Seals



Species	Seals
Indicator	Reported emergencies (entanglements, mortalities) since 2013. A baseline with an average across all years was used.
Data	Victorian Biodiversity Atlas, Melbourne Zoo's Marine Response Unit

Given the limited data on PPB seal monitoring, emergency records (entanglements, deceased, injured or required monitoring) by the Melbourne Zoo's Marine Response Unit were used to assess their status in PPB. The Australian Fur Seal, (*Arctocephalus pusillus doriferus*) is the predominant seal species seen in PPB. The most recognisable site for Australian Fur Seals is Chinaman's Hat located in the South Channel of PPB which serves as a haul out site (locations where seals come ashore to rest, moult or breed) predominantly for males. Other haul out sites include Pope's Eye, South Channel Fort and South Channel Marker, but also include smaller structures and buoys. The Australian Fur Seals do not breed within PPB, the closest breeding site is Seal Rocks located off Phillip Island, with an estimated population of 20,000 seals (McIntosh et al. 2018). PPB is occasionally visited by other seal species including sub-Antarctic Fur Seals, Leopard Seal, Southern Elephant Seal, New Zealand Fur Seal, Crabeater Seal and Australian Sea Lions.

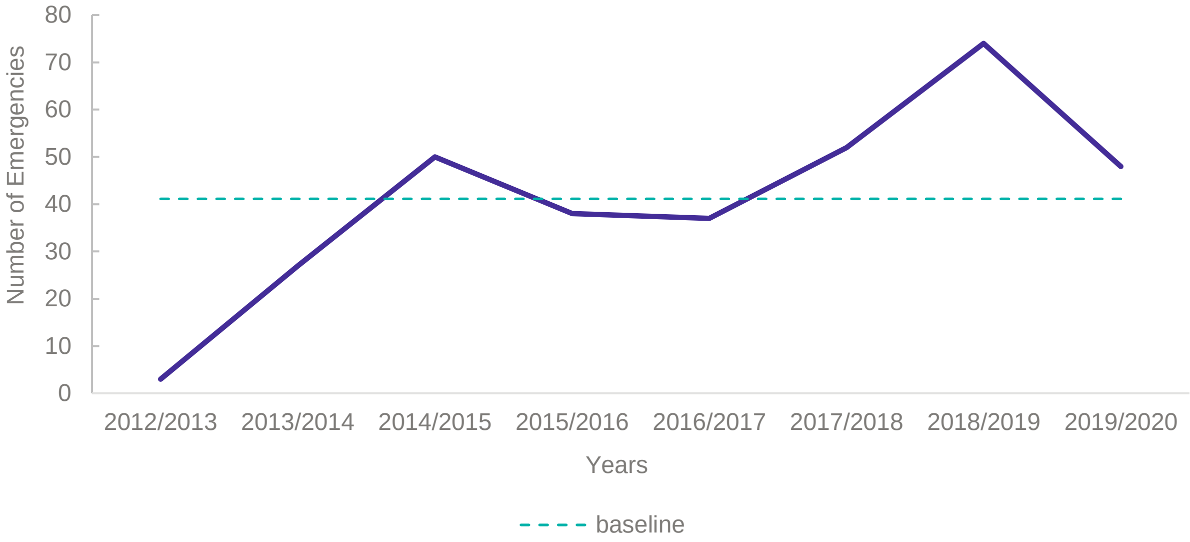


Figure 41. Number of seal emergency records (entanglements, deceased, injured or required monitoring) across PPB as reported by the Melbourne Zoo's Marine Response Unit.

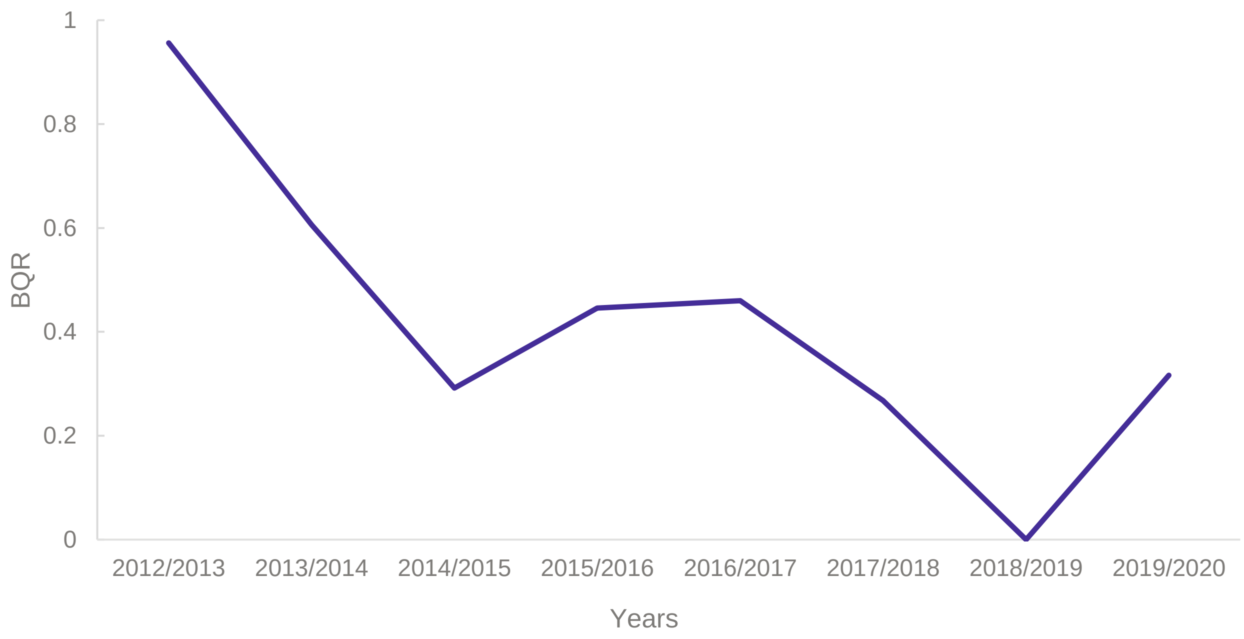
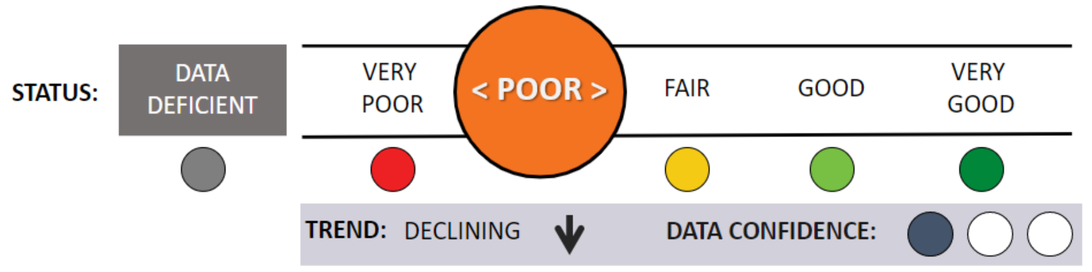


Figure 42. BQR method applied to seal emergency records (entanglements, deceased, injured or required monitoring) across PPB as reported by the Melbourne Zoo's Marine Response Unit.

7.4 Whales



Species	Whales are rarely seen entering PPB, but on the rare occasions sighted species include Southern Right Whale, Southern Humpback Whale, Killer Whale.
Indicator	Emergency records in the VBA was used as an indicator for whales. A baseline of zero was considered ‘Good’ status, and a ‘Very Poor’ status when >2 emergency records occurred within one financial year. A ‘Very Good’ status was achieved when no emergency records were obtained within 5 years.
Data	Victorian Biodiversity Atlas, Melbourne Zoo’s Marine Response Unit

Emergency records (stranding events) in the VBA were used as an indicator to assess Whales in PPB. Whales are sporadically present in PPB between the months of May and October. This presence is linked directly to migratory movements of Humpback and Southern Right Whales. Whilst most records pertain to the southern end of PPB, both species have been documented bay-wide, ranging as far north as St. Kilda and Williamstown.

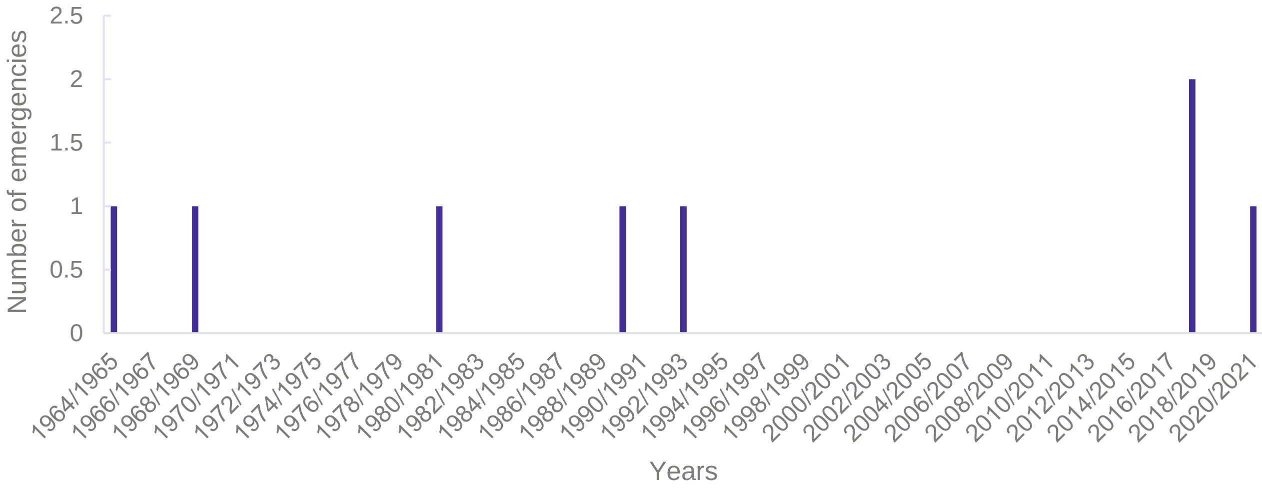


Figure 43. Number of whale emergency records (stranding event) across PPB as reported in the VBA.

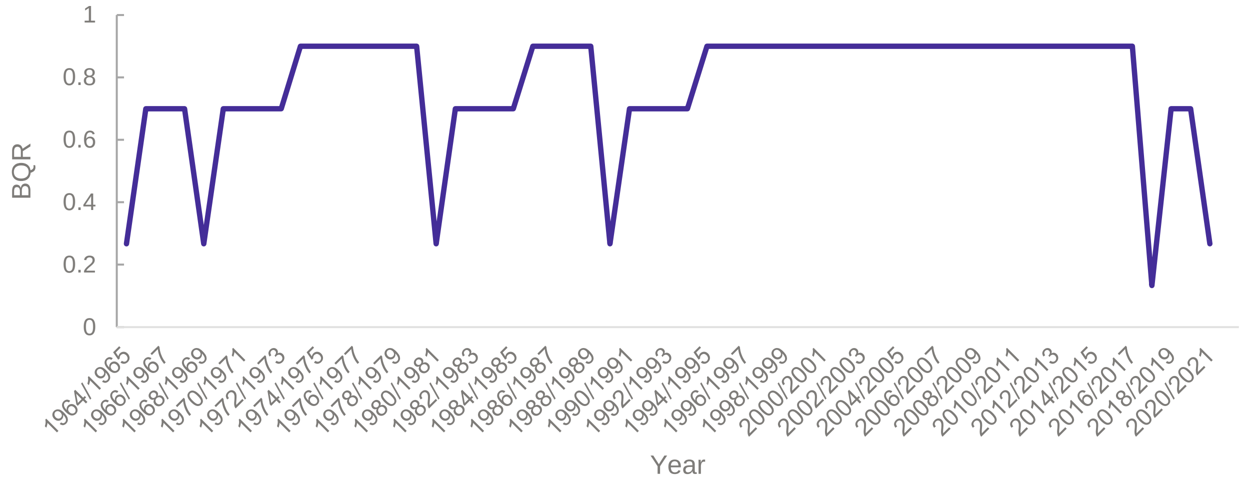


Figure 44. BQR that represents the number of whale emergency records (stranding event) across PPB as reported in the VBA.

8. Reporting

The MBI provides a high-level, map-based visualisation of ecosystem components and the nested taxa and species structure across the EMP jurisdiction, and is being integrated into the Experience Builder Reporting Platform for the EMP. The MBI as reported combines seven ecosystem components as displayed in Figure 45 and Figure 46, and each component will be quantified using the nested BQR approach. Currently only results for fauna ecosystem components have been reported for the MBI (Figure 47), however future reporting will be expanded to include habitats (Appendix 1). We recommend that management interventions and further investigations be triggered when the MBI report cards show significant or sudden declines and/or a BQR status that is below 'Good'. Calculating and reporting on the MBI provides evidence to highlight priority areas and direct future efforts towards of the marine ecosystem that are declining in health and can most benefit.

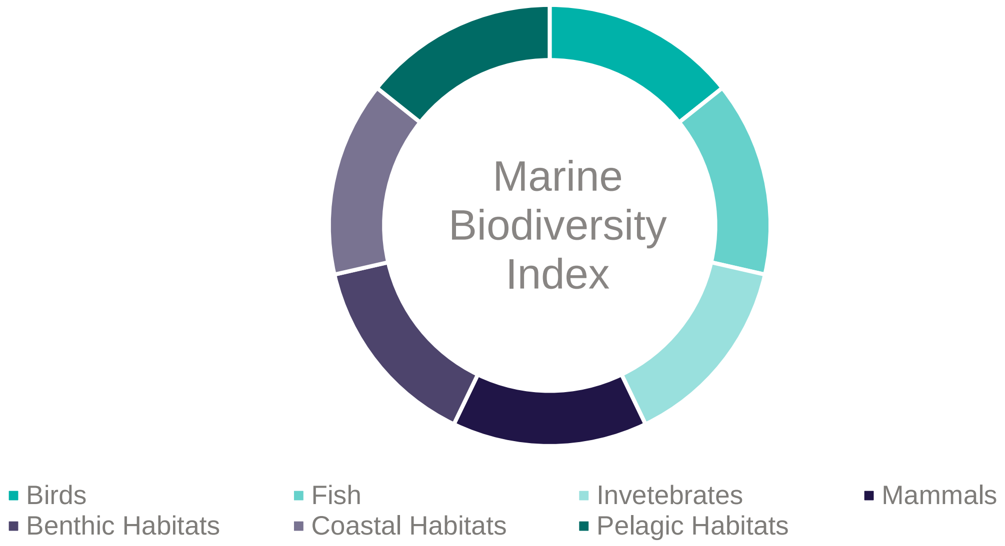


Figure 45. Seven ecosystem components that are reported on within the Marine Biodiversity Index (MBI).

8.1 Limitations and improvements

The nested approach of the MBI provides a system for assessing overall ecosystem health (MBI), yet also provides separate indicators for taxa (such as shorebirds) to ensure well performing indicators do not mask a poor performing indicator. Limitations are however inherent in biological datasets. There are data gaps in survey methods, inconsistent monitoring across time and in some cases inconsistency in survey methods. Furthermore, the spatial aspect captured by surveys differs for different taxonomic groups and sometimes within taxa group. The MBI approach aims to compile and standardise quantitative information where possible to support the assessment of PPB's biodiversity and report on its status. The MBI is limited in its ability to determine the reasons for declining status trends or sudden changes as well as appropriate management actions to apply for different taxa. However, it does build quantitative evidence to highlight the status of marine biodiversity which helps direct further research and investigation into priority taxa groups. Future expansion of the MBI to address specific management actions and questions may be possible with improved data on threats and ecosystem processes.

Improvements can be easily integrated into the MBI methodology as indicators are updated or new indicators are introduced. A BQR normalises the indicator scores and can be adopted into the MBI index. The method is flexible in that numerous indicators can be used, and weighting can be adjusted or altered. Currently data gaps do exist for numerous marine taxa groups and species across PPB which need to be understood. Future improvements can be added into the MBI approach as datasets become available and baselines and threshold values are established. Ecosystem components for PPB were chosen as based upon HELCOM (2018a; b) as well as former State of Environment reports (State of the Bays 2016; State of the Environment 2018), however ideally the selection of ecosystem components would entail a formal and comprehensive expert elicitation process.

9. Conclusion

The MBI will enable efficient reporting and evaluation of the delivery of the EMP's goal (to conserve and restore habitats and marine life; Figure 1). The method and its outputs are embedded into the Victoria's Marine and Coastal Knowledge Framework (MACKF), supporting the need for forming the future evidence base for assessing management interventions and environmental outcomes. It will help support informed decision-making to ensure a purposeful and systematic approach is taken to assessing marine ecosystems and their species (Figure 46). While developed for the EMP, the MBI method can be applied in other environmental management settings and applied more widely across the Victorian coast or other priority marine regions. The MBI supports the Victoria's Biodiversity 2037 plan by providing an integrated approach that can be used to evaluate marine and coastal species, helping address the state-wide target '*a net improvement in the outlook across all species by 2037'*.

It is recommended that the MBI be adopted for ongoing use in evaluation of the EMP, and the MBI results for the first four-yearly evaluation be used as a benchmark to identify habitat and marine life priorities and set targets for the following four years.

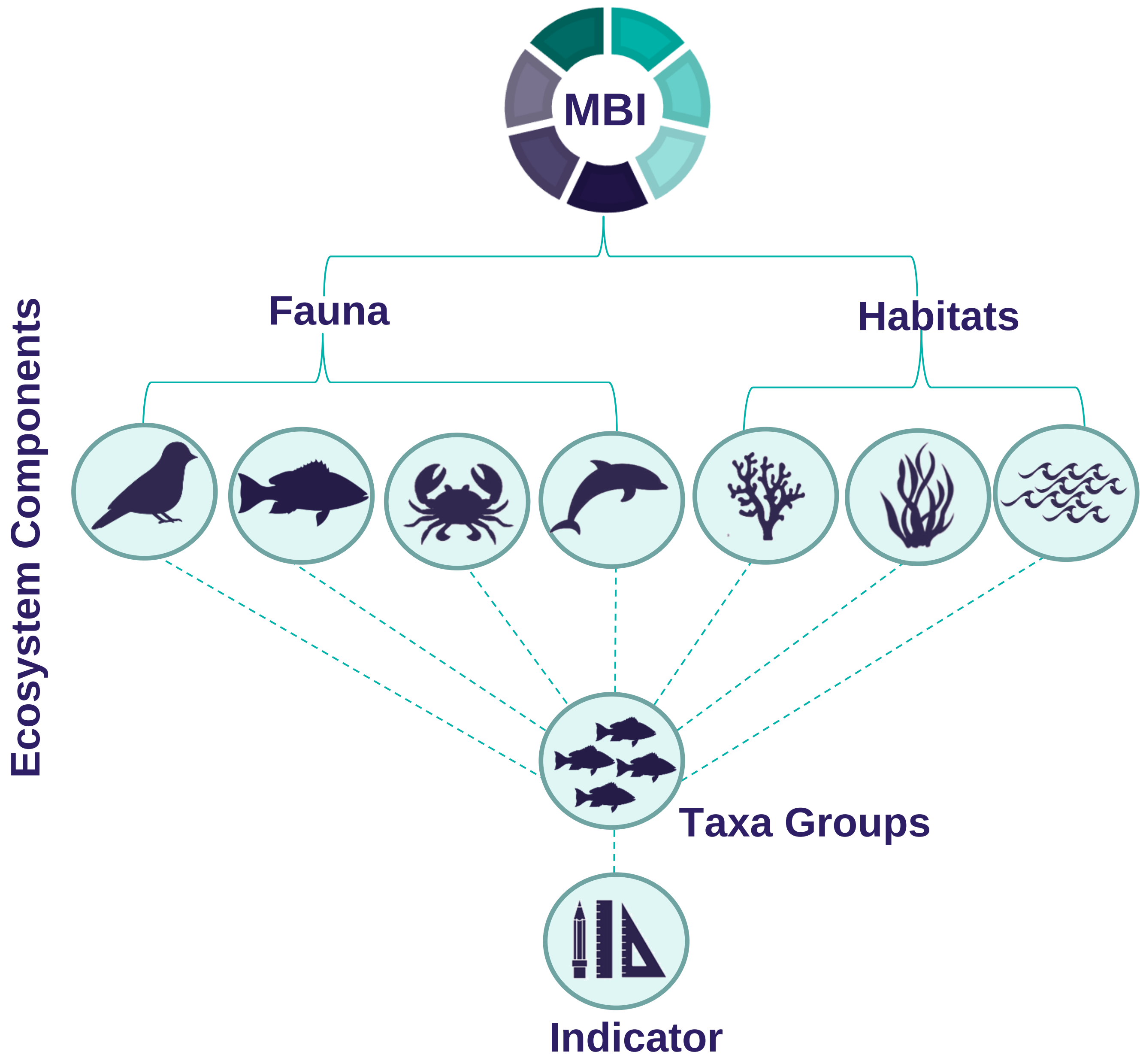


Figure 46. Overall diagram to represent the Marine Biodiversity Index (MBI) and its ecosystem components.

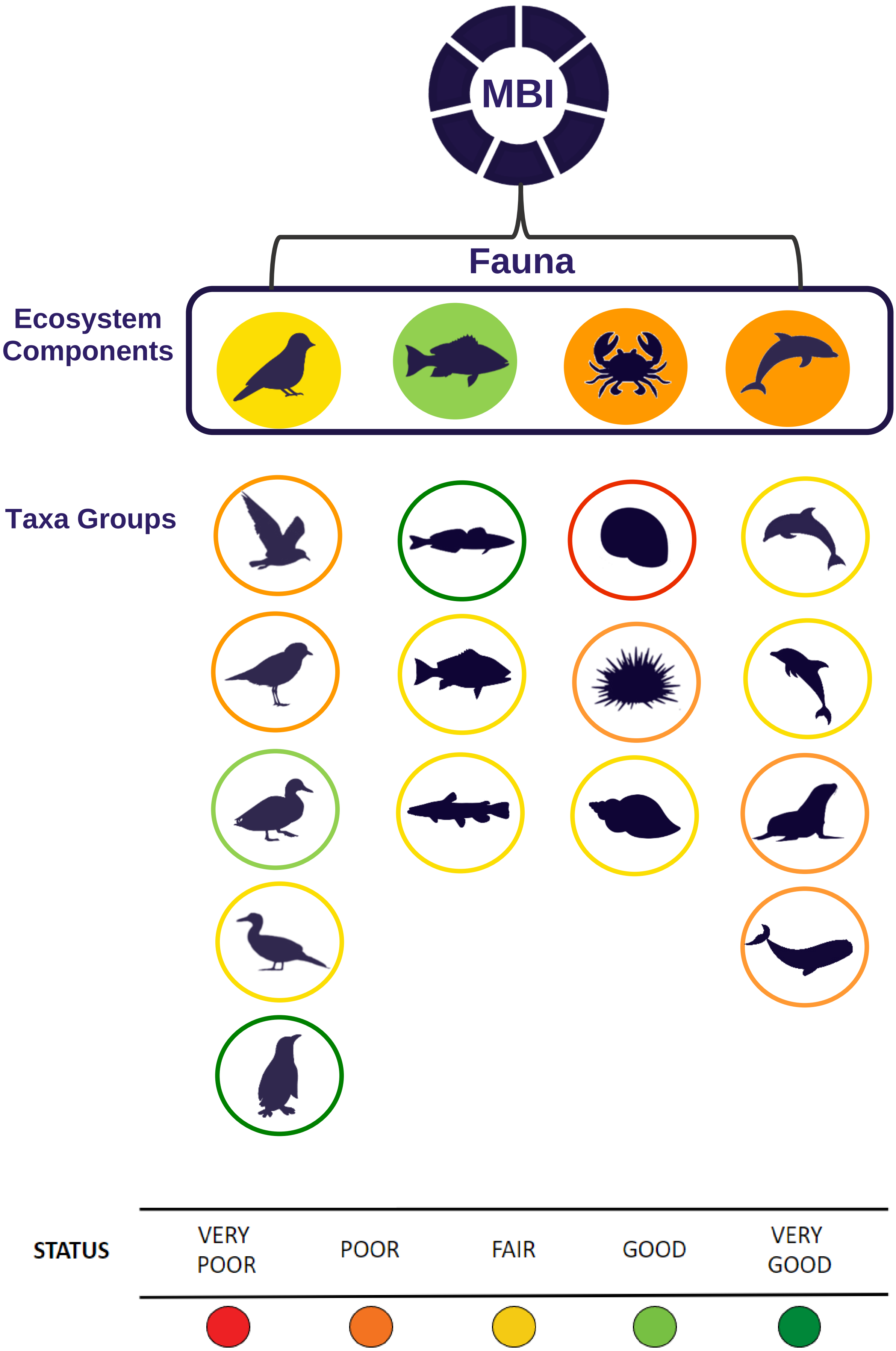


Figure 47. Overall diagram to represent the Marine Biodiversity Index (MBI) and its fauna ecosystem components and status.

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11. Appendix

1. Benthic habitats

Assessment Biota	Benthic and Subtidal Biotopes
Data Sources	CoastKit Biotope Atlas database and maps, SRMP
Expert Working Group	Dr Matt Edmunds (Australian Marine Ecology), Dr Adrian Flynn (Fathom Pacific), Dr. Giorgia Cecino (Fathom Pacific), Dr Greg Parry

For the ecosystem component 'Benthic Habitats' datasets were provided by different sources. The nested structure of reporting on benthic habitats is represented in Figure A1 below, where biotope records inform the benthic biotope distribution.

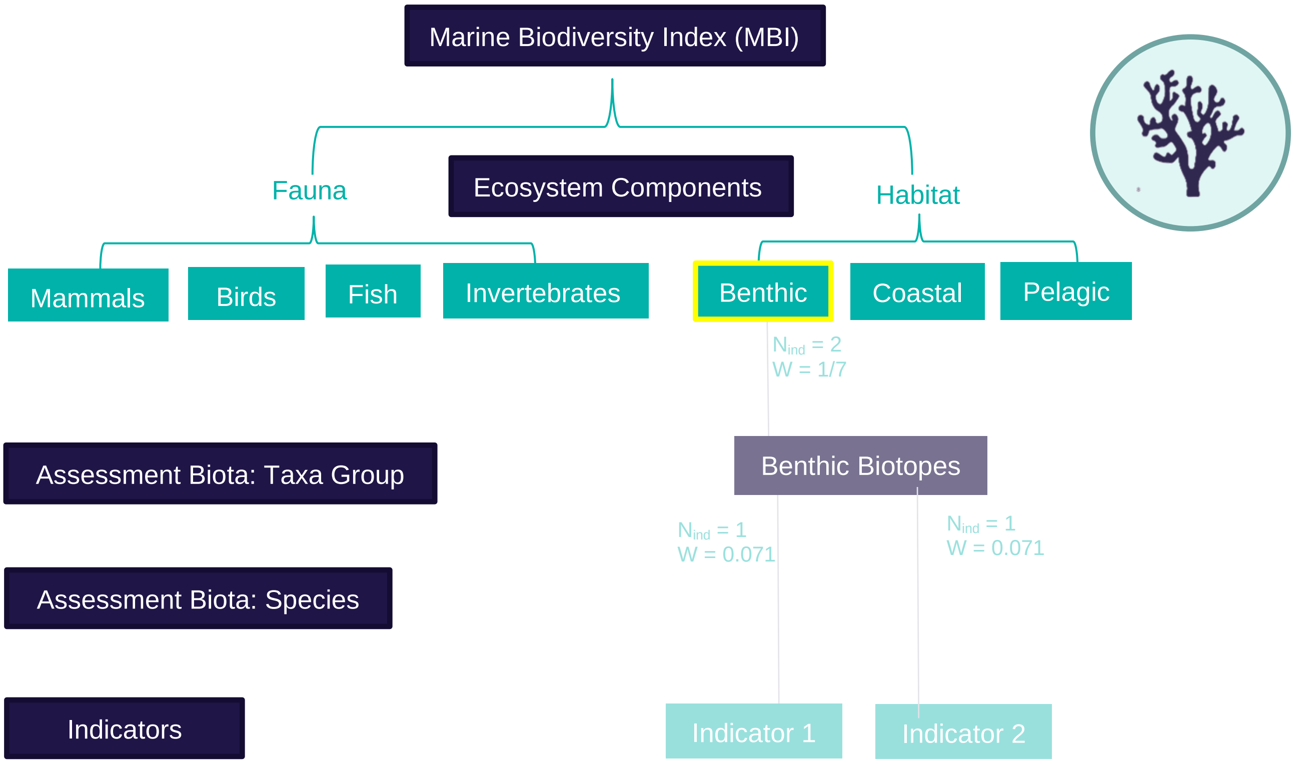

Figure A1. Nested structure of the Benthic Ecosystem Component. N_{ind} is the number of indicators used to measure the taxa group or species, and W is the weight applied in the overall nested structure.

Benthic Habitat Indicators

Indicators	Description
Indicator 1:	Marine condition
Indicator 2:	Habitat hectares

Benthic Biotopes:

Biotopes across PPB have been characterised by the Combined Biotope Classification Scheme (CBiCS) as developed and described by Edmunds and Flynn (2015, 2018). CBiCS has six, hierarchical classification components which categorise Victorian marine species and habitats, from broader environmental assemblages to more specific sub-biotopes. Biotopes are recognisable assemblages of species that occur within particular environments and habitats and are at level 5 of the CBiCS classification. Marine condition will be the key indicator for informing biotope changes and health. The indicator is based on four pillars that includes i) a structure score based on morphospecies composition and structural components, ii) an ecosystem importance score based on functional and mechanistic models, iii) a priority marine features score based on uniqueness and spatial distribution mapping, and iv) a GES score from 11 descriptors of the EU Marine Strategy Framework Directive for local relevance. Currently work has progressed on the Seaweed biotopes and will expand to other biotopes comprising a diversity of marine life forms such as: Anemones, Ascidians, Barnacles, Black corals, Bryozoa, Caulerpa, Coralline Algae, Feather stars, Gorgonians, Hard corals, Hydrocorals, Microphytobenthos, Octocorals, Rhodoliths, Seagrass, Sea Pens, Sponges, Seaweeds, Turf.

The Habitat Hectare assessment method that is currently used to assess terrestrial vegetation quality in Victoria is being revised and will have a new structure designed to be readily adapted to the marine environment. It will be employed to evaluate habitat condition for seabed communities.

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 1: Marine condition	Four pillars of marine condition (Structural score, EcoNet importance, Priority Marine Features Score, GES Score)	TBD	TBD	Expert Working Group to define using Table 3
Indicator 2: Habitat hectares	A metric that includes site condition and extent	TBD	TBD	Expert Working Group to define using Table 3

Current knowledge and previous assessments:

No previous assessment has been conducted on benthic habitat condition and status across PPB.

2. Coastal habitats

Assessment Biota	Coastal and Intertidal Biotopes; Seagrass, Mangroves, Saltmarsh, Reefs
Data Sources	CoastKit Biotope Atlas database and maps, SRMP, Ball et al. (2014), Boon et al. (2011), Satellite Imagery
Expert Working Group	Dr. Matt Edmunds (Australian Marine Ecology), Dr. Adrian Flynn (Fathom Pacific), Dr. Giorgia Cecino (Fathom Pacific), Prof. Peter Macreadie & Dr. Paul Carnell (Deakin University's Blue Carbon Lab), Dr. Alastair Hirst (EPA, DELWP), Dr. Steve Sinclair (ARI), Dr. Mariela Soto-Berelov (RMIT), Prof. Paul Boon (Victoria University), Dr. Tom Hurst (Melbourne Water), David Ball, Dr. Ruth Reef (Monash University)

For the ecosystem component ‘Coastal Habitats’ datasets were provided by different sources. The nested structure of reporting on intertidal coastal habitats is represented in Figure A2 below, where seagrass, saltmarsh and mangroves are assessed.

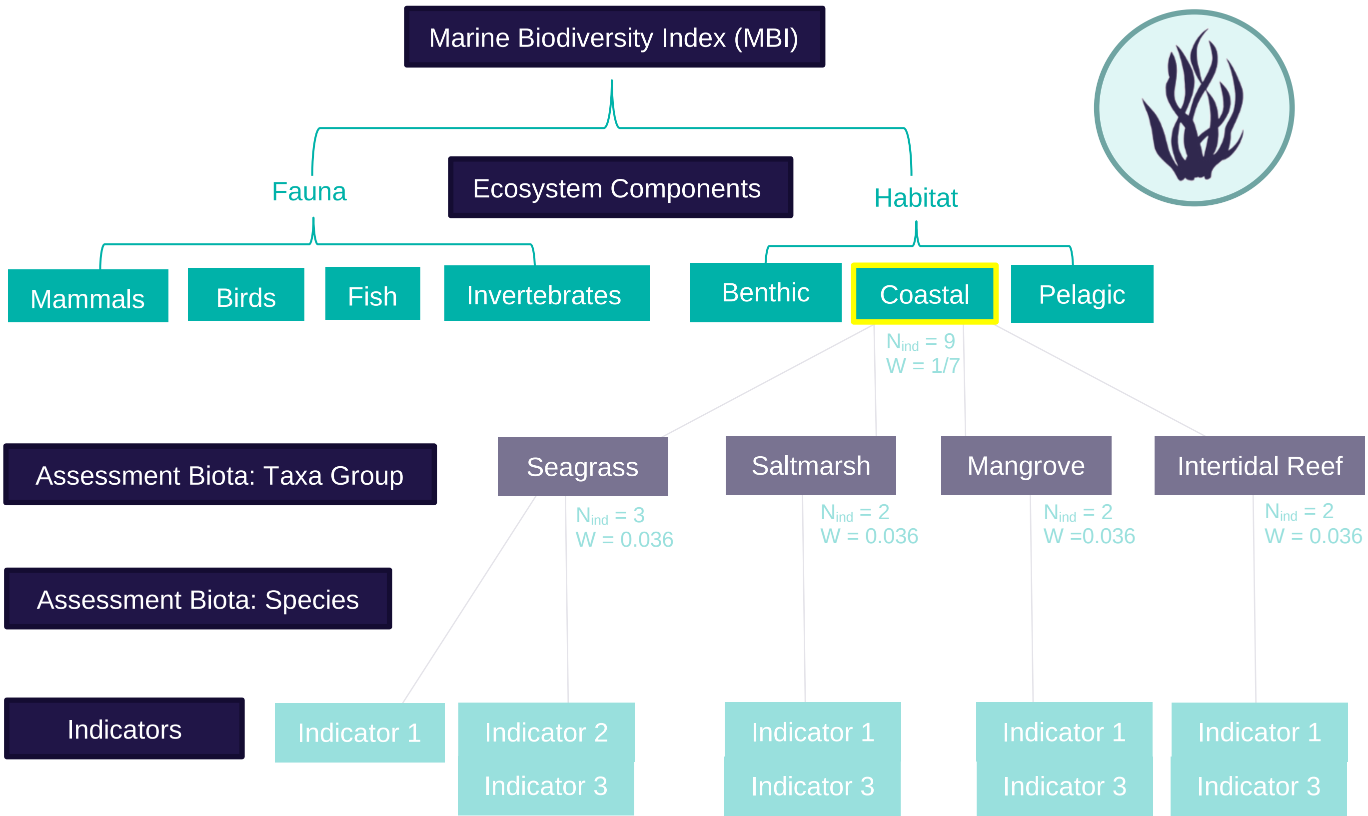

Figure.A2. Nested structure of the Coastal Ecosystem Component. N_{ind} is the number of indicators used to measure the taxa group or species, and W is the weight applied in the overall nested structure.

Coastal Habitat Indicators

Indicators	Description
Indicator 1:	Marine condition
Indicator 2:	Change in habitat extent
Indicator 3:	Habitat hectares

<u>Seagrass:</u>

Seagrasses are important indicators of ecosystem health, where changes in abundance and distribution signify environmental perturbation. Four dominant species of seagrass are found within PPB, *Zostera muelleri, Heterozostera tasmanica, Halophila australis*, and *Amphibolis antarctica*. In the year 2000, 169.4 km^2 of seagrass, macroalgae and Pyura was recorded, of which 67.99 km^2 (40%) was recorded as either seagrass or a mixture of seagrass and macroalgae (Blake & Ball et al. 2001). The general distribution may be relatively constant, the actual cover of seagrass at specific sites is ephemeral and can fluctuate significantly over short periods of time. Time series data is available from the 1940's to 2011 for three sites located at Blairgowrie, St Leonards and Bellarine Bank, and for an additional three sites (Point Henry West, Curlewis Bank and Swan Bay) from 2000 onwards (Ball et al. 2014). Intertidal and subtidal seagrass will be assessed separately.

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 1: Marine condition	Four pillars of marine condition (Structural score, ecosystem (EcoNet) importance, Priority Marine Features Score, GES Score).	TBD	TBD	Expert Working Group to define using Table 3
Indicator 2: Change in habitat extent	Intertidal seagrass extent from aerial imagery Ball et al. (2014)	1939 – 2011	TBD	Expert Working Group to define using Table 3

Saltmarsh:

Estimated depletion of coastal marsh in PPB since pre-1750's is estimated at 1,840 ha, with approximately 50% of saltmarsh remaining in 2011 (Boon et al. 2011). Loss of intertidal marsh is caused by intensive land-use practises particularly ponds for water treatment and salt production, and urbanisation (Boon et al. 2011).

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 1: Marine condition	Four pillars of marine condition (Structural score, ecosystem (EcoNet) importance, Priority Marine Features Score, GES Score).	pre-1750 – 2011	TBD	Expert Working Group to define using Table 3
Indicator 3: Habitat hectares	A metric that includes site condition and extent	TBD	TBD	Expert Working Group to define using Table 3

Mangroves:

Only one species, *Avicennia marina*, occurs in Victoria. Mangroves provide many ecosystem functions and services such as erosion prevention, water filtration (improving its quality) and carbon sequestration. The largest surviving stand of mangroves in northern PPB occurs along a 200 meter section of coast near Williamstown.

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 1: Marine condition	Four pillars of marine condition (Structural score, ecosystem (EcoNet) importance, Priority Marine Features Score, GES Score)	1991 – 2015	TBD	Expert Working Group to define using Table 3
Indicator 3: Habitat hectares	A metric that includes site condition and extent	TBD	TBD	Expert Working Group to define using Table 3

Intertidal Reefs:

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 1: Marine condition	Four pillars of marine condition (Structural score, ecosystem (EcoNet) importance, Priority Marine Features Score, GES Score)	1991– 2015	TBD	Expert Working Group to define using Table 3
Indicator 3: Habitat hectares	A metric that includes site condition and extent	TBD	TBD	Expert Working Group to define using Table 3

Current knowledge and previous assessments:

- State of the Environment (2018) Saltmarsh: Status 2021 = **Fair**, Status 2018 = **Fair**. While there have been significant losses of saltmarsh cover since European settlement, approximately half of the saltmarsh cover remains today.
- State of the Environment (2018) Mangroves: Status 2021 = **Unknown**, Status 2018 = **Not Assessed.** There is currently only about six hectares of mangroves in PPB and there is no baseline data to compare this value against.

3. Pelagic habitats

Assessment Biota	Zooplankton/Phytoplankton, Chlorophyll-a, Harmful algal bloom events
Data Sources	Environment Protection Authority (EPA) Victoria, Integrated Marine Observing System (IMOS)
Expert Working Group	Environment Protection Authority (EPA) Victoria

For the ecosystem component 'Pelagic Habitats' datasets were provided by different sources. The nested structure of reporting on pelagic habitats is represented in Figure A3 below, where three indicator groups zooplankton/phytoplankton, chlorophyll-a, cyanobacterial bloom.

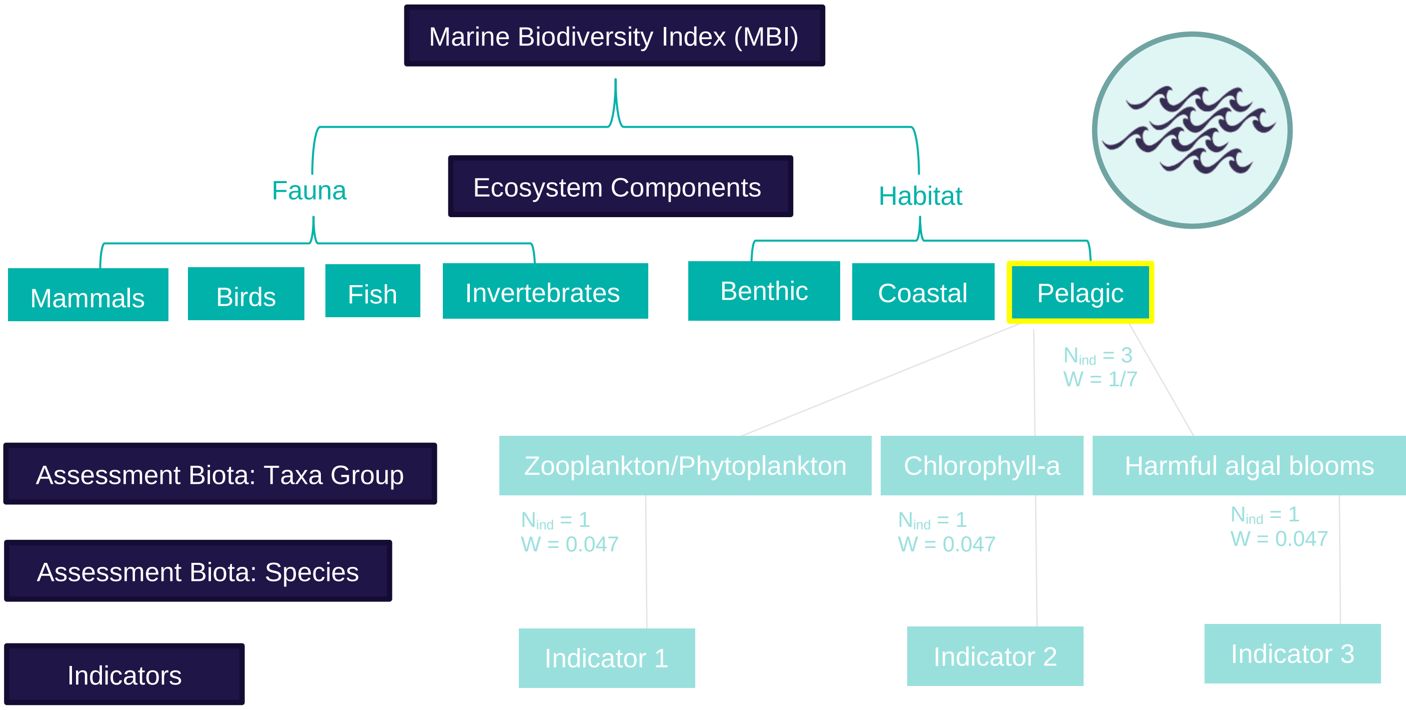

Figure A3. Nested structure of the Pelagic Ecosystem Component. N_{ind} is the number of indicators used to measure the taxa group or species, and W is the weight applied in the overall nested structure.

Pelagic Habitat Indicators

Indicators	Description
Indicator 1:	Zooplankton/Phytoplankton abundance
Indicator 2:	Chlorophyll-a conditions
Indicator 3:	Harmful algal bloom events

Zooplankton/Phytoplankton:

Zooplankton performs a vital role in the marine food web. The herbivorous zooplankton feed on phytoplankton and in turn constitute prey to animals at higher trophic levels, including fish. Hence, zooplankton and phytoplankton are an essential link in aquatic food webs, influencing energy transfer in the pelagic food webs and recruitment to fish stocks as well as ecosystem productivity, nutrient and carbon cycling. Therefore, the evaluation of zooplankton communities is a prerequisite for analysis of pelagic food web structure. As a rule, good status is achieved when large-bodied zooplankton are abundant in the plankton community (HELCOM 2018a; 2018b).

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 1: Zooplankton/Phytoplankton abundance	EPA data – cell count data for phytoplankton species	2008 – Present	TBD	Expert Working Group to define using Table 3

Chlorophyll-a conditions:

Chlorophyll-a concentration is used as a proxy of phytoplankton biomass. It increases along with eutrophication because of higher nutrient concentrations. EPA data from the 1990s to the present for PPB will be used along with thresholds based on State Environment Protection Policy (SEPP) and the Environment Reference Standard (ERS) objectives for Chlorophyll-a. The same data was also used in the Eutrophication Index.

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 2: Chlorophyll-a conditions	EPA data - Chlorophyll-a concentration for PPB	1990s – present	SEPP and ERS objectives	Expert Working Group to define using Table 3

Harmful algal blooms:

Harmful algal blooms (HELCOM 2018a; 2018b) were used to represent changes in primary producers. The same data was also used in the Eutrophication Index.

Indicators	Description	Time Period	Threshold	Confidence Status
Indicator 3: Number of cyanobacterial blooms	EPA data – Number of algal blooms above threshold (see Eutrophication Index)	TBD	TBD	Expert Working Group to define using Table 3

Table A1. List of migratory shorebird Species included in the analysis. Some species may have been excluded during the analysis due to the data inclusion criteria.

	Scientific Name	Bird Type	FFG Act 1988	IUCN Status	IUCN Trend
1	*Actitis hypoleucos*	Migratory Shorebird	No	LC	Decreasing
2	*Arenaria interpres*	Migratory Shorebird	No	LC	Decreasing
3	*Calidris acuminata*	Migratory Shorebird	No	LC	Stable
4	*Calidris alba*	Migratory Shorebird	No	LC	Unknown
5	*Calidris canutus*	Migratory Shorebird	No	NT	Decreasing
6	*Calidris falcinellus*	Migratory Shorebird	No	LC	Decreasing
7	*Calidris ferruginea*	Migratory Shorebird	Yes	NT	Decreasing
8	*Calidris melanotos*	Migratory Shorebird	No	LC	Stable
9	*Calidris pugnax*	Migratory Shorebird	No	LC	Decreasing
10	*Calidris ruficollis*	Migratory Shorebird	No	NT	Decreasing
11	*Calidris subminuta*	Migratory Shorebird	No	LC	Unknown
12	*Calidris tenuirostris*	Migratory Shorebird	Yes	EN	Decreasing
13	*Charadrius bicinctus*	Migratory Shorebird	No	NT	Decreasing
14	*Charadrius leschenaultii*	Migratory Shorebird	No	LC	Decreasing
15	*Charadrius mongolus*	Migratory Shorebird	No	LC	Unknown
16	*Gallinago hardwickii*	Migratory Shorebird	No	LC	Decreasing
17	*Limosa lapponica*	Migratory Shorebird	No	NT	Decreasing
18	*Limosa limosa*	Migratory Shorebird	No	NT	Decreasing
19	*Numenius madagascariensis*	Migratory Shorebird	Yes	EN	Decreasing
20	*Numenius phaeopus*	Migratory Shorebird	No	LC	Decreasing
21	*Phalaropus lobatus*	Migratory Shorebird	No	LC	Decreasing
22	*Pluvialis fulva*	Migratory Shorebird	No	LC	Decreasing
23	*Pluvialis squatarola*	Migratory Shorebird	No	LC	Decreasing
24	*Tringa brevipes*	Migratory Shorebird	No	NT	Decreasing
25	*Tringa glareola*	Migratory Shorebird	No	LC	Stable
26	*Tringa nebularia*	Migratory Shorebird	No	LC	Stable
27	*Tringa stagnatilis*	Migratory Shorebird	No	LC	Decreasing
28	*Xenus cinereus*	Migratory Shorebird	Yes	LC	Decreasing

Table A2. List of Resident Shorebird Species included in the analysis. Some species may have been excluded during the analysis due to the data inclusion criteria.

	Scientific Name	Bird Type	FFG Act 1988	IUCN Status	IUCN Trend
1	*Charadrius ruficapillus*	Resident Shorebird	No	LC	Unknown
2	*Cladorhynchus leucocephalus*	Resident Shorebird	No	LC	Stable
3	*Elseyornis melanops*	Resident Shorebird	No	LC	Increasing
4	*Erythrogonys cinctus*	Resident Shorebird	No	LC	Stable
5	*Haematopus fuliginosus*	Resident Shorebird	No	LC	Stable
6	*Haematopus longirostris*	Resident Shorebird	No	LC	Unknown
7	*Himantopus leucocephalus*	Resident Shorebird	No	LC	Increasing
8	*Recurvirostra novaehollandiae*	Resident Shorebird	No	LC	Stable
9	*Thinornis cucullatus*	Resident Shorebird	Yes	VU	Decreasing
10	*Vanellus miles*	Resident Shorebird	No	LC	Increasing
11	*Vanellus tricolor*	Resident Shorebird	No	LC	Unknown

Table A3. List of Waterbird Species included in the analysis. Some species may have been excluded during the analysis due to the data inclusion criteria.

	Scientific Name	Bird Type	FFG Act 1988	IUCN Status	IUCN Trend
1	*Anhinga novaehollandiae*	Waterbird	No	LC	Stable
2	*Anseranas semipalmata*	Waterbird	Yes	LC	Stable
3	*Antigone rubicunda*	Waterbird	Yes	LC	Decreasing
4	*Ardea alba*	Waterbird	Yes	LC	Unknown
5	*Ardea intermedia*	Waterbird	Yes	LC	Decreasing
6	*Ardea pacifica*	Waterbird	No	LC	Stable
7	*Anas castanea*	Waterbird	No	LC	Stable
8	*Anas gracilis*	Waterbird	No	LC	Decreasing
9	*Anas superciliosa*	Waterbird	No	LC	Unknown
10	*Aythya australis*	Waterbird	No	LC	Stable
11	*Biziura lobata*	Waterbird	No	LC	Decreasing
12	*Botaurus poiciloptilus*	Waterbird	Yes	EN	Decreasing
13	*Bubulcus ibis*	Waterbird	No	LC	Increasing
14	*Cereopsis novaehollandiae*	Waterbird	No	LC	Stable
15	*Chenonetta jubata*	Waterbird	No	LC	Stable
16	*Cygnus atratus*	Waterbird	No	LC	Stable
17	*Egretta garzetta*	Waterbird	Yes	LC	Increasing
18	*Egretta novaehollandiae*	Waterbird	No	LC	Unknown
19	*Fulica atra*	Waterbird	No	LC	Increasing
20	*Gallinula tenebrosa*	Waterbird	No	LC	Unknown
21	*Hypotaenidia philippensis*	Waterbird	No	LC	Stable
22	*Lewinia pectoralis*	Waterbird	No	LC	Decreasing
23	*Malacorhynchus membranaceus*	Waterbird	No	LC	Stable
24	*Microcarbo melanoleucos*	Waterbird	No	LC	Unknown
25	*Nycticorax caledonicus*	Waterbird	No	LC	Stable
26	*Oxyura australis*	Waterbird	Yes	NT	Stable
27	*Pelecanus conspicillatus*	Waterbird	No	LC	Stable

28	*Phalacrocorax carbo*	Waterbird	No	LC	Increasing
29	*Phalacrocorax fuscescens*	Waterbird	No	LC	Unknown
30	*Phalacrocorax sulcirostris*	Waterbird	No	LC	Unknown
31	*Phalacrocorax varius*	Waterbird	No	LC	Unknown
32	*Platalea flavipes*	Waterbird	No	LC	Stable
33	*Platalea regia*	Waterbird	No	LC	Stable
34	*Plegadis falcinellus*	Waterbird	No	LC	Decreasing
35	*Podiceps cristatus*	Waterbird	No	LC	Unknown
36	*Poliocephalus poliocephalus*	Waterbird	No	LC	Stable
37	*Porphyrio porphyrio*	Waterbird	No	LC	Unknown
38	*Porzana fluminea*	Waterbird	No	LC	Unknown
39	*Spatula rhynchotis*	Waterbird	No	LC	Stable
40	*Stictonetta naevosa*	Waterbird	Yes	LC	Stable
41	*Tachybaptus novaehollandiae*	Waterbird	No	LC	Increasing
42	*Tadorna tadornoides*	Waterbird	No	LC	Increasing
43	*Threskiornis moluccus*	Waterbird	No	LC	Stable
44	*Threskiornis spinicollis*	Waterbird	No	LC	Decreasing
45	*Tribonyx ventralis*	Waterbird	No	LC	Stable
46	*Zapornia pusilla*	Waterbird	No	LC	Unknown
47	*Zapornia tabuensis*	Waterbird	No	LC	Unknown