Assessment of Victoria's estuaries using the Index of Estuary Condition: Results 2021

Environment, Land, Water and Planning

Acknowledgments

We acknowledge the contribution of the following people and organisations to development and implementation of the Index of Estuary Condition: Victoria's Catchment Management Authorities, Melbourne Water, Environmental Protection Authority Victoria, EstuaryWatch volunteers, Rose Herben, Deirdre Murphy, Matt Khoury, Coastal Boards and Parks Victoria, Arthur Rylah Institute for Environmental Research, Deakin University, Jacobs Pty Ltd, Sarah McSweeney, Ventia Pty Ltd, ALS Pty Ltd and Andrew Boulton.

DELWP (2021). Assessment of Victoria's estuaries using the Index of Estuary Condition: Results 2021. The State of Victoria, Department of Environment, Land, Water and Planning, East Melbourne, Victoria.

Cover photo credit

'Mouth of the Fitzroy River estuary' By Jarred Obst, GHCMA

Aboriginal acknowledgment

The State Government proudly acknowledges the Traditional Owners of the Victorian marine and coastal environment as the traditional custodians of the land. We pay our respects to their ancestors and elders, past and present. We recognise and respect their unique cultural heritage, beliefs and relationship to their traditional lands, which continue to be important to them today. We recognise the intrinsic connection of Traditional Owners to their country and value the contribution their Caring for Country makes to the management of the land, its coastlines, its seas and its waterways. We support the need for genuine and lasting partnerships with Traditional Owners to understand their culture and connections to country in the way we plan for and manage the coast. We embrace the spirit of reconciliation, working towards equity of outcomes and ensuring an equal voice for Australia's first people.

ISBN 978-1-76105-620-8

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1. Introduction

1.1 Context for the IEC

The Victorian Waterway Management Program has well-established programs for monitoring the environmental condition of rivers and wetlands. The Index of Estuary Condition (IEC) framework was developed to complement these programs and address a lack of consistent and systematic measurement of estuarine condition in Victoria (Arundel et al. 2009). Specifically, the IEC assesses estuary condition for the purposes of:

- Reporting on estuarine condition to communities
- Guiding state policy and regional planning of estuary management
- Providing a benchmark for estuary environmental condition.

State-wide condition assessment programs provide information about the overall environmental condition of Victoria's waterways and guide state policy and regional investment programs (DELWP 2016). The current approach is to rotate these assessments among estuaries, wetlands, and rivers with each waterway type assessed approximately every decade. This monitoring frequency reflects that changes to the environmental condition of waterways are likely to be slow at the broad spatial scales assessed using relatively coarse data. However, at individual estuaries, there may be more rapid changes in response to new threats or management regimes. In the intervening periods between state-wide waterway condition assessments, management decisions will be informed by targeted monitoring of key aquatic values and threats in specific estuaries.

Photo: Pelicans at Gippsland Lakes (Sean Phillipson, EGCMA)

1.2 What are estuaries and why are they important?

Estuaries occur where fresh waters meet the sea, usually at the mouths of rivers. They are partially enclosed waterbodies that may be permanently or intermittently open to the sea and, because of the dilution of ocean water with fresh water, have salinities that vary from almost fresh to saline (Tagliapietra et al. 2009).

Estuaries are highly dynamic and complex environments. They contain diverse habitats and ecosystems, including open water, rocky reefs, intertidal sand and mudflats, mangroves, saltmarshes, and seagrass beds. Estuaries fulfil many key ecological functions such as maintaining water quality and cycling nutrients *(Figure 1)*, provide habitat for waterbirds, and are important nursery grounds for many fish species. Many estuaries are also recreationally and culturally important and are highly valued by residents and tourists alike. Traditional Owners have cultural, spiritual and economic connections to Victoria's estuaries, with connectedness to Country important for Aboriginal health and wellbeing (DELWP 2016).

DIVERSE VALUES

Estuaries are highly valued and their diverse habitats and ecological functions support recreational uses.

Organisms, nutrients, and pollutants travel between inland rivers and coastal waters via estuaries. The position of estuaries at the bottom of catchments means that their condition can be compromised by activities occurring in the upstream freshwater catchment. Extraction of river and groundwater, capture by farm and water supply dams, and flow diversion in upstream catchments all alter the timing and amount of freshwater flow that reaches estuaries (Gillanders and Kingsford 2002). Likewise, changes in land use (e.g. conversion of native forest to forestry plantations, pasture, crops, industrial or urban infrastructure) and declines in catchment condition can increase sediments, nutrients, and toxicants entering estuaries (Harris 2001). Consequently, the condition of the upstream catchment can be an important predictor of the ecological attributes of estuaries, such as the composition of the fish assemblage (Warry et al. 2018).

Most of Victoria's estuaries are brackish mouths of rivers and streams that flow directly into either the ocean or large marine bays such as Port Phillip Bay, Corner Inlet, and Western Port. Victoria's estuaries vary in size, depth, shape, and the proportion of time that they are open to the ocean (McSweeney et al. 2017). Many close intermittently due to sand-bar formation across the estuary entrance, usually during periods of low freshwater inflow. Such closures are a natural process and can be critical to the water quality and ecology of these estuaries *(see Box 2.2 on p29)*.

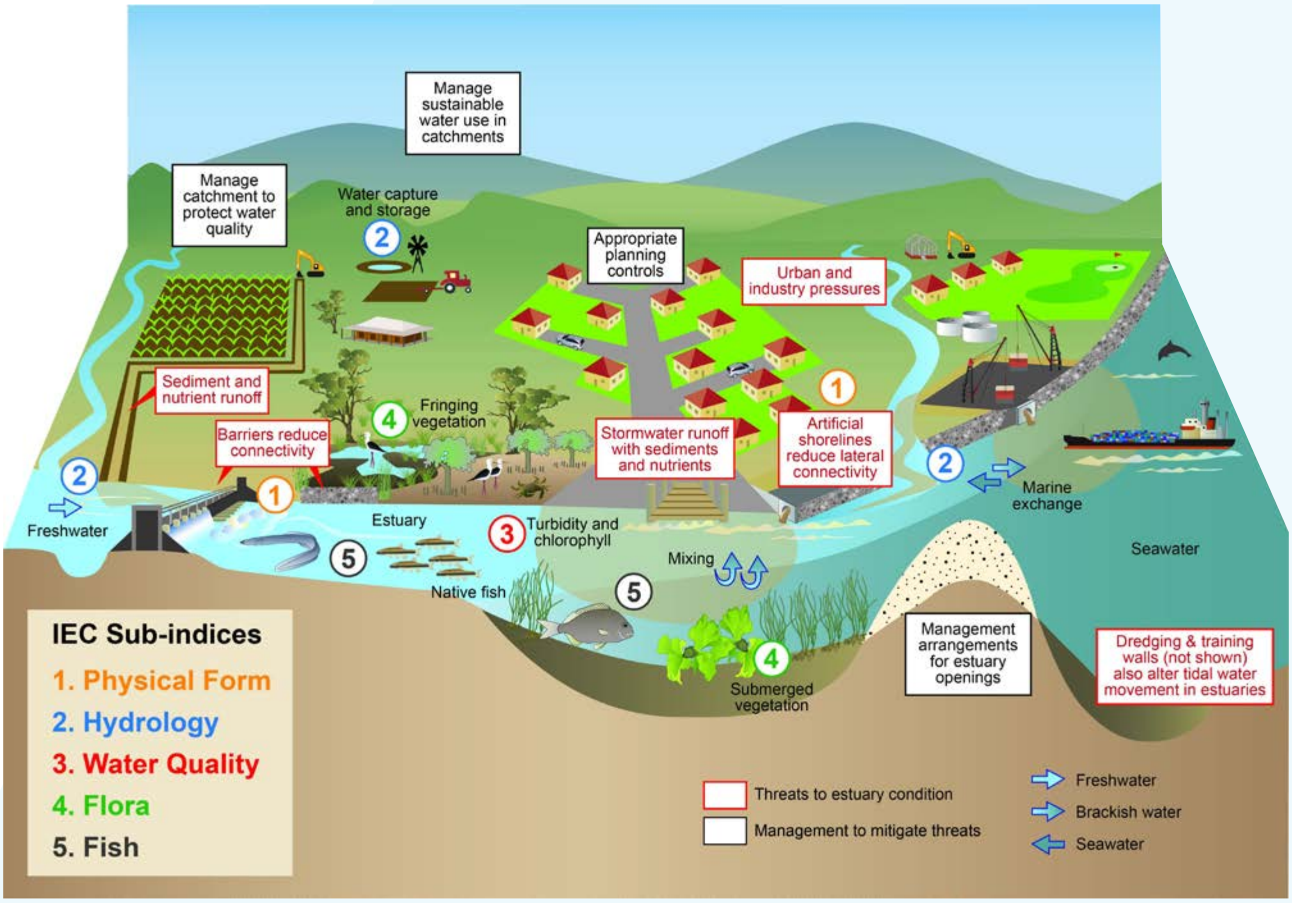


FIGURE 1

An overview of association between IEC sub-indices, with examples of common estuary threats (red boxes) and management options to mitigate threats (black boxes). The numbers within circles correspond to each of the five IEC sub-indices (as shown in the key at bottom left).

1.3 Threats to estuaries

Estuaries are exposed to a wide array of human impacts that threaten their ecological condition and their ability to provide ecosystem services such as nutrient cycling and safe fishing and swimming *(Figure 1)*. Broadly, the main threats to Victorian estuaries are changes to catchment land use (including urbanization of coastal regions, *see Box 1.1)*, altered flow regimes, and modifications to estuary mouths (Barton et al. 2008, *see Box 2.2 on p29)*. Estuaries are especially vulnerable to impacts from reduced freshwater inflows from rivers (VWMS 2013), which can reduce the frequency of mouth openings, increase the likelihood of algal blooms, and change sediment and nutrient dynamics.

The impacts of threats will vary among estuaries depending on aspects such as estuary size, depth, shape, and land use. It is also likely that many threats to estuaries will be exacerbated by climate change, due to changes to water temperature, salinity, and flow (Gillanders et al. 2012, Scanes et al. 2020). Decreases in rainfall may further compound the pressures of reduced freshwater inflows, influencing the dynamics of sediments, nutrients, and estuary mouth-opening. Sea-level rises may also lead to increasing coastal erosion and saltwater intrusion. All of these threats have impacts on estuarine water quality, plants, and animals, how estuaries function, and how humans can use them. To address these threats, we first need to better understand their effects by measuring the condition of each estuary, especially those aspects that might indicate particular impacts and threats.

Key threats to estuaries are changes to catchment land use, altered flow regimes, and modifications to their entrance opening regimes.

Photo: Hopkins River estuary (Jarred Obst, GHCMA)

BOX 1.1 LAND USE CHANGE GREATLY INFLUENCES ESTUARINE CONDITION

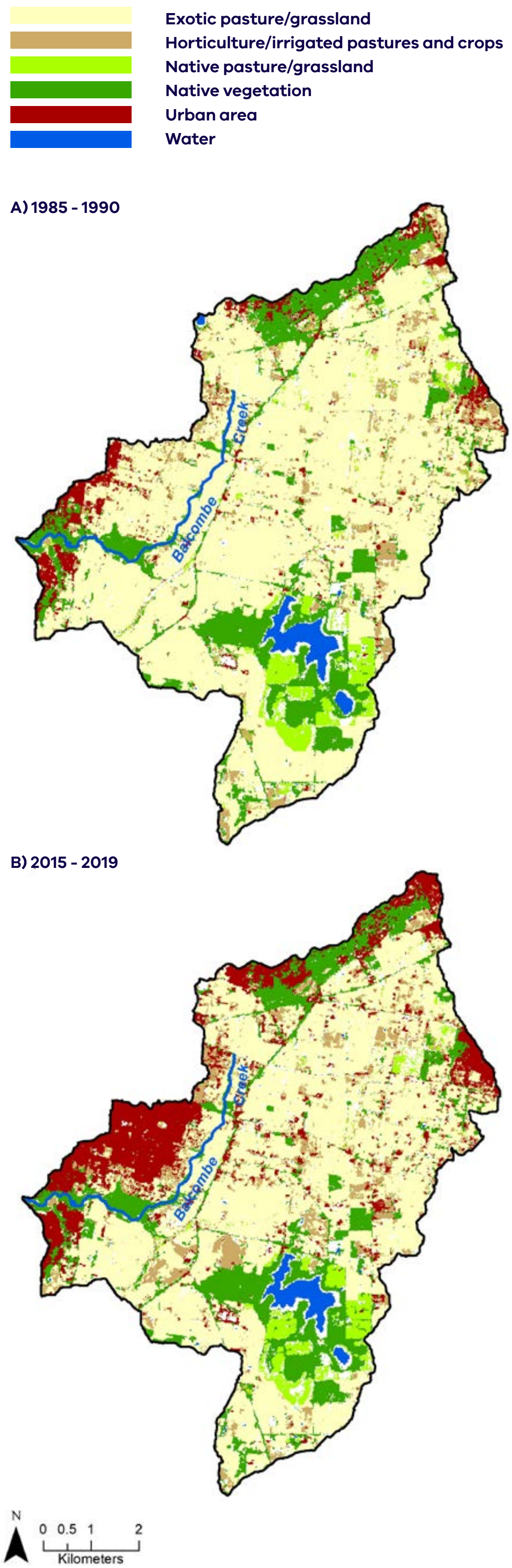
Sediments, nutrients, and organic matter (e.g. leaves) from the catchment are carried by runoff downstream to where they may influence estuarine ecological and biogeochemical processes. Changing land use, especially for intensive agriculture or urbanization, can have direct impacts on estuaries, such as loss of habitats for fish and waterbirds, as well as indirect impacts such as nutrient enrichment (causing algal blooms) and heavy metal pollution. Consequently, human activities in catchments can alter key drivers of estuarine processes and be a major influence on estuary condition.

Balcombe Creek is an estuary that opens into Port Phillip Bay on the Mornington Peninsula. It is a good example of how urbanization has intensified since the mid-1980s. Between 1985-1990 and 2015-2019, the urban footprint of the Balcombe Creek catchment nearly tripled from 4.5% to 13%. Urbanization exposes estuaries to a range of different stressors, including elevated nutrients, toxic chemical contaminants, built infrastructure, and non-native pests (O'Brien et al. 2019). Increasing the area of urbanized catchments will in turn affect the condition of estuaries.

FIGURE 1.1

Maps showing an example of land use change over a 30 year period within an estuary catchment. Major land use types within the Balcombe Creek estuary catchment and changes between 1985-90 (a) and 2015-2019 (b). Data were derived from Victoria's Land Cover Time Series, which classifies the most likely land cover class for each 25m pixel over distinct time periods. The six most dominant land use classes are shown in the Balcombe Creek catchment (https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series).

LAND COVER CLASSES



1.4 Management of estuaries

The Victorian Waterway Management Strategy (VWMS) provides the state-wide strategic direction on the management of estuaries. The management approach in the VWMS is delivered through the development and implementation of regional waterway strategies (RWSs) as a single planning document for managing the environmental condition of waterways (including estuaries). The RWSs include a strategic work program of management activities to guide investment.

The management of estuaries is also guided by the Marine and Coastal Policy 2018. The policy provides direction to decision makers including local councils and land managers on a range of issues such as dealing with the impacts of climate change, population growth and coastal structures. The Marine and Coastal Policy will be supported by the development of a Marine and Coastal Strategy. The strategy will give effect to the policy by detailing priority actions over a 5-year period and will be the key mechanism for addressing new and challenging issues.

1.5 Measuring estuary environmental condition across Victoria

1.5.1 Defining estuary condition

The Victorian Waterway Management Strategy (DEPI 2013) acknowledges that threats will influence waterway condition and values. As there is no universally accepted definition of environmental condition, "condition" is defined in the IEC as:

Environmental condition measures the extent to which environmental attributes that characterise an ecosystem in its desired state have been retained (or degraded).

This definition is consistent with relevant Victorian policies and tools including Habitat Hectares (Parkes et al. 2003), the Index of Wetland Condition (DSE 2005a) and the Index of Stream Condition (DSE 2005b). In this context, the 'desired state' may be characterised in several ways, including:

- supporting complex ecological structures and networks
- supporting maximum diversity of native species
- being free of invasive or exotic species
- having natural ecological, hydrological, and geomorphological processes that continue to operate effectively, including maintaining spatial and functional links with other systems and regions
- being relatively undisturbed by post-European human activity.

1.5.2 Selecting metrics to measure estuary condition

Estuaries are complex and dynamic ecosystems that may respond to threats in many ways. These responses usually represent changes to how an estuary functions (e.g. cycling nutrients) or reductions in an estuary's ability to provide certain benefits (e.g. supply suitable habitat for native fauna). Many of the complex environmental factors that contribute to the concept of estuarine condition cannot be feasibly measured within a broad-scale, snapshot assessment such as the IEC (see Box 1.2). Therefore, proxies for these complex factors are used in condition assessments to provide information on environmental processes and the threats thought to act on these processes (DELWP 2021). To adequately assess environmental condition, multiple metrics are used to summarise the complexity into a simpler form that is still scientifically valid (Stoddard et al. 2008).

The IEC uses two types of metrics: threat and condition. Threat metrics represent information on stressors and pressures. Stressors are physical, chemical, environmental, and biological attributes or processes that reduce estuary condition. Pressures are natural or human-caused attributes or processes that introduce or aggregate the effect(s) of stressors. An example of a threat metric is the modification of freshwater inflows to estuaries, which can influence water quality and fish fauna, which are aspects of condition.

Condition metrics represent measurable aspects (or proxies) of estuary condition, often integrating the influences of multiple threats. An example of a condition metric is pelagic chlorophyll a concentration which is influenced by threatening processes such as changes to nutrient availability and hydrology (stressors), and point and non-point source nutrient loads arising from catchment land uses (pressures).

Photo: Mallacoota Inlet
Michele Kohout, Arthur Rylah Institute

BOX 1.2 USES AND LIMITATIONS OF STATE-WIDE CONDITION ASSESSMENTS

Monitoring programs invariably involve trade-offs between the complexity of variables that are measured and the spatial and temporal resolution at which information is required. In state-wide condition assessments, it is not possible to directly assess all the complex factors that likely determine condition. Therefore, coarser proxies are used which might not be appropriate for detailed assessment of an individual estuary.

State-wide condition assessments are intended to enable broad spatial comparisons to answer the question: 'What is the relative condition of one estuary compared to the others?' However, separate sub-indices can also be interrogated to identify which specific parameters might be influencing overall condition. This can even be done in one or a few estuaries, and is a useful exercise for managers and the public interested in the estuaries in a particular region.

Although state-wide condition data can be used to help set broad management goals, these data are unlikely to be suitable for setting specific management targets and then evaluating the effectiveness of management strategies to meet such targets. Instead, target-setting and evaluation will likely require the measurement of carefully selected variables that are more directly linked to specific threats or management interventions.

Overall, when using and interpreting state-wide assessments of condition, it is important to be aware of their limitations. The IEC data are not intended for purposes beyond that stated above, particularly given that it provides information for a single snapshot in time.

Photo: Wingan Inlet (Sean Phillipson, EGCMA)

1.6 The Index of Estuary Condition

The IEC framework was developed to address a lack of consistent and systematic measurement of estuarine condition in Victoria (Arundel et al. 2009). The aim was to align estuarine assessments with the state-wide condition assessment and reporting tools used for Victorian rivers, streams, and wetlands. Full details of its background and development are presented in a companion report, *Assessment of Victoria's estuaries using the Index of Estuary Condition: Background and Methods 2021 (DELWP 2021)*. Please visit [water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/estuaries]() for more information.

The IEC was designed to assess key aspects of estuarine condition *(Figure 1)*, selected following expert workshops and interrogation of a range of candidate measures. Since its inception in 2008, the IEC has been refined as understanding of Victoria's estuaries has improved, monitoring approaches have been tested, and new approaches to estuarine condition assessment have become available.

Estuaries were included for assessment in the IEC if they are at least 1 km long or have lagoonal lengths of at least 300 m. Watercourses that run into coastal embayments (i.e. Western Port, Port Phillip Bay, Corner Inlet) and into the Gippsland Lakes were also included (DELWP 2021).

IEC SCORES

For each estuary, scores out of 10 for each sub-index (Physical Form, Hydrology, Water Quality, Flora, and Fish) were combined using an inverse weighted method (DELWP 2021) to give a best possible IEC score of 50.

1.6.1 Basic structure of the IEC

The IEC requires monitoring to be transparent, intuitive, and provide an appropriate balance among cost, rapid assessment, and scientific rigour (DELWP 2021). It is made up of five sub-indices – Physical Form, Hydrology, Water Quality, Flora, and Fish – which were selected as key aspects of the environmental condition of estuaries *(Figure 1; Box 1.3)*. The overall score for each estuary is based on individual scores for the five sub-indices. Sub-indices are made up of one or more measures that, in turn, are underpinned by one or more metrics that provide information on threats or condition (DELWP 2021). Assigning each IEC metric to represent measures of either threat or condition aids interpretation of results and conceptual understanding of observed estuary condition to guide management options.

1.6.2 Reference condition

The IEC assesses the condition of individual estuaries relative to a hypothetical reference condition, defined as what an estuary would have been expected to look like in its least disturbed or unmodified form. Using reference conditions in the IEC allows comparisons of the environmental condition of estuaries across the state. Different approaches have been used to define reference conditions for different IEC measures and the metrics within them (DELWP 2021). Choosing the best approach was informed by data availability and the strength of conceptual understanding of post-European impacts on estuaries.

1.6.3 Data sources

The IEC draws on pre-existing and new data (DELWP 2021). Some examples of pre-existing data sources that were used include maps and satellite images of estuary shorelines and barrier locations, historical and contemporary records of estuary mouth openings, and interviews with waterway managers about the location and type of engineering works at each estuary. Examples of new data include field measurements of estuarine water quality, fringing and submerged vegetation, and fish assemblages. Field data were collected by government scientists, citizen scientists (*see Box 1.4*), and consultants.

Photos: Eastern Great Egret in Aire River estuary, Great Ocean Photography via CCMA (top). Sandpipers in estuarine tributary of Gippsland Lakes, Sean Phillipson, EGCMA (second from top). EstuaryWatch citizen scientists involved in collecting water quality data for the IEC at St Georges Creek (bottom left) and Curdies Inlet (bottom right), Dierdre Murphy, Corangamite CMA.

BOX 1.3 WHY ARE SOME IMPORTANT ASPECTS OF ESTUARY CONDITION NOT INCLUDED IN THE IEC?

The five sub-indices in the IEC were selected as key aspects of the environmental condition of estuaries based on input from expert estuarine scientists. The IEC was limited to the five selected sub-indices because of the high cost and difficult logistics associated with sampling a greater number of variables in each estuary across the entire state. Furthermore, the five sub-indices were chosen to represent different aspects of condition and threat to minimise overlap and redundancy.

It is important to note that there are other potentially important characteristics of estuaries that can also be useful indicators of condition, such as sedimentation rates or the abundances and species richness of waterbirds. Characteristics such as these were investigated during a trial phase and were not included in the IEC as they weren't considered cost-effective or reliable indicators.

In the future, it may be possible to incorporate other aspects of estuary condition into the IEC.

BOX 1.4: CITIZEN SCIENTISTS PROVIDE WATER QUALITY DATA FOR THE IEC

In Victoria, EstuaryWatch groups are recognised as highly skilled volunteers who collect water quality data of a consistently high standard. The Department of Environment, Land, Water and Planning (DELWP) and Catchment Management Authorities (CMAs) partnered with EstuaryWatch citizen scientists to collect water quality data at twelve estuaries for the IEC.

Eleven of these estuaries are in the Corangamite catchment region and one (Powlett River) is in the West Gippsland catchment region. The Corangamite estuaries are Anglesea River, Barham River, Barwon River, Curdies Inlet, Erskine River, Gellibrand River, Painkalac Creek, Spring Creek, St Georges Creek, Thompson Creek, and Wye River.

BOX 1.5 A 'SNAPSHOT' NOT A TREND...

Like Victoria's other state-wide indices of condition such as the Index of Stream Condition (ISC), the IEC is not designed to assess trends (changes over time). Instead, it provides a 'snapshot' of estuarine condition across the state at the time of monitoring.

To measure trends would require comparable data collected more frequently over a long period of time (typically 10-20 years). This time period is necessary to ensure that there are sufficient data to be able to infer whether there has been an increase or decrease in condition and to be confident that the change is outside the range of natural variability expected over time. Often, such monitoring needs to be designed in ways that may be specific to a certain estuary or group of estuaries. This restricts the general applicability of indicators and/or monitoring protocols that have been used for the IEC assessment.

The current IEC assessment provides the first benchmark of condition for Victorian estuaries. This state-wide 'snapshot' will be used to inform future monitoring through time and strategic investigations at estuaries.

1.6.4 Data quality assessments

Differences in assessment approaches, sampling effort (both spatially and temporally), or data availability will influence the quality of the data, calculation of metrics, and the strength of inferences that can be drawn from the data. To communicate the potential influence of these factors, data quality rankings are provided for each metric. These rankings and their derivation are outlined in *Assessment of Victoria's estuaries using the Index of Estuary Condition: Background and Methods 2021 (DELWP 2021)*. Please visit water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/estuaries for more information.

1.6.5 Limitations of the IEC

It is important to keep the limitations of the IEC in mind when interpreting the findings presented in this report. As the IEC provides a coarse snapshot of relative estuary condition across Victoria *(see Box 1.5)*, it is not suitable for assessing fine-scale trends in specific components of estuary ecosystems. It was also not possible to directly measure all of the complex factors and responses that contribute to estuary condition (DELWP 2021), so parameters were included as proxies for these. For example, chlorophyll a was measured as a proxy for primary production (the rate of conversion of sun's energy into organic material via photosynthesis), which is more difficult to measure directly. Consequently, the IEC is not appropriate for the evaluation of management interventions or to provide detailed understanding of the complexities of how particular estuaries function or respond to particular threats. Several future avenues of work will help address some of these limitations (*see 'Next Steps' on p34*).

Although ideal as a snapshot of state-wide estuarine condition, the IEC is not intended for monitoring changes through time or attributing causes for change.

Photo: Shifting sands at the mouth of Wingan River estuary (Sean Phillipson, EGCMA)

1.6.5 Limitations of the IEC (continued)

Another limitation is the number of estuary components that could be covered in the IEC. The five sub-indices were chosen to cover most of the main aspects of estuary condition *(Figure 1)* but there were other potentially important aspects that could not be included *(see Box 1.3 on p13)*. One example is sedimentation rates, which can be a useful indicator of the condition of estuaries (Hallett et al. 2019) but can be highly variable through time and thus challenging to measure accurately. Waterbirds are another good example of a notable and measurable aspect of estuary condition, because many bird species use estuaries. However, waterbirds are highly mobile and sometimes cryptic, so their observed presence or absence at the time of surveys is not reliably reflective of estuary condition. Both sediment and waterbirds were investigated as possible indicators during a trial phase of developing useful IEC metrics but ultimately were not deemed to be reliable indicators or cost effective and other options were chosen in preference.

Photo: Gippsland Lakes estuary (Sean Phillipson, EGCMA)

Furthermore, there are other metrics that may be relevant components of the sub-indices but were not used. For instance, pH (a measure of the acidity or alkalinity of water in an estuary) was not included in the Water Quality sub-index because it can naturally vary widely in poorly buffered estuaries. However, some estuaries (e.g. Anglesea River) may periodically receive inflows of acidic water that impact estuarine values.

The five sub-indices and metrics within them included in the IEC will differ in terms of how much they vary through time. For instance, changes to the artificial barriers and artificial shorelines measures in the Physical Form sub-index will not occur without significant modifications to estuaries, such as the construction of new barriers or training walls. If such changes do not occur, these measures will remain consistent through time. In contrast, water quality and fish assemblages are likely to vary over both short (e.g. throughout the tidal cycle, daily) and long (e.g. seasonal, annual) time-frames. Given the IEC is a one-off snapshot, it is important to consider that there may be greater uncertainty associated with the results for sub-indices and metrics (especially Fish and Water Quality) that are more inherently variable.

The IEC Methods Report (DELWP 2021) is a companion document to this report and contains details of other limitations and caveats associated with the five sub-indices and their associated measures. These are summarised below:

- Metrics in the artificial shorelines and artificial barriers measures of the Physical Form sub-index are proxies for the modification of physical form in estuaries. However, lateral and longitudinal connectivity will also be influenced by other factors such as hydrology, bathymetry, and geomorphology which were not included but may be relevant. Ultimately, the ecological effects of modified physical form will also depend on the magnitude, type, and duration of any changes as well as the sensitivity of biota and ecosystem processes to these changes.
- The percent artificial opening metric of the Hydrology sub-index does not adequately differentiate between illegal and authorised openings. The metric therefore does not account for the risk associated with illegal estuary openings and the subsequent impacts on condition *(see Box 2.2 on p29)*. Furthermore, this metric doesn't take into account when an artificial estuary opening occurred, so the score reflects both recent and historic openings equally, even though contemporary management of the opening regime may have changed.
- The freshwater inflows measure in the Hydrology sub-index has three caveats associated with it. First, this measure uses total catchment storage volumes as a proxy for water usage or interception, and does not account for all sources of water extraction (e.g. direct pumping for irrigation, stock, and domestic use, groundwater extraction). Second, the Bureau of Meteorology's Australian Water Resource Assessment Landscape model was used to derive runoff estimates in a consistent way for each estuary but has several limitations (e.g. it does not consider changed runoff in urban areas, runoff estimates are less reliable for smaller catchments (Frost and Wright 2018)). Third, this measure omits positive metrics of water recovery during the delivery of environmental water. The measure does not recognise that environmental water entitlements are often managed to deliver positive estuarine outcomes.
- Water quality sampling in this IEC assessment did not capture the full range of water quality conditions in each estuary. For example, to capture 'baseline' Water Quality, sampling was not undertaken directly after high-flow events which means some estuaries that scored highly may experience episodic Water Quality issues that were not detected. Furthermore, Water Quality data were collected across different years, and effects of interannual and climatic variability (particularly rainfall and temperature) have not been examined at this stage. Finally, the IEC uses an approach that sets the observed turbidity and chlorophyll a values in the context of the SEPP Waters (SEPP Waters 2018) objectives for riverine estuaries which are intended to protect the beneficial uses of Victoria's estuaries. The IEC is not intended to assess compliance against the SEPP Waters obligations.
- Fringing vegetation was measured using visual estimates of cover, which is appropriate for state-wide comparison. However, different methods are needed to monitor more subtle changes within each estuary. As fifteen estuaries had no obvious edge to their fringing vegetation, an arbitrary buffer width was used to define the extent of their fringe, scaled according to stream flow. At fifteen other estuaries, there was no detectable seagrass or macroalgae. For those estuaries, it was not possible to assign a score for submerged vegetation and the fringing vegetation score was the sole contributor to the Flora sub-index score. In these instances, the Flora score should be interpreted with some caution, noting that submerged vegetation may have been present in these estuaries but not detected due to sampling conditions or the methodology used. Seagrass and macroalgae are also inherently dynamic and their extent can change dramatically from year to year.
- The Fish sub-index involved metrics based on the presence, richness, and relative abundance of fish groups (guilds) that represent their estuary use, habitat associations, and feeding behaviour. These metrics did not always align with the relative abundance of recreationally important fish species *(see Box 1.6 on p18)*. This means that some estuaries that scored poorly may still support rich fisheries. The Fish sub-index is useful for benchmarking estuarine ecological condition at the state-wide scale but resembles other fish-based multi-metric indices that cannot detect the mechanisms that lead to good or poor condition (Harrison and Whitfield 2006).

1.7 Purpose and structure of this report

The purpose of this report is to communicate the results of the first state-wide assessment of the condition of Victorian estuaries using IEC methods to the general public, natural resource managers, policy-makers, and other interested readers.

An overall summary of the condition of estuaries across Victoria is provided in Chapter 2 (p20), with an overview of next steps from the state-wide IEC assessments in Chapter 3 (p34). Following this, more specific information about individual estuaries within different regions is presented:

- Glenelg Hopkins (Chapter 4, p36)
- Corangamite (Chapter 5, p42)
- Port Phillip & Western Port (Chapter 6, p48)
- West Gippsland (Chapter 7, p54)
- East Gippsland (Chapter 8, p62)

IEC data sets are available on request for download from www.data.vic.gov.au. For details on the technical background and methods underpinning the IEC, see *Assessment of Victoria's estuaries using the Index of Estuary Condition: Background and Methods 2021 (DELWP 2021).* Please visit *water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/estuaries* for more information.

Photo: Fishing on the Maribyrnong River estuary (Trish Grant, Melbourne Water)

BOX 1.6: WHY MIGHT THE IEC FISH SUB-INDEX RESULTS NOT MATCH EXPECTATIONS BASED ON RECREATIONAL FISHING EXPERIENCES?

You might expect that if an estuary scores highly for the IEC Fish sub-index, it would be equally highly valued for recreational fishing. However, this might not occur for several reasons. The first is that the sub-index does not target only recreational species. Instead, it provides an overview of the diversity of various groups of species (e.g. trophic groups, habitat associations, occupancy patterns). These groups include many species not typically sought by fishers.

Second, estuary fish assemblages are very dynamic in both space and time – as all anglers know. The IEC provides only a snapshot of the types of species detected within an estuary at a given point in time. It relies on once-off sampling which may miss the times when particular recreational species are at peak abundances. Further, the sampling methods differ from those used to catch fish by recreational fishers.

Therefore, a relatively low IEC Fish sub-index score does not mean that healthy populations of recreationally valued species such as Black Bream, Whiting, or Flathead are missing from an estuary. Nor should an estuary with a high score necessarily be the place for your next fishing trip!

Photo: Kayaker meeting swans in Mallacoota Inlet (Sean Phillipson, EGCMA)

2. Results from the first state-wide IEC

2.1 State-wide overview of estuary condition

During the 2021 IEC benchmark, 101 estuaries in Victoria were assessed and classified into five condition classes *(Table 1, see Box 2.1 on p22)*. Thirteen percent were in excellent condition, 26% in good condition, 32% in moderate condition, 25% in poor condition, and 5% in very poor condition *(Figure 2, Figure 3)*. However, it is important to highlight that these condition classes are very broad and have some uncertainty. Therefore, some estuaries in different condition classes may share similar characteristics.

Estuaries in excellent condition were in the east of the state within the West and East Gippsland catchment regions. Seven estuaries in the East Gippsland catchment region and six in the West Gippsland catchment region were in excellent condition. This corresponds to 27% of estuaries assessed in East Gippsland and 21% of those assessed in West Gippsland. There were no estuaries in excellent condition in the Glenelg Hopkins, Corangamite, or Port Phillip and Western Port catchment regions.

There were estuaries in poor, moderate and good condition throughout the state. These three classes were the most common, comprising over three-quarters of the estuaries assessed.

Five estuaries in very poor condition were close to Melbourne in the Port Phillip and Western Port catchment region. This corresponds to 24% of estuaries assessed in this region. No other region had estuaries in very poor condition.

Photo: WIngan Inlet (DELWP) and Elwood Canal (David Reid, DELWP), as representative examples of estuaries having excellent and very poor environment condition, as determined using IEC, respectively.

BOX 2.1: WHAT DOES AN ESTUARY IN EXCELLENT VERSUS POOR CONDITION LOOK LIKE?

Estuaries in **excellent** condition are not threatened by modified physical form or hydrology. Freshwater inflows to the estuary are not intercepted by water storages or farm dams in the catchment, and the estuary's connection to the marine environment is unmodified. Water quality supports estuarine environmental values with no indication of excess sediments or nutrients in the water column (i.e. water is clear and there is no excess primary production which can cause problems for estuary food webs). Fringing vegetation is intact with no impacts from built structures or weed incursions. Submerged vegetation is dominated by seagrasses which provide shelter for animals, support food webs, and stabilise sediments. Fish assemblages are diverse, indicating that reproduction, feeding, and migration of fish species is supported by the estuary. No introduced fish species are present.

Estuaries in **poor** or **very poor** condition usually have their physical form and hydrology modified. Artificial instream barriers may limit the estuary's inland extent and prevent migratory species from moving between freshwater and estuarine environments. Artificial shorelines may also impact some of the estuary. Much of freshwater entering the estuary may be intercepted by water storages or farm dams. Connectivity with the marine environment is often altered by engineering of the entrance (e.g. dredging) or artificial estuary mouth openings. High concentrations of suspended sediments make the water turbid while excess nutrients in the water column cause algal blooms. Fringing vegetation has been impacted by built structures and weed incursions, and submerged vegetation is dominated by nuisance macroalgae. Fish assemblages typically have few species, including several introduced ones.

The condition of each estuary was classified from 'excellent' to 'very poor'.

Photo: Bridled goby in Gippsland Lakes (Sean Phillipson, EGCMA)

FIGURE 2

Distribution of the different estuarine condition classes for the 101 estuaries statewide and for the five different catchment regions; table shows the ranges of IEC scores corresponding to the five condition classes; the IEC score ranges from 5 to 50.

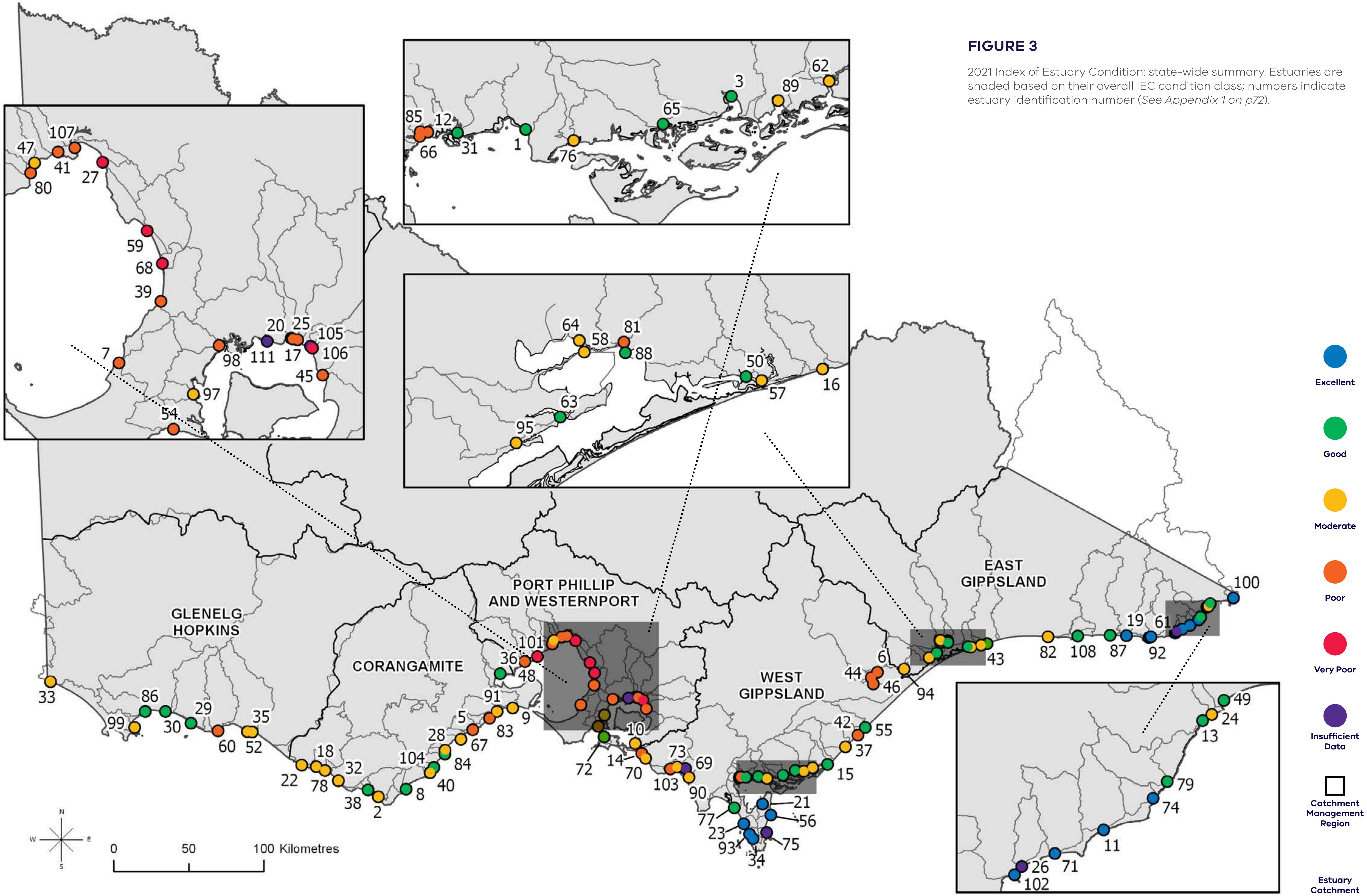


FIGURE 3

2021 Index of Estuary Condition: state-wide summary. Estuaries are shaded based on their overall IEC condition class; numbers indicate estuary identification number (*See Appendix 1 on p72*).

Photo: Shipwreck Creek estuary (Sean Phillipson, EGCMA)

Table 1 : Percentage of estuaries in each IEC condition class in each catchment region

	Excellent	Good	Moderate	Poor	Very poor
Glenelg Hopkins (8)	0	37.5	37.5	25	0
Corangamite (17)	0	29	59	12	0
Port Phillip & Western Port (21)	0	5	19	52	24
West Gippsland (29)	21	24	24	31	0
East Gippsland (26)	27	38	31	4	0
Overall (101)	13	25	32	25	5

Percentage of estuaries in each condition class in five catchment regions and the 101 estuaries across Victoria where sufficient sub-indices were sampled to calculate an overall score. Numbers in parentheses indicate the number of estuaries assessed in each catchment region.

2.2 State-wide Physical Form

The Physical Form sub-index reflects the extent of artificial instream barriers and modified shorelines. These modifications are most common in estuaries with dense urbanization, intensive industry, and ports and docks (e.g. around Melbourne and Geelong). They also occur where upstream runoff is diverted for agriculture and where channels and banks have been modified during drainage schemes.

Most estuaries in the state had unmodified (36%) or near unmodified (34%) Physical Form *(Table 2)*. Physical Form was moderately, considerably, or extremely modified at 25%, 3%, and 2% of estuaries, respectively.

Artificial instream barriers were identified at 31 Victorian estuaries. Four of these were considered complete barriers and 27 were partial barriers to the movement of water and aquatic animals such as fish and prawns. Artificial barriers included weirs, rock barriers, culverts and sand slugs.

In some cases, the percentage of artificial shorelines exceeded 80%, such as along Patterson River and Elwood Canal, which are constructed estuaries. Other estuaries with substantial percentages of artificial shorelines included some in the Port Phillip and Western Port catchment region (e.g. Laverton Creek, Yarra River, Bunyip River), western tributaries to Corner Inlet (i.e. Stockyard Creek and Bennison Creek) and the Anglesea River estuary. Artificial shorelines can reduce lateral connectivity, alter hydrodynamics and estuary geomorphology, and reduce the capacity of the estuary to migrate (e.g. under scenarios of rises in sea level due to climate change). All these changes have repercussions for estuarine plants, animals, and ecological processes.

Most estuaries (70%) had unmodified or near unmodified Physical Form.

As both artificial barriers and artificial shorelines influence the Physical Form of an estuary, estuaries experiencing different threats to Physical Form may achieve similar scores for the IEC Physical Form sub-index. For example, an estuary with a highly modified shoreline but few instream barriers would get a similar score for the Physical Form sub-index as an estuary with a slightly modified shoreline but many instream barriers.

Table 2 : Percentage of estuaries in each Physical Form condition class in each catchment region

	Unmodified (10)	Near unmodified (8-9)	Moderately modified (6-7)	Considerably modified (4-5)	Extremely modified (1-3)
Glenelg Hopkins (8)	37.5	25	37.5	0	0
Corangamite (17)	24	41	29	6	0
Port Phillip & Western Port (21)	14	24	43	9.5	9.5
West Gippsland (29)	34.5	41.5	24	0	0
East Gippsland (26)	57.5	38.5	4	0	0
Overall (106)	36	34	25	3	2

Percentage of estuaries in each Physical Form condition class in five catchment regions and all estuaries across Victoria where Physical Form was sampled. Numbers in parentheses next to catchment region names indicate the number of estuaries assessed; note that 106 estuaries were sampled for Physical Form but not all had data from sufficient sub-indices to receive an overall IEC score. Numbers in parentheses under the condition classes indicate the range of scores in that condition class.

2.3 State-wide Hydrology

The Hydrology sub-index of the IEC integrates information on the extent of modifications to marine exchange and freshwater inflows to estuaries. The modification of hydrological exchange between estuaries and the marine environment can influence estuarine floodplain inundation regimes, water quality, physical processes, and geomorphology, with flow-on effects for estuarine plants, animals, and ecological processes. Modification of freshwater inflows to estuaries can affect floodplain inundation regimes, delivery of sediments and nutrients to estuaries, water quality, spawning and migration cues for fauna such as fish, and connectivity to the marine environment.

The Hydrology of estuaries varied across the state *(Table 3)*. Most estuaries had Hydrology that was extremely modified (23%), considerably modified (22%), or moderately modified (24%). Hydrology was unmodified or near unmodified at 13% and 18% of estuaries, respectively.

In the Port Phillip and Western Port catchment region, the Hydrology of several estuaries was extremely modified by substantial interception of runoff as well as engineering works at the entrance such as dredging (e.g. Yarra River, Mordialloc Creek). Some estuaries with extremely modified Hydrology had catchments with substantial water storages intercepting runoff and also had their entrances artificially opened (e.g. Snowy River, Glenelg River, *see Box 2.2)*. Other estuaries had catchments where farm dams dominated interception of catchment runoff as well as being subject to artificial entrance opening, resulting in extremely modified Hydrology (e.g. estuaries of the Bass Coast: Bourne Creek, Powlett River, Wreck Creek).

As the Hydrology sub-index integrates modifications to hydrology from interception of runoff within the catchment and altered marine exchange, estuaries experiencing different hydrological threats may be assigned similar scores. For instance, an estuary with highly modified marine exchange through artificial opening of the estuary mouth (*see Box 2.2)* but minimal modification of freshwater flows could receive a similar score to an estuary with no modification of marine exchange but substantial modification of freshwater inflows intercepted by dams in the catchment.

Environmental water is used to mitigate the impacts of hydrological modification in several coastal catchments (e.g. the Glenelg River, *Box 4.1 on p44)*. The Hydrology sub-index used for the IEC does not capture information on environmental water delivery for estuary objectives (*Section 1.6.5 on p16*).

Table 3: Percentage of estuaries in each Hydrology condition class in each catchment region

	Unmodified (10)	Near unmodified (8-9)	Moderately modified (6-7)	Considerably modified (4-5)	Extremely modified (1-3)
Glenelg Hopkins (8)	0	12.5	37.5	12.5	37.5
Corangamite (17)	6	29	24	41	0
Port Phillip & Western Port (21)	0	0	24	28.5	47.5
West Gippsland (29)	17	31	31	0	21
East Gippsland (26)	23	15.5	15.5	27	19
Overall (105)	13	18	24	22	23

Percentage of estuaries in each Hydrology condition class in five catchment regions and all estuaries across Victoria where Hydrology was sampled. Numbers in parentheses next to catchment region names indicate the number of estuaries assessed; note that 105 estuaries were sampled for Hydrology but not all had data from sufficient sub-indices to receive an overall IEC score. Numbers in parentheses under the condition classes indicate the range of scores in that condition class.

BOX 2.2: HOW DOES ARTIFICIAL OPENING OF ESTUARY ENTRANCES AFFECT ESTUARINE CONDITION?

The entrances of many estuaries close naturally, usually when freshwater inflows become too small to counter the effects of bar formation via sediment redistribution by oceanic currents. When estuaries close, estuarine water levels rise and inundate low-lying shores and flats. This inundation is a natural process and plays important roles in the cycling of nutrients, deposition of sediments, and life cycles of many species. Periodic inundation of adjacent wetlands and fringing vegetation is also necessary to maintain their health.

Reduced freshwater inflows occur during extended periods of reduced rainfall and as a result of interception of surface water by dams in the catchment. Climate change is also predicted to continue to reduce flows across much of Victoria. These flow reductions could mean fewer flushing flows that open estuary entrances and may lead to longer periods of estuary closure. High water levels and prolonged inundation can have social and economic impacts through flooding of adjacent agricultural or residential land, roads, and structures such as jetties and boat ramps. To minimise social and economic costs associated with estuarine flooding of built assets, entrances are sometimes artificially opened to allow the excess water to flow out to sea.

However, there are potential environmental impacts associated with artificially opening an estuary if conducted under certain conditions. These impacts can include changes to natural patterns of variation in water quality, adverse effects on plants and animals (e.g. fish deaths), and disruption of animal migration and reproductive cycles.

A history of unpermitted estuary entrance openings and community concern about the lack of clear and consistent guidelines led the Victorian Government to develop the Estuary Entrance Management Support System. This provides managers with a powerful tool for assessing impacts of opening entrances on the environmental, social, and economic values of an estuary and properly accounting for the likely risks involved with decisions regarding whether to artificially open an estuary or not.

Only 31% of the state's estuaries had unmodified or near unmodified Hydrology whereas 45% had extremely or considerably modified Hydrology.

Photo: Artificial estuary opening using an excavator (Sarah McSweeney, University of Melbourne)

2.4 State-wide Water Quality

The Water Quality sub-index was based on two metrics: turbidity (a signal of sediment inputs from the catchment), and chlorophyll **a** concentration (a proxy for primary productivity in the water column and a signal of nutrient pollution). Elevated sediments and nutrients in the water column of estuaries can alter the production of benthic plants (e.g. seagrasses and macroalgae) and disrupt food webs with flow-on effects for estuarine fauna.

> Water Quality was good or excellent in 54% of the state's estuaries. It was poor or very poor in 25% of them, usually estuaries with catchments that were predominantly urban or agricultural.

The Water Quality of estuaries varied across the state *(see Table 4)*. A quarter of the state's estuaries had poor or very poor Water Quality. Water Quality was moderate, good, or excellent at 21%, 26%, and 28% of estuaries respectively.

Estuaries with very poor or poor Water Quality were characterised by elevated chlorophyll a and turbidity indicating a combination of nutrient enrichment and sedimentation from the catchment. Estuaries with very poor or poor Water Quality included those with catchments dominated by urban, agricultural, or both land uses *(see Box 2.3)*. Estuaries with very poor or poor Water Quality whose catchments are dominated by urban land uses include Kororoit Creek and Elwood Canal. Those with catchments dominated by agricultural land uses include tributaries to Lake Wellington (i.e. Avon River, Lake Wellington Main Drain) and western tributaries to Corner Inlet (i.e. Bennison Creek, Stockyard Creek, Old Hat Creek). Estuaries with catchments dominated by urban and agricultural land uses include Watsons Creek, Werribee River, and Merri River.

Table 4 : Percentage of estuaries in each Water Quality condition class in each catchment region

	Excellent (10)	Good (8-9)	Moderate (6-7)	Poor (4-5)	Very poor (1-3)
Glenelg Hopkins (8)	37.5	50	0	12.5	0
Corangamite (17)	35	41	18	6	0
Port Phillip & Western Port (20)	10	20	25	10	35
West Gippsland (25)	20	20	24	8	28
East Gippsland (22)	45.5	18	23	4.5	9
Overall (92)	28	26	21	8	17

Percentage of estuaries in each Water Quality condition class in five catchment regions and all estuaries across Victoria where Hydrology was sampled. Numbers in parentheses next to catchment region names indicate the number of estuaries assessed; note that 92 estuaries were sampled for Water Quality but not all had data from sufficient sub-indices to receive an overall IEC score. Numbers in parentheses under the condition classes indicate the range of scores in that condition class.

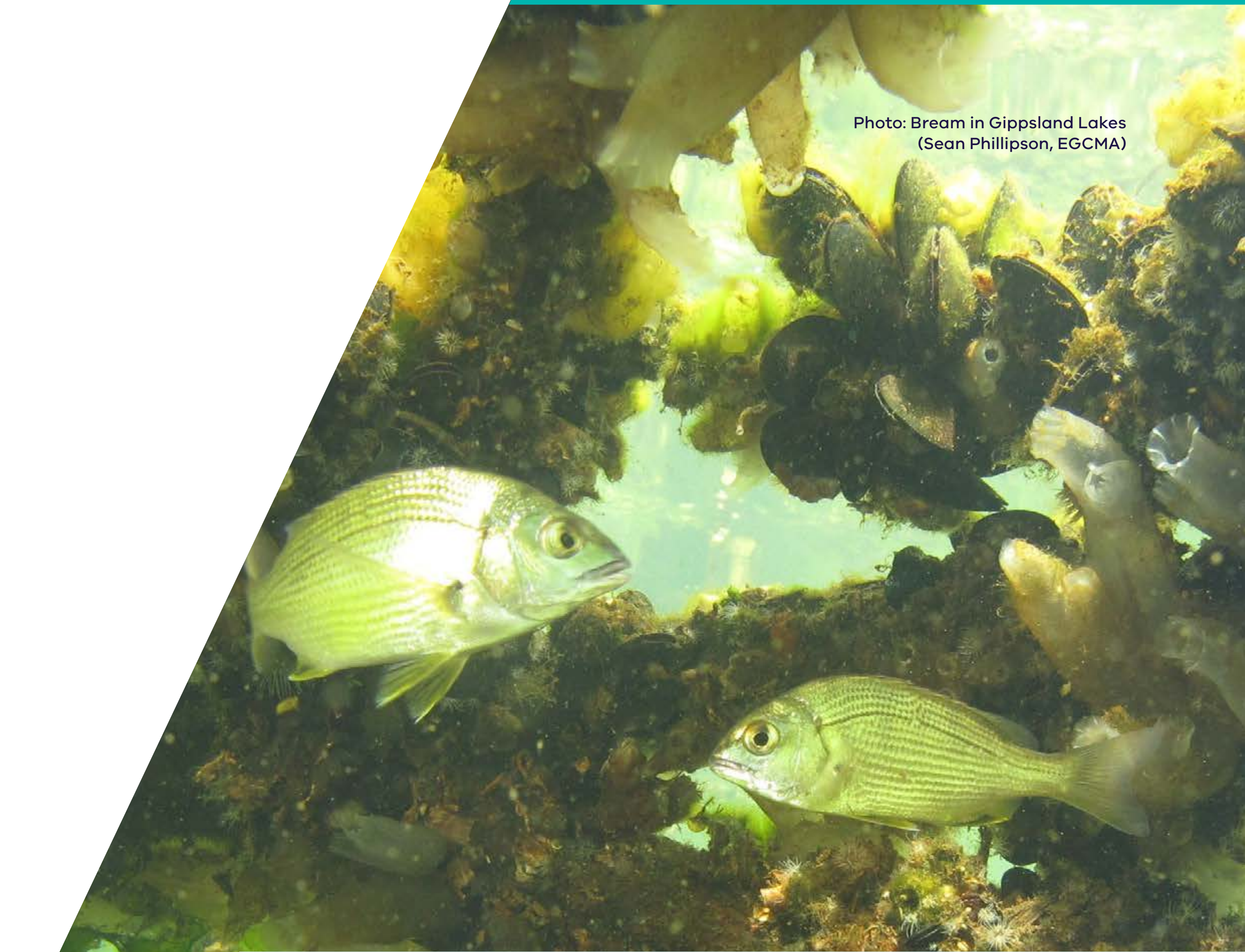


Photo: Bream in Gippsland Lakes (Sean Phillipson, EGCMA)

BOX 2.3: CATCHMENT LAND USE IS OFTEN REFLECTED IN SCORES FOR THE WATER QUALITY SUB-INDEX

As estuaries are ultimately 'sinks' for their catchments, their water quality reflects their catchment land use, although in some estuaries this can be somewhat offset by tidal flushing. The effects of land use on Water Quality are especially evident for land uses that may generate excessive sediments (leading to high turbidity) or nutrients (elevating chlorophyll a concentrations in response to enhanced primary productivity in the water column). Estuaries downstream of minimally developed forested catchments (often within National or State Parks or public reserves) typically have excellent Water Quality with low turbidity and chlorophyll a whereas estuaries downstream of agricultural and urban catchments typically have very poor Water Quality with high turbidity and chlorophyll a. In such estuaries downstream of catchments with more intensive land uses, the poor Water Quality has severe impacts on submerged plants such as seagrasses. Loss of these plants changes the habitat available for estuarine fauna, disrupts food webs, and may cause further water quality problems such as low dissolved oxygen.

2.5 State-wide Flora

The condition of estuarine flora is threatened by anthropogenic land use, hydrological modifications, and invasions by exotic plants. The Flora sub-index of the IEC consists of two measures: fringing vegetation and submerged vegetation. Fringing vegetation includes intertidal and riparian plants that provide important habitat for estuarine fauna such as fish and waterbirds, and its condition can influence the condition of the rest of the estuary (e.g. by filtering overland flows of water, chemicals, and organisms that come from the surrounding catchment). It also has important aesthetic values. Submerged vegetation, such as seagrass, also provides habitat for estuarine fauna, and promotes crucial ecological processes such as nutrient processing and organic matter breakdown.

Seventeen percent of the state's estuaries had Flora in excellent condition *(see Table 5)*. Flora was in good, moderate, or poor condition at 33%, 39%, and 11% of estuaries, respectively. No estuaries were assessed as having Flora in very poor condition.

The estuaries with Flora in poor condition had estuarine floodplains dominated by agriculture (e.g. Curdies Inlet, Tarwin River, Neils Creek, Mitchell River) and, to a lesser extent, urbanization (e.g. Mordialloc Creek).

Half of the state's estuaries had Flora in excellent or good condition, and only 11% had Flora in poor condition. No estuaries had Flora in very poor condition.

The condition of Flora was moderate or better at 89% of Victoria's estuaries. Estuaries with Flora in excellent condition were predominantly those within parks and reserves. Estuaries with Flora in good condition included some estuaries adjacent to coastal towns (e.g. Painkalac Creek, Spring Creek, Thompson Creek).

As two measures are used to assess Flora for the IEC (in most cases), estuaries with different components of the Flora in different condition may achieve similar scores for the Flora sub-index. For instance, an estuary with largely intact fringing vegetation but submerged vegetation lacking seagrass and dominated by macroalgae will receive a similar score to an estuary with fringing vegetation that is adversely affected by built structures and weeds but with submerged vegetation dominated by seagrass.

Table 5: Percentage of estuaries in each Flora condition class in each catchment region

	Excellent (10)	Good (8-9)	Moderate (6-7)	Poor (4-5)	Very poor (1-3)
Glenelg Hopkins (8)	0	12.5	75	12.5	0
Corangamite (17)	0	35	53	12	0
Port Phillip & Western Port (17)	12	35	41	12	0
West Gippsland (29)	31	21	38	10	0
East Gippsland (25)	24	48	16	12	0
Overall (100)	17	33	39	11	0

Percentage of estuaries in each Flora condition class in five catchment regions and all estuaries across Victoria where Flora was sampled. Numbers in parentheses next to catchment region names indicate the number of estuaries assessed; note that 100 estuaries were sampled for Flora but not all had data from sufficient sub-indices to receive an overall IEC score. Numbers in parentheses under the condition classes indicate the range of scores in that condition class.

2.6 State-wide Fish

Fish assemblage composition was included in the IEC because different fish and their life stages occupy many different groups (e.g. herbivores, piscivores, planktivores) in estuarine food webs and thereby need a diversity of intact ecosystem processes to survive, grow, and reproduce (Deegan et al. 1997). These different groups of fish will respond to physical, chemical, and ecological disturbances prompted by major threats to estuaries, including changes to catchment land use, estuary form (e.g. depth, shorelines), and hydrology. Healthy estuarine fish assemblages include species with different trophic ecology (herbivores to piscivores), habitat associations (e.g. on the bottom (benthic), near it (demersal), or in the open water (pelagic)) and occupancy patterns (e.g. opportunistic or resident; Elliott et al., 2007) *(see Box 2.4 on p34)*. Therefore, there are multiple pathways for human disturbances to influence the composition of fish assemblages (Deegan et al., 1997). The following variables were used as metrics in the IEC Fish sub-index (for further details see DELWP 2021):

- Richness of species that can complete their life-cycle within estuaries
- Presence or absence of introduced species
- Richness of demersal species
- Relative abundance of demersal species
- Richness of trophic specialists
- Relative abundance of trophic specialists
- Richness of diadromous species.

The condition of fish assemblage composition was excellent or good at 13.5% and 34% of the state's estuaries, respectively (*Table 6*). Fish assemblages were in moderate or poor condition at 28% and 20% of estuaries, respectively. Only three percent of estuaries were assessed as having Fish assemblages in very poor condition. As estuary fish assemblages vary considerably through time, it is important to highlight that the IEC only provides a snapshot of estuarine fish assemblage composition at the time of monitoring. This is partly why some estuaries that support rich fisheries had low scores for this index (*see Section 1.6.5 on p16*).

Fish assemblage composition was in excellent or good condition in 48% of the state's estuaries. Only 3% had Fish assemblages in very poor condition.

Table 6: Percentage of estuaries in each Fish condition class in each catchment region

	Excellent (9-10)	Good (7-8)	Moderate (5-6)	Poor (3-4)	Very poor (1-2)
Glenelg Hopkins (7)	0	29	57	14	0
Corangamite (14)	7	36	29	21	7
Port Phillip & Western Port (20)	5	15	35	35	10
West Gippsland (24)	12.5	41.5	21	25	0
East Gippsland (22)	32	45	23	0	0
Overall (88)	13.5	34	28.5	20.5	3.5

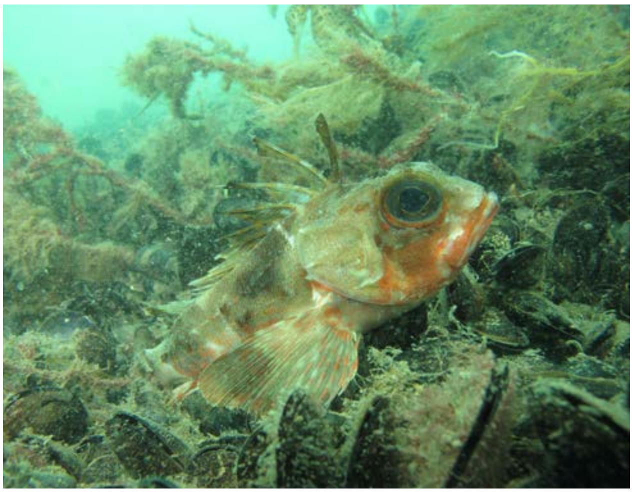
Percentage of estuaries in each Fish condition class in five catchment regions and all estuaries across Victoria where Fish were sampled. Numbers in parentheses next to catchment region names indicate the number of estuaries assessed; note that 88 estuaries were sampled for Fish but not all had data from sufficient sub-indices to receive an overall IEC score. Numbers in parentheses under the condition classes indicate the range of scores in that condition class.

BOX 2.4: WHAT DOES A HEALTHY ESTUARY FISH ASSEMBLAGE LOOK LIKE?

A healthy estuarine Fish assemblage is considered to have:

- Plenty of **species that can complete their lifecycles within estuaries** – an estuary in good condition should support a high richness of species that rely on a suite of ecological functions that are provided in intact estuaries to complete their life cycles. Examples of such species include Black Bream (*Acanthopagrus butcheri*) and Estuary Perch (*Percalates colonorum*).
- Plenty of **species that live in the bottom portion of the water column** – an estuary in good condition should support a high richness of demersal species which indicates that habitat (e.g. seagrass) and food is available for these species and that water quality, particularly dissolved oxygen, in the bottom water is suitable. Some examples include Yellow-eye Mullet (*Aldrichetta fosteri*) and King George Whiting (*Sillaginodes punctatus*).
- Plenty of **specialist feeders** – diverse intact habitats and trophic pathways are needed to support a high richness of specialist feeders. Human impacts reduce the availability of niches for trophic specialists such as Dusky Flathead (*Platycephalus fuscus*).
- Some **species that migrate between fresh and marine waters** – the presence of these species indicates that the connectivity between freshwater, estuarine, and marine habitats is suitable for them to survive. Examples include Common Galaxias (*Galaxias maculatus*) and Spotted Galaxias (*Galaxias truttaceus*).
- **No introduced species** – the presence of introduced species represents a direct measure of anthropogenic modification. Introduced species are often invasive and may displace native fish and other fauna. Some examples include Yellowfin Goby (*Acanthogobius flavimanus*) and Eastern Gambusia (*Gambusia holbrooki*).

For these reasons, the Fish sub-index in the IEC included metrics that assessed these features in the state-wide snapshot of estuarine condition. It is important to note though that a wider range of species, such as those that live predominantly in coastal marine environments but occasionally venture into connected estuaries, were also recorded but not included in scoring. Full lists of the fish species recorded at each estuary can be downloaded from data.vic.gov.au.



Gurnard Perch in Gippsland Lakes estuary (Sean Phillipson, EGCMA)

Burnt landscape in lower Benedore River estuary catchment (Sean Phillipson, EGCMA)

2.7 Interpreting overall IEC results: some caveats

It is important to reiterate several caveats with interpreting the results of the IEC assessments:

- The results of the IEC represent a single snapshot in time, aimed at supporting state-wide reporting on the relative condition of all of Victoria's major estuaries. Estuaries are characteristically dynamic systems that are subject to large and sometimes irregular natural cycles of physical and chemical conditions, including, for example, freshwater discharge. Many estuaries are also exposed to substantial anthropogenic disturbance due to their location at the bottom of catchments (Perez-Dominguez et al. 2012). Disturbance gradients within an estuary may co-vary with particular gradients of natural variability, such as estuary geomorphology, tidal regime, or hydrological characteristics. Therefore, distinguishing natural environmental variability from anthropogenic disturbance is often challenging. An index like the IEC that is intended for broad-scale comparison between estuaries is not a suitable tool for assessing these fine-scale patterns or changes over time within each estuary *(see Box 1.5 on p14)*.
- Extreme events can occur that will have an impact on estuary condition *(see Box 2.5)*. For instance, the data for the IEC were collected prior to the 2019/20 bushfires which had major impacts on coastal catchments, especially those of some of the estuaries in East Gippsland.

For logistical and resourcing reasons, the sub-indices and metrics used in the IEC are not able to cover every relevant aspect of estuarine condition (*see Section 1.6.5 on p16*). There will always be some aspects of estuary condition that are not captured or are represented at low resolution. For example, Water Quality focused on turbidity and chlorophyll a but pH could indicate the presence of acid events that threatened estuarine values like fish in some rivers.

BOX 2.5: IMPACTS OF EXTREME EVENTS ON ESTUARY CONDITION

Extreme events like floods, drought and bushfires can dramatically change the condition of all landscapes, including estuaries. Major floods obviously have short-term effects on estuary hydrology. High flows can also redistribute a range of materials, from sediments and nutrients to large woody habitats, which have longer term effects on physical form, water quality, flora and fauna. Extended droughts have a longer term effect on hydrology than the pulsed impact of floods. Reduced freshwater inflows during drought can cause elevated salinities and stratification that extend up the estuary, lead to poor water quality, and disconnect estuaries from the sea. We know that floods and droughts are a feature of the Australian landscape and associated variability in ecosystem condition is also important to acknowledge. However, as much as possible, IEC monitoring was done when conditions were relatively benign, for safety and to facilitate meaningful comparisons of condition across all of Victoria's estuaries.

IEC monitoring occurred in East Gippsland prior to the devastating bushfires in the summer of 2019/20 that impacted an area of over 1.5 million hectares across the east of Victoria. The area from the Sydenham Inlet catchment to Mallacoota Inlet catchment was most impacted, with some entire catchments affected by fire. Documented impacts of the fires on estuaries included a period of diminished water quality and fish deaths in some systems.

IEC results highlighted that East Gippsland had many estuaries in excellent condition, prior to the bushfires. The region is globally recognised for supporting megadiverse wildlife, including having the majority of intact habitat for many native fish with restricted ranges. Efforts are underway to examine the impact of, and recovery from, the bushfires. East Gippsland Catchment Management Authority is working alongside other agencies, local communities and landholders to accelerate the recovery of waterways via activities such as re-establishing stock exclusion fencing and weed management to encourage vegetation recovery *(see Box 8.1 on p77)*.

3. Next Steps

This report provides the first state-wide IEC assessment, and the intention is that the approach will be reviewed and improved to reflect improved knowledge of the ecology of Victoria's estuaries for future assessments. Next steps include:

- Ongoing refinement and improvement of IEC metrics through better understanding of the relationships between threats and environmental responses within estuaries. This may include investigating the sensitivity of estuarine responses to threats and variation in responses to threats among different types of estuaries (e.g. intermittently open and closed estuaries versus permanently open estuaries). Refining and improving IEC metrics through improved understanding of threat-response relationships will help address some of the limitations of the IEC listed in Section 1.6.5 (*p16*).
- Investigation of improved methods to capture data to support calculation of IEC metrics. As new techniques for data collection are developed and tested, there may be opportunities to make IEC data collection more efficient so that information can be collected more frequently. These improved methods could include modelling approaches, remote sensing of vegetation cover or using environmental DNA for faunal sampling.
- The same principles developed to guide refinement of the Index of Stream Condition data collection methods (DEPI 2011) will be used for the IEC. That is, changes to the methodology will only be made if: the new method is a demonstrable improvement on the old method; there was a strong reason to integrate new methods with existing methods for continual improvement; the new method has been tested; and the new methods conforms to the criteria of being transparent, intuitive, with an appropriate balance of cost, speed, accuracy and scientific rigour (DEPI 2011).

Targeted surveillance monitoring and strategic research is needed to support estuary management. Although the snapshot provided by the IEC is valuable, it does not support the assessment of fine-scale trends in components of estuarine ecosystems *(see Box 1.5 on p14)*, evaluation of management interventions, or advances in detailed understanding of the complexities of how particular estuaries function. This detailed understanding, needed to manage Victoria's estuaries effectively, is best addressed with question-driven monitoring and research.

The next state-wide IEC assessment is proposed to be undertaken around 2030. The proposed interval between assessments reflects the long timeframes expected for changes in condition that can be detected with the methods used for state-wide assessments. During the periods between state-wide IEC condition assessments, local management decisions will be informed by existing data on changing threats and contexts (e.g. changes in climate, land use, water quality, and stream flow), monitoring to evaluate the outcomes of management actions such as artificial openings, and research to fill important knowledge gaps.

Region-specific information

The IEC assessments provide information that is used to inform state-wide estuary management. The information is also used by Catchment Management Authorities (CMAs) and Melbourne Water to inform regional estuary management. Using consistent information from IEC assessments across coastal catchment regions in Victoria facilitates alignment between state-wide and regional estuary management. The IEC results for each catchment region are summarised within the following chapters of this report.

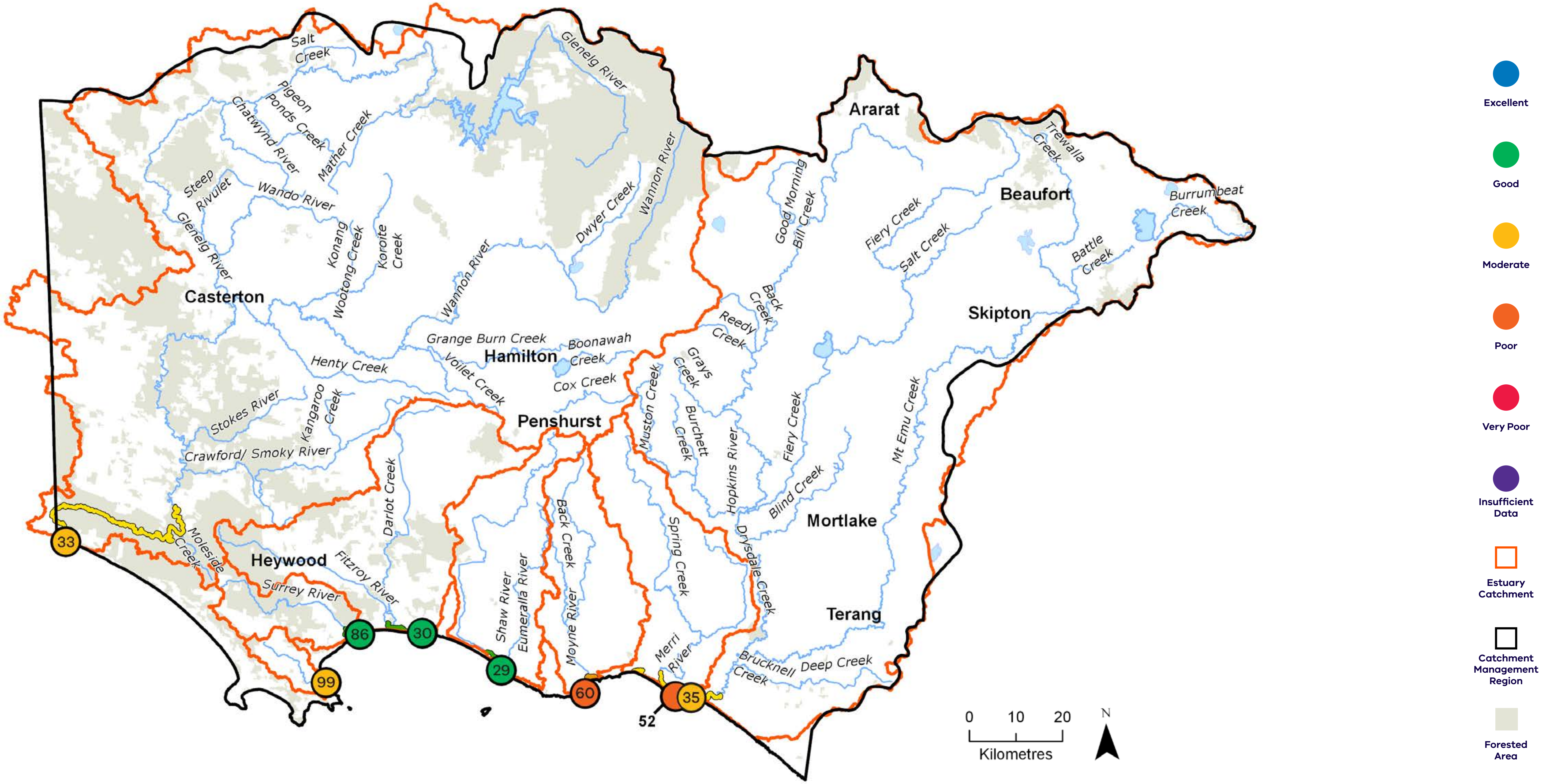
4. Glenelg Hopkins Catchment Region

Eight estuaries were sampled in the Glenelg Hopkins catchment region. Most of them are along the open coastline, typically with entrances that intermittently open and close to the ocean.

However, Moyne estuary and the smaller outlet associated with Wattle Hill Creek (Fawthrop Lagoon) are artificially kept permanently open *(see Box 2.2 on p29)*. The region's estuaries have high environmental and cultural values. The lower section of the Glenelg River is one of 18 Heritage Rivers in Victoria as listed under the Heritage Rivers Act 1992, and the Glenelg River estuary lies within the Glenelg Estuary and Discovery Bay Ramsar site. The Fitzroy River estuary is connected to the UNESCO-listed Budj Bim Cultural Landscape. The Yambuk Lake complex, which forms part of the Eumeralla River estuary, is listed as a wetland of national significance in the Directory of Important Wetlands in Australia (DIWA). The Merri River estuary has two channels to the sea; one flows to Stingray Bay in Warrnambool and another section flows through the DIWA-listed Lower Merri Wetlands and exits at Rutledge's Cutting to the west of Warrnambool.

The proximity of estuaries in the Glenelg Hopkins catchment region to coastal settlements and high-value farming land increases the risk to estuarine condition from activities associated with these land-uses, particularly from degradation of riparian vegetation by land development and stock access. Estuaries in the region have catchments generally dominated by agricultural land uses (e.g. Eumeralla River). The regional centre of Warrnambool is adjacent to the Hopkins River and Merri River estuaries, while Portland is next to Wattle Hill Creek. Other estuaries flow through smaller coastal settlements such as the Moyne River estuary through Port Fairy.

Photo: Mouth of Hopkins River estuary (Jarred Obst, GHCMA)



4.1 Glenelg Hopkins Catchment Region Scores

The IEC assessed eight estuaries in the Glenelg Hopkins catchment region. Three of these (37.5%) were in good condition, three (37.5%) were in moderate condition, and two (25%) were in poor condition *(Figure 4, Table 7)*. Catchments of estuaries in good condition, such as the Surrey River and Fitzroy River, tended to have higher cover of native vegetation than estuaries in poor condition (i.e. Moyne River and Merri River) which have ~90% of their catchment under exotic pasture (grassland).

In the Glenelg Hopkins catchment region, 37.5% of the estuaries sampled were in good condition, 37.5% were in moderate condition, and 25% were in poor condition.

FIGURE 4

Map showing IEC condition classes for estuaries in the Glenelg Hopkins catchment region. From west to east, the estuaries are Glenelg River (33), Wattle Hill Creek (99), Surrey River (86), Fitzroy River (30), Eumeralla River (29), Moyne River (60), Merri River (52) and Hopkins River (35).

Table 7: Summary of IEC scores for Glenelg Hopkins region

ESTUARY (ESTUARY NUMBER)	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	Condition Class
Glenelg River (33)	10	3	9	6	7	30	Moderate
Wattle Hill Creek (99)*	6	3	10	7	N/A	28	Moderate
Surrey River (86)	10	8	10	6	5	34	Good
Fitzroy River (30)	10	7	10	7	6	37	Good
Eumeralla River (29)+	9	6	9	7	6	34	Good
Moyne River (60)	7	2	9	6	7	26	Poor
Merri River (52)^	7	6	4	5	6	26	Poor
Hopkins River (35)	9	4	9	9†	4	30	Moderate

Results for the five sub-indices and the IEC condition class for the sampled estuaries (arranged west to east) within the Glenelg Hopkins catchment region. Scores for the sub-indices range from 1 (poorest condition) to 10 (best condition), whilst IEC Score ranges from 5 (poorest condition) to 50 (best condition). NA = not assessed.

*Also known as Fawthrop Lagoon

+Also known as Lake Yambuk

^Scores reported for the Merri River incorporate information from the Merri River main channel and Rutledges Cutting to the west

†Flora sub-index for Hopkins River based solely on fringing vegetation measure. Unable to apply measure for assessing submerged vegetation (i.e. the ratio of macroalgae to total vegetation) as no submerged vegetation was detected within the estuary.

Photo: Tupong which migrate and spawn in Victorian estuaries (Arthur Rylah Institute)

Photo: Saltmarsh in Moyne River estuary (Jarred Obst, GHCMA)

Photo: Mouth of the Glenelg River estuary (Jarred Obst, GHCMA)

BOX 4.1: ENVIRONMENTAL WATER FOR ESTUARIES – GLENELG RIVER ESTUARY

Using water for agriculture and to supply our cities and towns means less water in our rivers and less flow to the estuaries of many coastal flowing rivers. Inflows to estuaries are important for supporting the estuaries' plants and animals and for driving the ecological processes that are needed for a healthy estuary.

Victoria's environmental water program aims to redress the impact of reduced river flows by recovering water for the environment. This water is held in environmental entitlements and is released at times when it is needed to provide the missing parts of the natural flow regime. This benefits the whole of the river system, from the top of the catchment where reservoirs are normally found, through to the estuary where the river meets the sea.

An example where this occurs is the Glenelg River in western Victoria. The Glenelg River estuary is listed as a heritage river reach and a site of international significance under the Ramsar Convention. Water for the environment in the western region of Victoria is primarily supplied from water held under an environmental entitlement in Rocklands Reservoir at the top of the Glenelg River in the Grampians. The Glenelg and Wimmera river systems share the water available under the environmental entitlement.

The Glenelg River estuary benefits from releases of water for the environment to upstream reaches of the Glenelg River. Freshes, or short term increases in flow that normally follow rainfall, can be augmented by environmental flow releases. One of the benefits of fresh releases is to increase the likelihood of successful spawning and migration of migratory fish such as Common Galaxias and Tupong that spawn in estuaries. Migration of these fish species along with others like Short-finned Eels is also helped by complementary programs such as major works recently completed by Glenelg Hopkins CMA to improve fish passage in the Glenelg River at Sandford Weir, Dergholm Gauge and Warrock.

4.2 Physical Form

Three estuaries (37.5%, i.e. Fitzroy River, Glenelg River and Surrey River) in the Glenelg Hopkins catchment region had unmodified Physical Form, and a further two estuaries (25%, i.e. Eumeralla River and Hopkins River) were assessed as being near unmodified *(Table 7).*

The Physical Form of the other three, or 37.5% of, estuaries in the region was moderately modified. The estuaries of Merri River, Moyne River, and Wattle Hill Creek have substantial lengths of artificial shorelines, typical of waterways flowing through urban or industrial areas. Wattle Hill Creek also has an artificial instream barrier that slightly limits the extent of the estuary compared to unmodified conditions.

4.3 Hydrology

The Hydrology of estuaries of the Glenelg Hopkins catchment region ranged from near unmodified to extremely modified *(Table 7 on previous page)*. Surrey River was the only estuary in the region with near unmodified Hydrology. Three estuaries (37.5%, i.e. Eumeralla River, Fitzroy River and Merri River) had moderately altered Hydrology and one estuary (13%, i.e. Hopkins River) had considerably modified Hydrology.

The other three, or 37.5% of, estuaries in the region were assessed as having extremely modified Hydrology. The Hydrology of Moyne River and Wattle Hill Creek has been particularly affected by the modification of marine exchange due to artificial estuary opening and entrance engineering works such as training walls *(see Box 2.2 on p29)*. The Hydrology of the Glenelg River estuary has also been modified by artificial estuary openings, as well as substantial interception of freshwater inflows. In the Hydrology sub-index, the threat of modified freshwater inflows is assessed as the percentage of runoff that is intercepted by water storages across the whole catchment. Within the Glenelg River catchment, large reservoirs and farm dams in the upper catchment contribute to the low Hydrology sub-index score, and ultimately the overall IEC score, for the Glenelg River estuary.

Delivery of water for the environment can help address threats of modified hydrology to aquatic values. Water for the environment is delivered in the Glenelg River system to mitigate the threats of hydrological modification in this catchment *(see Box 4.1)*, However, this delivery of environmental water is not recognised in the IEC Hydrology sub-index score (*see Section 1.6.5 on p16*).

4.4 Water Quality

Most estuaries of the Glenelg Hopkins catchment region were assessed as having good or excellent Water Quality. Three estuaries (37.5%, i.e. Fitzroy River, Surrey River and Wattle Creek) had excellent Water Quality and a further four estuaries (50%, i.e. Eumeralla River, Glenelg River, Hopkins River and Moyne River) had good Water Quality.

One estuary had poor Water Quality: the Merri River estuary. High concentrations of chlorophyll *a* were detected in the Merri River, indicating excess nutrients in the water column at the time of sampling. The Merri River catchment is dominated by agriculture and the river flows adjacent to the regional urban centre of Warrnambool *(see Box 2.3 on p31)*.

4.5 Flora

The Flora of most estuaries (i.e. 75% of those assessed) of the Glenelg Hopkins catchment region was assessed as being in moderate condition. Flora was in good condition at one estuary (i.e. Hopkins River) and poor condition at another (i.e. Merri River).

For the Hopkins River estuary, the scores for the Flora sub-index are based solely on results of assessments of fringing vegetation. As no submerged vegetation (i.e. seagrass or macroalgae) was detected within the Hopkins River estuary during the IEC surveys, it is not possible to calculate the submerged vegetation measure (which assesses the dominance of macroalgae relative to seagrass). This is acknowledged as a limitation of the IEC and the Flora score should be interpreted with some caution (*see Section 1.6.5 on p16*).

Flora was in poor condition in the Merri River estuary, which includes the primary channel and Rutledges Cutting to the west. Weeds were present within the fringing vegetation and the structural complexity of the fringing vegetation was comparatively low. Overall, submerged vegetation was dominated by macroalgae relative to seagrass, indicating a potential eutrophication response (Woodland et al. 2015). This was particularly true in Rutledges Cutting. More seagrass relative to macroalgae was found in the main channel of the Merri River estuary.

At the Glenelg River estuary, fringing vegetation was in excellent condition. However, submerged vegetation was dominated by macroalgae relative to seagrass at the time of the IEC assessments.

4.6 Fish

In the Glenelg Hopkins catchment region, most estuaries (i.e. 57% of those assessed) had Fish assemblages in moderate condition, whilst 29% of estuaries had Fish assemblages in good condition.

Estuaries with Fish assemblages in good condition were the Glenelg River and the Moyne River estuaries, which supported moderately diverse Fish assemblages that included species that can complete their life cycles within estuaries (e.g. Black bream and Estuary Perch), species that are specialist feeders and those that migrate between marine, estuarine and freshwater environments. No introduced species were detected in those estuaries *(see Box 2.4 on p34)*.

One estuary in the region had Fish assemblages assessed as being in poor condition: the Hopkins River estuary. The IEC Fish sub-index provides only a snapshot of estuary Fish assemblage composition. It is important to note that the IEC Fish sub-index does not assess the population structure of estuary fish species. Rather it provides an overview of the types of species detected within an estuary at a given point in time. It is acknowledged that some estuaries that scored poorly using the IEC Fish sub-index support recreational fishing opportunities for estuarine species *(see Box 1.6 on p18)*. For example, Black bream *(Acanthopagrus butcheri)* and Estuary perch *(Macquaria colonorum)* were both recorded at the Hopkins River estuary.

5. Corangamite Catchment Region

The estuaries of the Corangamite catchment region are predominantly located along the open coastline, with the entrances of many intermittently opening and closing to the ocean.

Some of these estuaries are short (~1 – 2 km long, e.g. Kennett River and Wye River estuaries), while others are quite long (~ 15 – 20 km) with substantial lagoonal sections (e.g. Curdies Inlet and Barwon River estuaries).

Estuaries of the Corangamite catchment region are positioned at the bottom of catchments with variable land uses. The growing city of Geelong is within the Barwon River catchment. Several estuaries on the Surf Coast are located adjacent to coastal towns and settlements that are popular tourist destinations (e.g. Painkalac Creek at Aireys Inlet), some with growing populations of permanent residents (e.g. Spring Creek at Torquay).

The region includes estuaries with high environmental and social values. Several estuaries are either located within (or have upstream riverine reaches located within) National Parks and reserves, including the Great Otway National Park. The heritage listed Aire River, for example, flows through a varied landscape of agriculture, reserves and National Parks – including the Great Otway National Park.

Photo: Aerial of St George River
Corangamite CMA

5.1 Corangamite Catchment Region Scores

The IEC assessed 17 estuaries in the Corangamite catchment region. Twenty-nine percent of estuaries in this region were in good condition, 59% were in moderate condition and 12% were in poor condition *(Table 8, Figure 5)*. The two estuaries with poor condition were Anglesea River, which has considerably modified Hydrology and had a low Fish score, and Spring Creek, which has ~45% of its catchment under exotic pasture (grassland). The four estuaries in good condition all had high (i.e. 50-90%) cover of native vegetation.

FIGURE 5

Map showing IEC condition classes for estuaries in the Corangamite catchment region. From west to east, the estuaries are Curdies Inlet (22), Campbell Creek (18), Sherbrook River (78), Gellibrand River (32), Johanna River (38), Aire River (2), Barham River (8), Kennett River (40), Wye River (104), St George River (84), Erskine River (28), Painkalac Creek (67), Anglesea River (5), Spring Creek (83), Thompson Creek (91), Barwon River (9) and Hovells Creek (36).

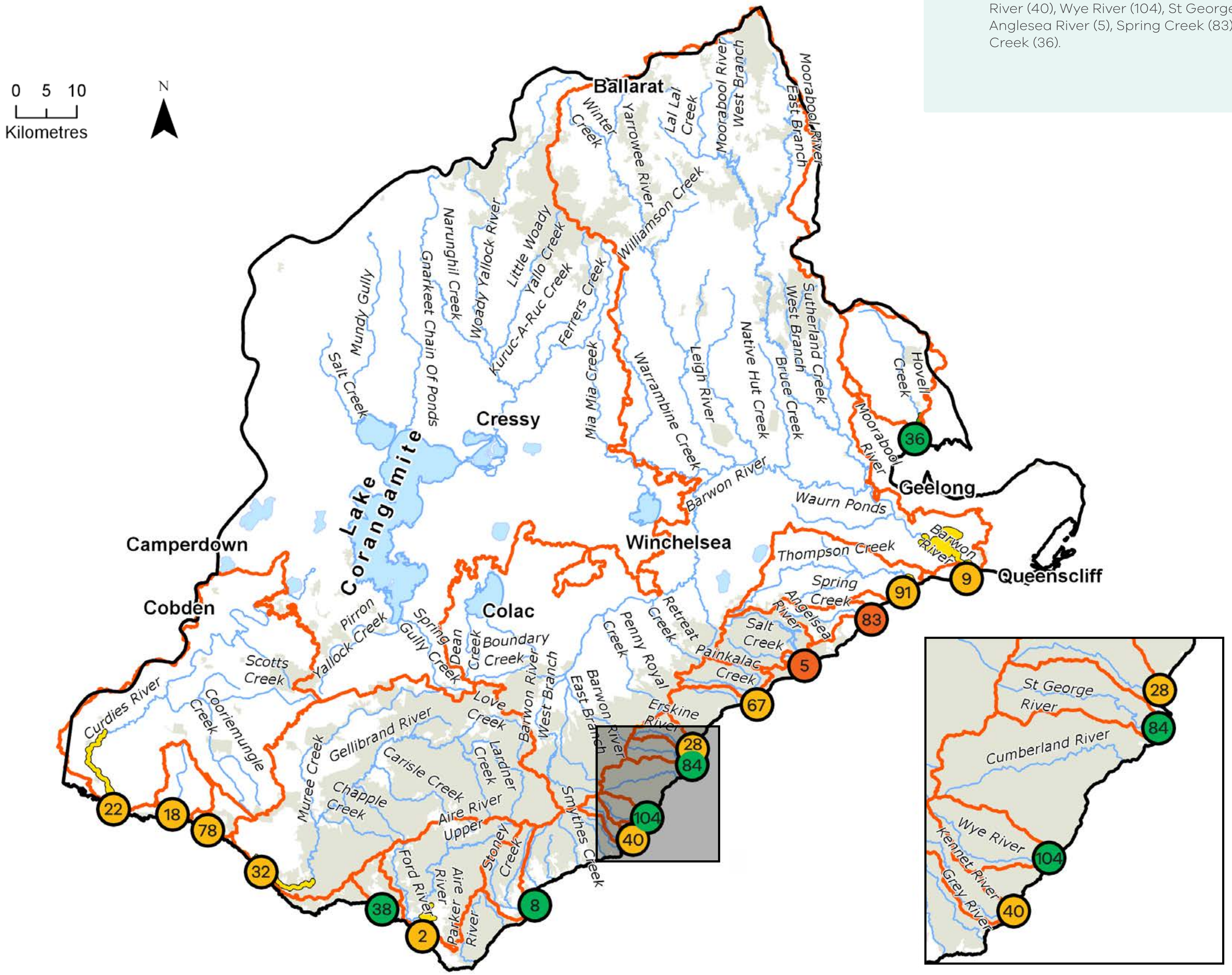


Table 8: Summary of IEC scores for Corangamite region

ESTUARY (ESTUARY NUMBER)	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	Condition Class
Curdles Inlet (22)	10	4	10	5	7	30	Moderate
Campbell Creek (18)	8	7	10	6	5	32	Moderate
Sherbrook River (78)	9	7	10	7	4	33	Moderate
Gellibrand River (32)	9	6	9	6	5	31	Moderate
Johanna River (38)	10	9	10	7	4	35	Good
Aire River (2)	10	6	6	7	7	32	Moderate
Barham River (8)	10	8	9	7	7	38	Good
Kennett River (40)	9	9	8	7[†]	4	33	Moderate
Wye River (104)	7	10	10	4	N/A	34	Good
St George River (84)	9	8	7	7	6	35	Good
Erskine River (28)	4	8	8	7[†]	N/A	32	Moderate
Painkalac Creek (67)	8	4	9	9	N/A	33	Moderate
Angelsea River (5)	7	4	10	8[†]	2	25	Poor
Spring Creek (83)	7	4	4	9	6	26	Poor
Thompson Creek (91)	7	4	8	8	7	31	Moderate
Barwon River (9)	7	5	6	8	7	31	Moderate
Hovells Creek (36)	9	5	9	8	9	37	Good

Results for the five sub-indices and the IEC condition class for the sampled estuaries (arranged west to east) within the Corangamite catchment region. Scores for the sub-indices range from 1 (poorest condition) to 10 (best condition), whilst IEC Score ranges from 5 (poorest condition) to 50 (best condition). NA = not assessed.

[†]Flora sub-index for Anglesea River, Erskine River and Kennett River based solely on fringing vegetation measure. Unable to apply measure for assessing submerged vegetation (i.e. the ratio of macroalgae to total vegetation) as no submerged vegetation was detected within the estuary.

Photo: Mouth of Gellibrand River estuary (CCMA)

In the Corangamite catchment region, 29% of the estuaries sampled were in good condition, 59% were in moderate condition, and 12% were in poor condition.

5.2 Physical Form

Twenty-four percent of estuaries in the Corangamite catchment region had unmodified Physical Form, and a further 41% were assessed as being near unmodified (*Table 8*). The Physical Form of 29% of estuaries in the region was moderately modified. Physical Form was considerably modified at one estuary: Erskine River, which had considerable artificial shorelines and an artificial instream barrier.

5.3 Hydrology

The Hydrology of estuaries of the Corangamite catchment region ranged from unmodified to considerably modified (*Table 8*).

Wye River was assessed as having unmodified Hydrology, with no interception of runoff in the catchment or alteration of marine exchange at the estuary mouth (e.g. through artificial entrance opening). Twenty-nine percent of estuaries had near unmodified Hydrology.

In the Corangamite catchment region, 24% of estuaries had moderately modified Hydrology, and 41% had considerably modified Hydrology. Several estuaries with considerably modified Hydrology have been subject to artificial estuary openings *(see Box 2.2 on p29)*, as well as interception of runoff within their catchments, namely: Painkalac Creek, Thompson Creek, Curdies Inlet, Anglesea River and Spring Creek. Other estuaries assessed as having considerably modified Hydrology are not subject to artificial estuary openings or entrance engineering works but considerable interception of runoff within the catchment interrupts freshwater inflows to the estuary, e.g. Barwon River.

Delivery of water for the environment was not incorporated into the IEC Hydrology sub-index. In the Corangamite catchment region, releases of water from the Painkalac Reservoir is aimed at addressing the threat of modified freshwater inflows to the Painkalac Creek to support estuary values *(see Box 5.1)*.

BOX 5.1: ENVIRONMENTAL WATER FOR PAINKALAC CREEK

Flows in the Painkalac Creek and estuary are modified by the Painkalac Reservoir, which supplied potable water to the towns of Aireys Inlet and Fairhaven until 2016. When the reservoir was taken offline as a potable water supply, the Corangamite CMA and Barwon Water began coordinating releases from the reservoir for environmental benefits in the creek. Releases occur throughout the year to mimic natural flows as much as possible, prevent downstream reaches in the creek from drying out, help maintain water quality and habitat for fish, frogs and birds, and provide water for recreational values. The timing of releases can be adapted to coincide with an artificial opening of the Painkalac Creek mouth by the Surf Coast Shire Council, to help sustain an open estuary mouth and lower the risk of fish deaths. As the water held in Painkalac Reservoir is still held under Barwon Water's bulk entitlement, it is not part of the Environmental Water Reserve.

5.4 Water Quality

Most estuaries of the Corangamite catchment region were assessed as having good or excellent Water Quality (*Table 8*). Thirty-five percent of estuaries had excellent Water Quality and a further 41% had good Water Quality.

Eighteen percent of estuaries had moderate Water Quality. Spring Creek was the only estuary in the Corangamite catchment region assessed as having poor Water Quality. High turbidity and chlorophyll a levels were detected at Spring Creek, indicating elevated sediment and nutrient inputs to the estuary, respectively.

The Anglesea River estuary was assessed as having excellent Water Quality, using the IEC Water Quality sub-index. It is important to note that the IEC Water Quality sub-index only includes chlorophyll a and turbidity, which are signals of nutrient and sediment inputs to estuaries, respectively. Waters of the Anglesea River estuary are clear (indicated by low turbidity levels) and did not showing signs of excessive primary production in the water column (indicated by low chlorophyll a levels). The IEC Water Quality sub-index does not include pH (*see Section 2.7 on p35*) and it is acknowledged that the river experiences periods of low pH water due to natural sources of acid sulfate soils in the catchment. These low pH events can threaten estuary values e.g. fish (see Anglesea River 2012-2020 Estuary Management Plan).

5.5 Flora

The condition of Flora varied from good to poor among estuaries of the Corangamite catchment region (*Table 8*). Flora was in good condition at 35% of estuaries, including Painkalac Creek, Anglesea River, Spring Creek, Thompson Creek, Barwon River and Hovells Creek. However, the Flora sub-index for the Anglesea River estuary was based only on fringing vegetation, as no submerged vegetation was detected in the estuary at the time of assessment, making it impossible to calculate the submerged vegetation measure (which assesses the dominance of macroalgae relative to seagrass). This is acknowledged as a limitation of the IEC and the Flora score should be interpreted with some caution (*see Section 1.6.5 on p16*).

Flora was in moderate condition at 53% of estuaries in the region. Flora was in poor condition at two estuaries in the Corangamite catchment region: Curdies Inlet and Wye River. These estuaries had submerged vegetation dominated by macroalgae (relative to seagrasses).

5.6 Fish

The condition of Fish assemblages varied across the Corangamite catchment region from excellent to very poor (*Table 8*). Fish assemblages were in excellent or good condition at 43% of estuaries *(see Box 2.4 on p34)*. These included the Aire River, Barham River, Barwon River, Curdies Inlet, Hovells Creek (Limeburners Lagoon) and Thompson Creek.

Twenty-nine percent of estuaries in the region had Fish assemblages in moderate condition. Fish assemblages were in poor condition at 21% of estuaries, and very poor condition at one estuary: the Anglesea River. The Fish assemblage of the Anglesea River estuary was in the poorest condition among estuaries of the Corangamite catchment region, with few species or individuals detected. This is likely due to the history of fish deaths and acidic inflows in this location (Sharley et al. 2014).

Photo: Spring Creek estuary (CCMA)

6. Port Phillip - Western Port Catchment Region

Numerous discrete estuaries enter the iconic embayments of Port Phillip Bay and Western Port, in the most intensively developed region of Victoria.

Predominantly, the entrances of these estuaries are permanently open, however some smaller estuaries have entrances that intermittently open and close (e.g. Balcombe Creek and Merricks Creek). Melbourne Water is the waterway manager for estuaries in the Port Phillip and Western Port catchment region.

The estuaries that enter Port Phillip Bay are positioned at the bottom of catchments dominated by urban land use. Estuaries entering Western Port are located within catchments dominated by mixed urban and agricultural land use. Upper catchments for some estuaries in this region are within National and State Parks and reserves (e.g. the Yarra River and Bunyip River catchments).

The region includes highly modified estuaries due to their proximity to metropolitan Melbourne, agricultural land use and the associated historical clearing of native vegetation and coastal drainage works. Despite proximity to threats, the region includes estuaries with high environmental values, including those that are located within Ramsar sites. Little River and Werribee River estuaries are within the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site. The lower reaches of several estuaries entering Western Port (e.g. Watsons Creek and Bass River estuaries) are included within the Western Port Ramsar site. The estuaries also have high social values for the large population of metropolitan residents and visitors to the region, including amenity and recreational values such as fishing, boating and swimming.

Photo: Werribee River estuary (Trish Grant, Melbourne Water)

6.1 Port Phillip – Western Port Catchment Region Scores

The IEC assessed 21 estuaries in the Port Phillip and Western Port catchment region. Five percent of estuaries were assessed as being in good condition *(Table 9, Figure 6)*, whilst 19% had moderate condition. However, most estuaries in the region were either in poor condition (52% of estuaries in the region) or very poor condition (24% of estuaries in the region). Many of the estuaries in the region, especially those in poor or very poor condition had catchments with high proportions (i.e. >40%) of their land use as agriculture (e.g. Yallock Drain, Deep Creek, Bunyip River), or are highly urbanised (e.g. Elwood Canal, Kananook Creek).

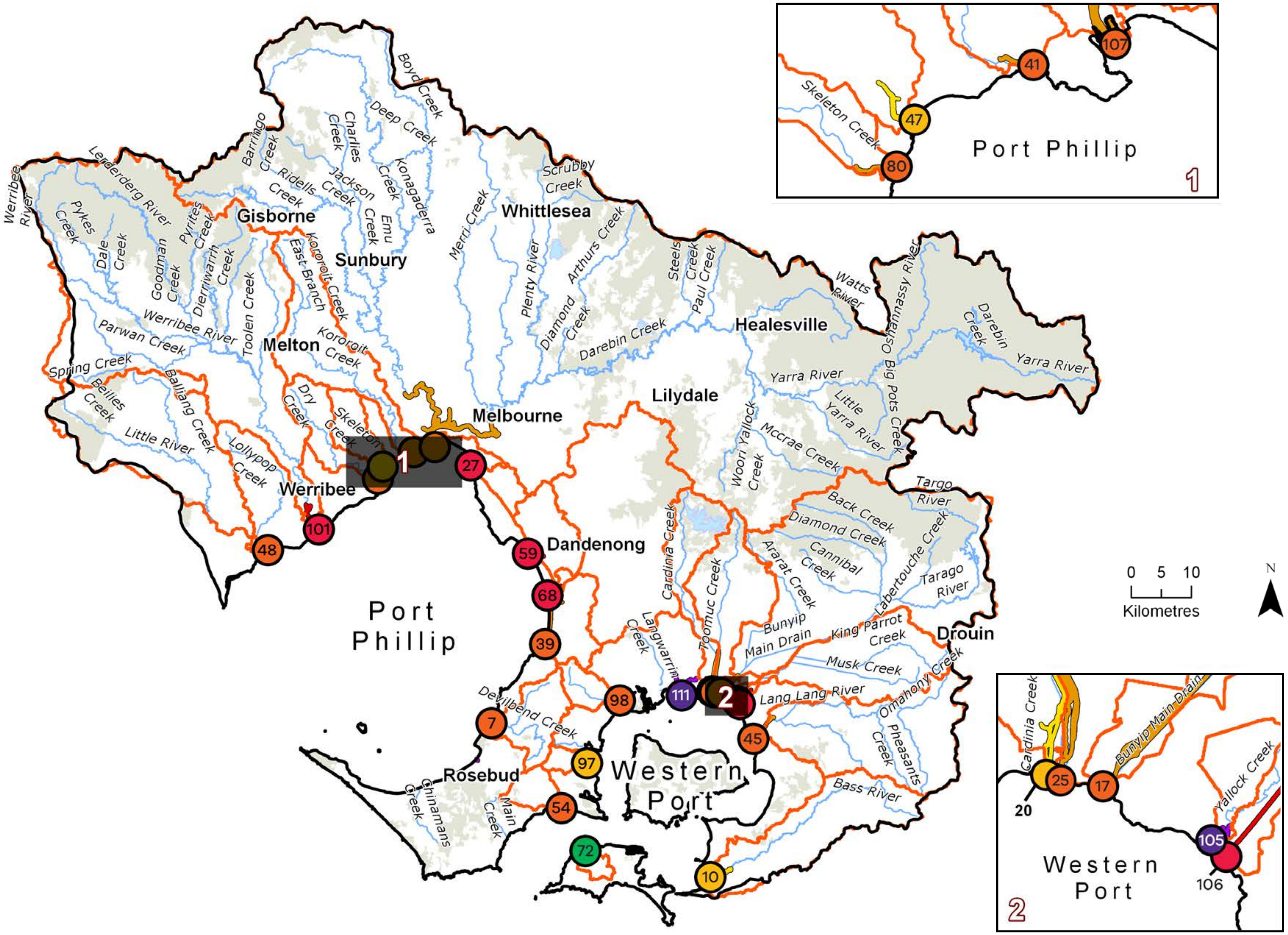


FIGURE 6

Map showing IEC condition classes for estuaries in the Port Phillip and Western Port catchment region. From west to east, the estuaries are Little River (48), Werribee River (101), Skeleton Creek (80), Laverton Creek (47), Kororoit Creek (41), Yarra River (107), Elwood Canal (27), Mordialloc Creek (59), Patterson River (68), Kananook Creek (39), Balcombe Creek (7), Merricks Creek (54), Warringine Creek (97), Watsons Creek (98), Tooradin Inlet (111), Cardinia Creek (20), Deep Creek (25), Bunyip River (17), Yallock Creek (105), Yallock Drain (106), Lang Lang River (45), Bass River (10) and Saltwater Creek (72).

Table 9: Summary of IEC scores for Port Phillip and Western Port Estuaries region

ESTUARY (ESTUARY NUMBER)	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	Condition Class
Little River (48)	9	3	4	6††	4	21	Poor
Werribee River (101)	8	2	2	5	6	18	Very poor
Skeleton Creek (80)	4	5	6	9††	3	22	Poor
Laverton Creek (47)	7	3	10	6	6	27	Moderate
Kororoit Creek (41)	6	6	3	6	8	26	Poor
Yarra River (107)	6	1	10	7††	6	24	Poor
Elwood Canal (27)	1	7	4	N/A	1	11	Very poor
Mordialloc Creek (59)	6‡	2	8	4	4	19	Very poor
Patterson River (68)	2	2	9	N/A	7	19	Very poor
Kananook Creek (39)	6‡	2	9	8	6	26	Poor
Balcombe Creek (7)	9	1	7	7	5	23	Poor
Merricks Creek (54)	8	5	2	9††	2	20	Poor
Warringine Creek (97)	10	6	3	10††	6	29	Moderate
Watsons Creek (98)	10	5	1	10††	7	25	Poor
Cardinia Creek (20)	7	3	7	9††	6	28	Moderate
Deep Creek (25)	7	4	6	9††	4	26	Poor
Bunyip River (17)	7	3	8	9††	4	26	Poor
Yallock Drain (106)	4	4	2	N/A	3	15	Very poor
Lang Lang River (45)	6	4	7	N/A	4	22	Poor
Bass River (10)	8	6	2	7	9	27	Moderate
Saltwater Creek (72)	10‡	6	N/A	7	N/A	37	Good

Results for the five sub-indices and the IEC condition class for the sampled estuaries (arranged west to east) within the Corangamite catchment region. Scores for the sub-indices range from 1 (poorest condition) to 10 (best condition), whilst IEC Score ranges from 5 (poorest condition) to 50 (best condition). NA = not assessed.

‡ Physical Form sub-index for Kananook Creek, Mordialloc Creek and Saltwater Creek based solely on artificial shorelines measure. These estuaries were not assessed for artificial barriers.

†† Flora sub-index for marked estuaries based solely on fringing vegetation measure. These estuaries were not assessed for submerged vegetation.

6.2 Physical Form

Fourteen percent of estuaries in the Port Phillip and Western Port catchment region had unmodified Physical Form, and a further 24% were assessed as being near unmodified (*Table 9*). Across the region, the Physical Form was moderately modified at 43% of estuaries, considerably modified at 10% of estuaries, and extremely modified at 10% of estuaries.

Several estuaries had large percentages of artificial shorelines. These included estuaries with long stretches of concrete armouring or rock walls (e.g. Yarra River) and those where the original flow course of the estuary had been artificially modified, and an estuary now flows through areas that were not part of the original estuarine floodplain (e.g. Yallock Drain, Patterson River) *see Box 6.1 on p60*.

Six estuaries had artificial instream barriers: Elwood Canal, Kororoit Creek, Patterson River, Skeleton Creek, Werribee River and Yallock Drain.

In the Port-Phillip Western Port catchment region, 5% of the estuaries sampled were in good condition, 19% were in moderate condition, 52% were in poor condition, and 24% were in very poor condition.

BOX 6.1: HISTORICAL ALTERATION OF THE COURSE OF RIVERS AND ESTUARIES FOR DRAINAGE

Two large swamps once existed in the Melbourne region; the Carrum Carrum swamp and the Koo Wee Rup Swamp. Multiple waterways drained to these swamps, but there may have only been one or two outlets from the swamp connecting to Port Phillip Bay or Western Port. In the mid to late 1800s, multiple new watercourses (cut drains) were created to convert low-lying swamp to land suitable for agriculture and urban growth. These new channels terminated in some estuaries that would have not previously existed. Some of these 'new' estuaries have been assessed in the IEC. The Physical Form score of many of these 'new' estuaries was assessed as moderate: whilst they often had large extents of their shorelines covered by built structures, they often had minimal barriers (consistent with their primary purpose being drainage). For such watercourses, there was no 'natural' inland extent of the estuary. Therefore, when calculating the Artificial Barriers measure, the endpoints of the 'natural' inland extents for these estuaries were estimated from the most likely locations had there been a marine influence downstream (Pope et al. 2015).

Photos: Aerial image of channelisation of waterways designed to drain Carrum Carrum Swamp (38°02′53″S, 145°09′59″E, Google Earth version 9.134.0.0, accessed 13 April 2021).

6.3 Hydrology

The Hydrology of estuaries of the Port Phillip and Western Port catchment region ranged from moderately to extremely modified (*Table 9*). Twenty-four percent of estuaries had moderately altered and 29% had considerably modified Hydrology. Hydrology was extremely modified at 48% of estuaries in the region.

The Hydrology of these estuaries was extremely modified by interception of runoff by storages within the catchment (including large reservoirs, for example in the Werribee and Yarra River catchments), and modification of marine exchange. Marine exchange was modified through artificial entrance openings (e.g. Balcombe Creek, *see Box 2.2 on p29*), or entrance engineering works such as dredging or the construction of training walls (e.g. Kananook Creek, Mordialloc Creek, Yarra River).

Delivery of water for the environment was not incorporated into the IEC Hydrology sub-index (*Box 4.1 on p44*). In the Port Phillip and Western Port catchment region, water for the environment is delivered in the Werribee, Yarra and Bunyip river systems.

6.4 Water Quality

Water Quality in estuaries of the Port Phillip and Western Port catchment region was variable, as reflected in the Water Quality sub-index condition assessment (*Table 9*). Across the region, 10% of estuaries had excellent Water Quality and 20% had good Water Quality. This included the Yarra River where Water Quality was assessed as excellent. Monitoring was undertaken at the Princess Bridge. It is worth noting that water quality monitoring for the IEC aimed to assess Water Quality under base flow conditions, therefore monitoring during or immediately after rainfall events was avoided. High rainfall and surface runoff events can deliver substantial amounts of nutrients and sediments into estuaries, including the Yarra River estuary.

Twenty-five percent of estuaries in the region had moderate Water Quality. Forty-five percent of estuaries in the region had poor or very poor Water Quality, with high turbidity and chlorophyll a levels, indicating elevated sediment and nutrient inputs to estuaries, respectively. Elevated turbidity was generally more of an issue than chlorophyll a for estuaries entering Western Port. Chlorophyll a levels were particularly high at Watsons Creek, Little River and Elwood Canal, indicating excessive nutrients entering these estuaries.

6.5 Flora

The condition of Flora varied from poor to excellent among estuaries of the Port Phillip and Western Port catchment region (*Table 9*). Flora was in excellent condition at 12% of estuaries, good condition at 35% of estuaries, and in moderate condition at 41% of estuaries in the region. However, the Flora sub-index was based only on fringing vegetation for many of these estuaries. Several of the estuaries with Flora in excellent or good condition flow into Western Port and have fringing vegetation dominated by mangroves. Sediment inputs to Western Port are acknowledged as a threat to seagrasses (Melbourne Water 2018). This is not reflected in IEC Flora scores for estuaries where submerged vegetation was not assessed and Flora scores should be interpreted with some caution *(see Section 1.6.5 on p16)*.

6.6 Fish

The condition of Fish assemblages varied from excellent to very poor among estuaries of the Port Phillip and Western Port catchment region (*Table 9*). Fish assemblages of 20% of estuaries in the region were in good or excellent condition. Fish assemblages were in moderate condition at 35% of estuaries, poor condition at 35% of estuaries, and very poor condition at two estuaries: Elwood Canal and Merricks Creek.

Fish assemblages were in good or excellent condition at the Bass River, Kororoit Creek, Patterson River and Watsons Creek estuaries. At these estuaries, the fish assemblage was relatively diverse and included species that can complete their life cycles within estuaries, inhabit the bottom portion of the water column and species that migrate between marine and fresh waters (diadromous species, e.g. Tupong and Galaxids) (*see Box 2.4 on p34*).

Introduced fish species were detected at several estuaries in the region: Cardinia Creek, Elwood Canal, Little River, Merricks Creek, Skeleton Creek, Werribee River, Yallock Drain and Yarra River.

The IEC Fish sub-index provides only a snapshot of estuary Fish assemblage composition. It is important to note that the IEC Fish sub-index does not assess the population structure of estuary fish species. Rather it provides an overview of the types of species detected within an estuary at the time of monitoring (*see Box 1.5 on p14*). It is acknowledged that some estuaries that scored poorly using the IEC Fish sub-index support recreational fishing opportunities for estuarine species. For example, Black bream *(Acanthopagrus butcheri)* at the Werribee River estuary (*see Box 1.6 on p18*).

7. West Gippsland Catchment Region

The estuaries of the West Gippsland catchment region are diverse.

They include the estuarine reaches of rivers and streams that directly flow into the ocean or a large embayment (including those that flow into Corner Inlet), estuarine reaches of rivers and streams that flow into coastal barrier lagoons (Gippsland Lakes) and coastal inlets (e.g. Shallow Inlet).

The estuaries entering Corner Inlet and Nooramunga experience large tidal amplitudes relative to other estuaries in Victoria. The estuarine reaches of rivers entering Lake Wellington are microtidal. Some estuaries in the region are located along open coastlines with entrances that intermittently open and close to the ocean. Depending on the inflows, estuary shape, floodplain extent and sea state the entrance can remain closed for long periods.

The region includes estuaries with high environmental values, including those that are connected to or within the Corner Inlet and Gippsland Lakes Ramsar sites.

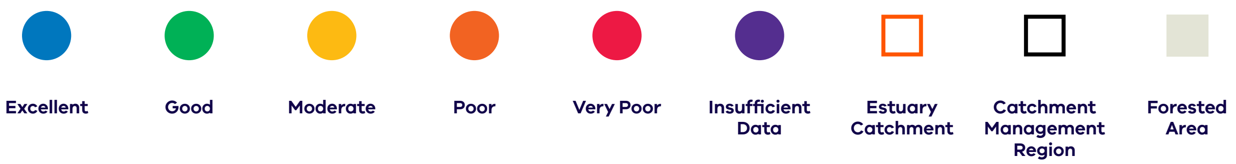
Due to their location at the bottom end of catchments, estuaries are influenced by a range of catchment processes including land use, development and extraction of water. The estuaries of the West Gippsland catchment region are positioned at the bottom of catchments with variable land uses, including agricultural and urban land uses as well as National Parks and reserves, such as the Wilsons Promontory National Park.

Photos: Mouth of Powlett River estuary (Jemima Stirling, WGCMA)

7.1 West Gippsland Catchment Region Scores

The IEC assessed 29 estuaries in the West Gippsland catchment region. Twenty-one percent of estuaries were assessed as being in excellent condition *(Table 10, Figure 7)*. Twenty-four percent were in good condition, 24% in moderate condition and 31% in poor condition.

Estuaries in excellent condition included those within Wilsons Promontory National Park. Estuaries in good condition were mostly tributaries to Corner Inlet (*see Box 7.1 on p69*). Estuaries in poor overall condition included tributaries to Lake Wellington, estuaries along the western shoreline of Corner Inlet and intermittently open and closed estuaries of the Bass Coast *(Table 10)*. The estuaries in poor condition, with the exception of the Avon and Latrobe rivers, had the majority of their catchments dominated by agriculture.



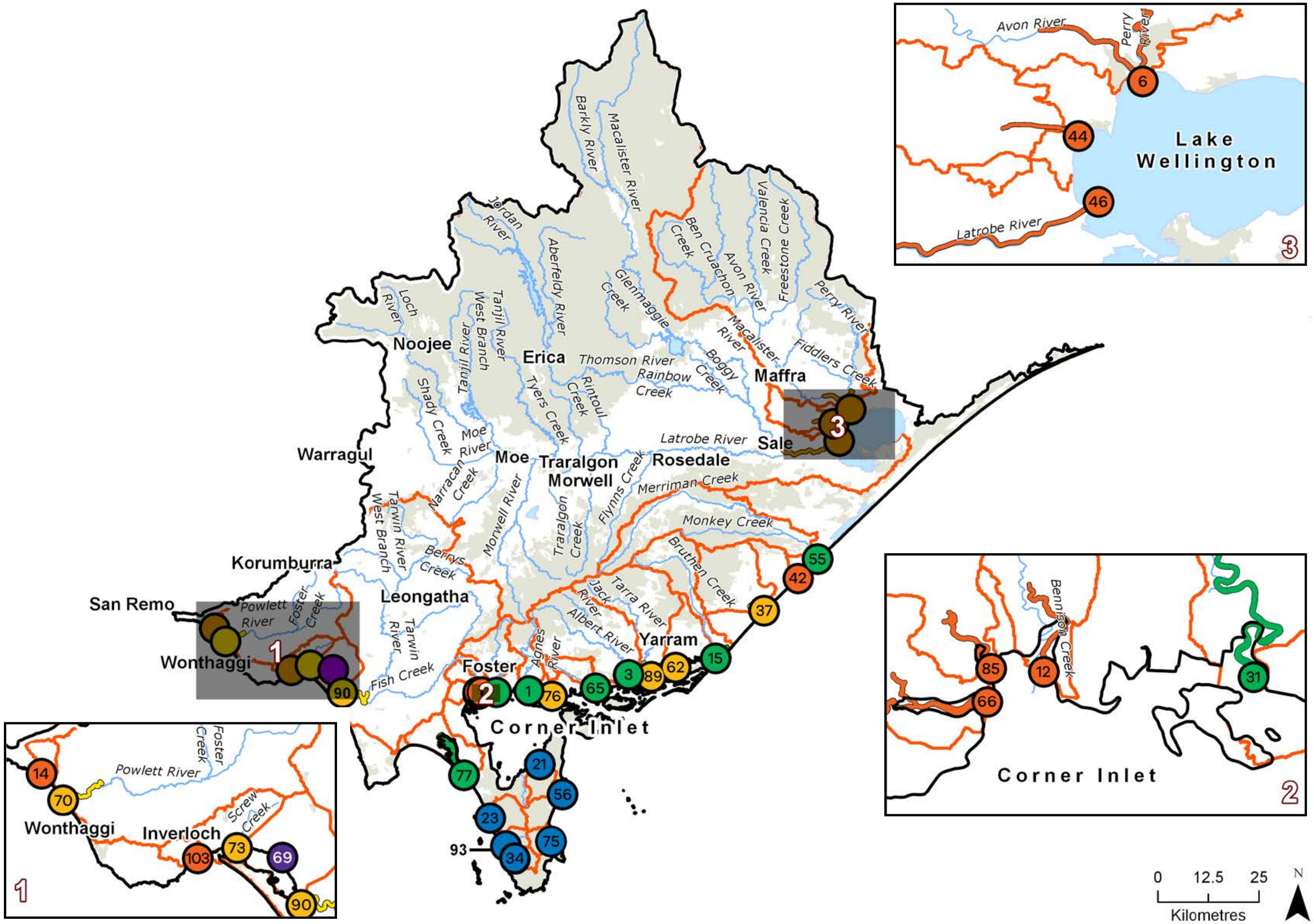


FIGURE 7

Map showing IEC condition classes for estuaries in the West Gippsland catchment region. From west to east, the estuaries are Bourne Creek (14), Powlett River (70), Wreck Creek (103), Screw Creek (73), Pound Creek (69), Tarwin River (90), Shallow Inlet (77), Darby River (23), Tidal River (93), Growler Creek (34), Sealers Creek (75), Miranda Creek (56), Chinaman Creek (21), Old Hat Creek (66), Stockyard Creek (85), Bennison Creek (12), Franklin River (31), Agnes River (1), Shady Creek (76), Nine Mile Creek (65), Albert River (3), Tarra River (89), Neils Creek (62), Bruthen Creek (15), Jack Smith Lake (37), Lake Denison (42), Merriman Creek (55), Latrobe River (46), Lake Wellington Main Drain (44) and Avon River (6).

Table 10: Summary of IEC scores for West Gippsland region

ESTUARY (ESTUARY NUMBER)	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	Condition Class
Bourne Creek (14)	9	3	4	7	4	22	Poor
Powlett River (70)	8	3	10	6	6	28	Moderate
Wreck Creek (103)	8	2	8	6	3	21	Poor
Screw Creek (73)	10	6	8	9††	4	31	Moderate
Tarwin River (90)	7	7	6	4	7	29	Moderate
Shallow Inlet (77)	8	7	10	6	8	36	Good
Darby River (23)	10	10	10	10†	5	41	Excellent
Tidal River (93)	9	9	10	10††	7	42	Excellent
Growler Creek (34)	10	10	N/A	10††	N/A	50	Excellent
Sealers Creek (75)	10	10	N/A	10††	N/A	50	Excellent
Miranda Creek (56)	10	10	N/A	10††	N/A	50	Excellent
Chinaman Creek (21)	10	10	N/A	10††	8	47	Excellent
Old Hat Creek (66)	8	8	2	6†	7	26	Poor
Stockyard Creek (85)	7	7	1	6†	6	23	Poor
Bennison Creek (12)	7	8	2	6†	4	22	Poor
Franklin River (31)	8	8	8	10†	6	37	Good
Agnes River (1)	10	8	8	7	9	40	Good
Shady Creek (76)	7	8	2	9	7	28	Moderate
Nine Mile Creek (65)	8	6	10	6	7	34	Good
Albert River (3)	8	8	6	9†	7	35	Good
Tarra River (89)	8‡	7	4	7	9	32	Moderate
Neils Creek (62)	10	6	7	5	8	32	Moderate

Photo: Anderson's Inlet (WGCMA)

Table 10: Summary of IEC scores for West Gippsland region (continued)

ESTUARY (ESTUARY NUMBER)	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	Condition Class
Bruthen Creek (15)	8	8	6	8	9	36	Good
Jack Smith Lake (37)	6	8	6	5	N/A	29	Moderate
Lake Denison (42)	10	6	1	7	N/A	24	Poor
Merriman Creek (55)	8	7*	9	8	7	37	Good
Latrobe & Thomson Estuary (46)	10	1	6	10†	4	23	Poor
Lake Wellington Main Drain (44)	6	3	3	8†	6	22	Poor
Avon River (6)	7	3	2	10†	4	20	Poor

Results for the five sub-indices and the IEC condition class for the sampled estuaries (arranged west to east) within the West Gippsland catchment region. Scores for the sub-indices range from 1 (poorest condition) to 10 (best condition), whilst IEC Score ranges from 5 (poorest condition) to 50 (best condition). NA = not assessed.

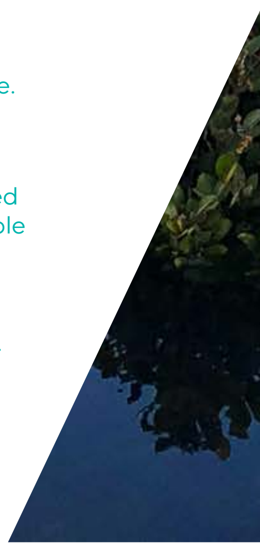
‡ Physical Form for Tarra River sub-index based solely on artificial shorelines measure. These estuaries were not assessed for artificial barriers.

* Hydrology sub-index for Merriman Creek based solely on freshwater inflow measure as data were not available to support assessment of marine exchange.

†† Flora sub-index for marked estuaries based solely on fringing vegetation measure. These estuaries were not assessed for submerged vegetation

† Flora sub-index for marked estuaries based solely on fringing vegetation measure. Unable to apply measure for assessing submerged vegetation (i.e. the ratio of macroalgae to total vegetation) as no submerged vegetation was detected within the estuary.

In the West Gippsland catchment region, 21% of the estuaries sampled were in excellent condition, 24% were in good condition, 24% in moderate condition and 31% in poor condition.



Photos: Left, Livestock in the upper Corner Inlet catchment (David Fletcher via WGCMA). Right, Corner Inlet (Matt Bowler via WGCMA)

BOX 7.1: CATCHMENT-SCALE PLANNING AND MANAGEMENT REAP REWARDS FOR CORNER INLET

Estuary condition is reflective of the land uses and management of upstream coastal catchments. So, realising improvements in estuary condition requires coordinated catchment-scale planning and management involving a range of stakeholders with a shared understanding that improvements will be incremental over multi-decadal timeframes. One example of this approach is the development and implementation of the Corner Inlet Water Quality Improvement Plan. The objectives and prescribed management actions in the Plan are underpinned by rigorous science. Implementation of the Plan is ongoing and builds upon the already significant progress towards catchment-scale remediation. For example, approximately 80% of Agnes River has been fenced off to exclude livestock access and counter associated erosion and water quality issues, whilst invasive willow species have been removed and replaced with indigenous vegetation. This has been complemented by aiding landholders to implement farming practices with localised and catchment-scale benefits. Mitigating the threat of excess sediment and nutrients entering waterways has benefits for uses of water by surrounding townships and industry, as well as the highly valued seagrass in the Corner Inlet Ramsar site. The long-term vision in the Plan and continued investment in actions has proven worthwhile, with the recent findings showing that overall economic benefits of management exceed the costs. This will inspire continuing work in the region and elsewhere.

7.2 Physical Form

The Physical Form of most estuaries of the West Gippsland catchment region was unmodified to near unmodified (*Table 10*). Thirty-four percent of estuaries in the West Gippsland catchment region had unmodified Physical Form, and a further 41% were assessed as being near unmodified. The Physical Form of 24% of estuaries in the region was moderately modified.

7.3 Hydrology

The Hydrology of estuaries of the West Gippsland catchment region ranged from unmodified to extremely modified *(Table 10)*.

Seventeen percent of estuaries were assessed as having unmodified Hydrology, with no interception of runoff in the catchment or alteration of marine exchange at the estuary mouth (e.g. through artificial entrance opening or entrance engineering works). Thirty-one percent of estuaries had near unmodified Hydrology.

Thirty-one percent of estuaries had moderately modified, and 21% had extremely modified Hydrology.

Estuaries with extremely modified Hydrology included tributaries to Lake Wellington (Avon River, Latrobe River and Lake Wellington Main Drain) that have substantial storages within their catchments that intercept runoff, interrupting freshwater inflows to the estuary. Marine exchange was also modified at these systems because of dredging at Lakes Entrance. Lake Wellington Main Drain also has a constructed mouth.

The Powlett River and Wreck Creek on the Bass Coast also had extremely modified Hydrology resulting from a combination of interception of runoff due to catchment storages and modification of marine exchange through artificial entrance openings (*see Box 2.2 on p29*).

The Hydrology at Merriman Creek was assessed as moderately modified. This assessment was based on the freshwater inflow metric only. It is worth noting that this metric does not incorporate direct pumping of water from the creek upstream of the estuary that may occur for, for example, stock and domestic purposes. Merriman Creek is an important water source for agriculture and the town of Seaspray. It is acknowledged that unauthorised artificial estuary openings have been observed at Merriman Creek. Unfortunately, records of these openings were not sufficient to support calculation of the IEC marine exchange measure.

Delivery of water for the environment was not incorporated into the IEC Hydrology sub-index (*see Box 4.1 on p44*). In the West Gippsland catchment region, water for the environment is delivered in the Thomson and Macalister River systems which are connected to the Latrobe/Thomson estuary system.

7.4 Water Quality

Water Quality in estuaries of the West Gippsland catchment region was variable, ranging from excellent to very poor (*Table 10*).

Across the region, 20% of estuaries had excellent Water Quality and 20% had good Water Quality. However, Water Quality issues were detected at several estuaries. Twenty-four percent of estuaries in the region had moderate Water Quality, 8% had poor Water Quality and 28% had very poor Water Quality, with high turbidity and chlorophyll a levels indicative of elevated sediment and nutrient inputs to the estuary, respectively. Estuaries with very poor Water Quality included those on the western shore of Corner Inlet (e.g. Bennison Creek, Stockyard Creek, Old Hat Creek) and tributaries to Lake Wellington (e.g. Avon River, Lake Wellington Main Drain). Water Quality was assessed as moderate in the Latrobe-Thomson estuary. Monitoring for this system was undertaken below the confluence of the Latrobe and Thomson rivers and therefore reflects catchment inputs from both rivers.

BOX 7.2: *SPARTINA* CONTROL ALONG WEST GIPPSLAND ESTUARIES

Spartina is an invasive intertidal grass that can form large meadows to change the dynamics and ecology of intertidal mudflats, displace native saltmarsh communities and impact on populations of invertebrates and the feeding grounds of shorebirds. Therefore, it is considered a major threat to estuaries and neighbouring endangered saltmarsh, including the Corner Inlet Ramsar Site and other estuaries of West Gippsland. The control of *Spartina* involves a collaborative approach between multiple management agencies and research institutions. Ground-based campaigns have been combined with use of helicopters, facilitating significant progress towards the long-term goal of eradication at Corner Inlet. Monitoring has found a 70% reduction in *Spartina* coverage after each annual treatment. Continuing effort is essential to maintain past gains, given the hardy and persistent nature of this species, which requires multiple treatments to eradicate infestation sites.

7.5 Flora

The condition of Flora varied from excellent to poor among estuaries of the West Gippsland catchment region *(Table 10)*. Flora was in excellent condition at 31% of estuaries and good condition at 21% of estuaries.

Estuaries with Flora in excellent condition included those within the Wilsons Promontory National Park. Flora was also in excellent condition at the Latrobe and Avon River estuaries where the estuarine fringing vegetation is within the Gippsland Lakes Ramsar site, the Heart Morass and Dowd Morass Wildlife Reserve (Latrobe), and the Clydebank Morass Wildlife Reserve (Avon). The Franklin River estuary on the northern shoreline of Corner Inlet also had Flora in excellent condition, with large areas of intact mangroves. It should be noted that the condition of Flora at the Latrobe, Avon and Franklin River estuaries is based on fringing vegetation only. No submerged vegetation was detected during field assessments, preventing the application of the submerged vegetation measure that assesses the ratio of macroalgae to total submerged vegetation. Submerged vegetation may have been absent from these systems, which are characterised by deep channels, because there was insufficient light for submerged vegetation to grow.

Flora was in moderate condition at 38% of estuaries and poor condition at 10% of estuaries in the region.

Flora was in poor condition at Jack Smith Lake and the Tarwin River. At Jack Smith Lake this result was driven by the condition of submerged vegetation, which was almost completely dominated by macroalgae, whereas the fringing vegetation was in good condition. At the Tarwin River estuary submerged vegetation was almost completely dominated by macroalgae with little or no seagrass present. The fringing vegetation of the Tarwin River estuary also had weeds and the structure of native vegetation was modified. *Spartina* sp. was detected in some estuaries, e.g. Shallow Inlet and tributaries to Corner Inlet *(see Box 7.2)*.

Photo: Helicopters refuelling during Spartina control operations in Corner Inlet (Janine Clark, via WGCMA).

7.6 Fish

The condition of Fish assemblages varied from excellent to poor among estuaries of the West Gippsland catchment region *(Table 10)*. Fish assemblages of 13% of estuaries in the region were in excellent condition and 42% or estuaries had Fish assemblages in good condition.

Estuaries with Fish assemblages in good or excellent condition included Agnes River, Bruthen Creek, Tarra River, Chinaman Creek, Neils Creek and Shallow Inlet. These fish assemblages included specialist feeders, species that can complete their life cycles within estuaries and species that migrate between freshwater and marine environments *(i.e. diadromous species - see Box 2.4 on p34)*. Several of these estuaries are tributaries to Corner Inlet (i.e. Agnes River, Bruthen Creek, Tarra River and Chinaman Creek). Corner Inlet provides important habitat, feeding opportunities, dispersal and migratory pathways and spawning sites for numerous fish species, including several fish species which are estuary residents or depend on estuaries to complete their life cycle, and diadromous (or migratory) species (e.g. Tupong, *Pseudaphritis urvillii*) which migrate between freshwater streams, estuaries and Corner Inlet to complete its life cycle.

Across the region, 21% of estuaries had Fish assemblages in moderate condition and 25% in poor condition. Estuaries with Fish assemblages in poor condition included the intermittently open and closed estuaries of the Bass Coast (i.e. Powlett River, Bourne Creek and Wreck Creek) and tributaries to Lake Wellington (i.e. Avon River and Latrobe/Thomson Estuary). In these fish assemblages there were few species that were specialist feeders or species that live in the bottom portions of the water column (i.e. demersal species) that can be limited by water quality and availability of suitable habitat. Invasive species (e.g. Eastern Gambusia) were also detected at the Latrobe/Thomson Estuary and Lake Wellington Main Drain.

The IEC Fish sub-index provides only a snapshot of estuary Fish assemblage composition. It is important to note that the IEC Fish sub-index does not assess the population structure of estuary fish species. Rather it provides an overview of the types of species detected within an estuary at the time of monitoring *(see Box 1.5 on p14)*. It is acknowledged that some estuaries that scored poorly using the IEC Fish sub-index support recreational fishing opportunities for estuarine species *(see Box 1.6 on p18)*. For example, the Black bream *(Acanthopagrus butcheri)* at the Latrobe/Thomson estuary.

8. East Gippsland Catchment Region

The estuaries of the East Gippsland catchment region are diverse.

They include estuaries located along open coastlines with entrances that intermittently open and close to the ocean, including those with large inlets, e.g. Lake Tyers and Mallacoota Inlet. The region also includes the estuarine reaches of riverine tributaries to the Ramsar listed Gippsland Lakes, including the major tributaries to Lake King – the Mitchell River, Nicholson River and Tambo River. The region also includes the nationally significant Snowy River estuary and Sydenham Inlet and smaller estuaries that are in close to pristine condition.

East Gippsland is one of the few places on mainland Australia where continuity of natural ecosystems – from the alps to the sea – still exists. The East Gippsland catchment region has the largest concentration of estuaries with catchments predominantly within National Parks and reserves in the state, including those within the Croajingolong National Park and Sand Patch Wilderness Area, e.g. Wingan Inlet, Benedore River, Red River. Other estuaries in the region are within catchments where upper catchments are forested, while lowland areas and floodplains are dominated by agricultural land use, e.g. the Mitchell River.

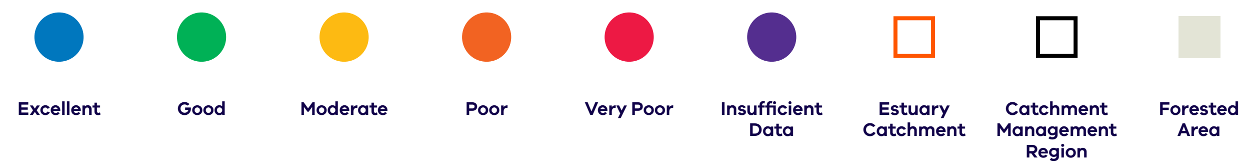
The East Gippsland CMA has undertaken extensive rehabilitation works in coastal catchments including exclusion of livestock from waterways and revegetation. Estuaries are connected to their catchments and catchment rehabilitation can contribute to the protection of estuary water quality, flora and fauna *(see Box 8.1 on p77).*

The East Gippsland catchment region was severely impacted by bushfires during the summer of 2019/20. Coastal catchments were among the areas affected. Data collection for the IEC occurred prior to these bushfires so the IEC does not capture their impact on the region's estuaries *(see Box 2.5 on p35).*

Photo: Thurra estuary
(Sean Phillipson, EGCMA)

8.1 East Gippsland Catchment Region Scores

The IEC assessed 26 estuaries in the East Gippsland catchment region. Twenty seven percent of estuaries were assessed as being in excellent condition *(Table 11, Figure 8)*. Thirty-eight percent were in good condition, 31% in moderate condition and only 4% (one estuary) was in poor condition. Estuaries in excellent condition, which were generally located within National Parks and reserves, had very high cover of native vegetation (i.e. 60-100%). The poor condition estuary was Slaughterhouse Creek, which is dominated by agricultural and horticulture land uses that covers >70% of the catchment.



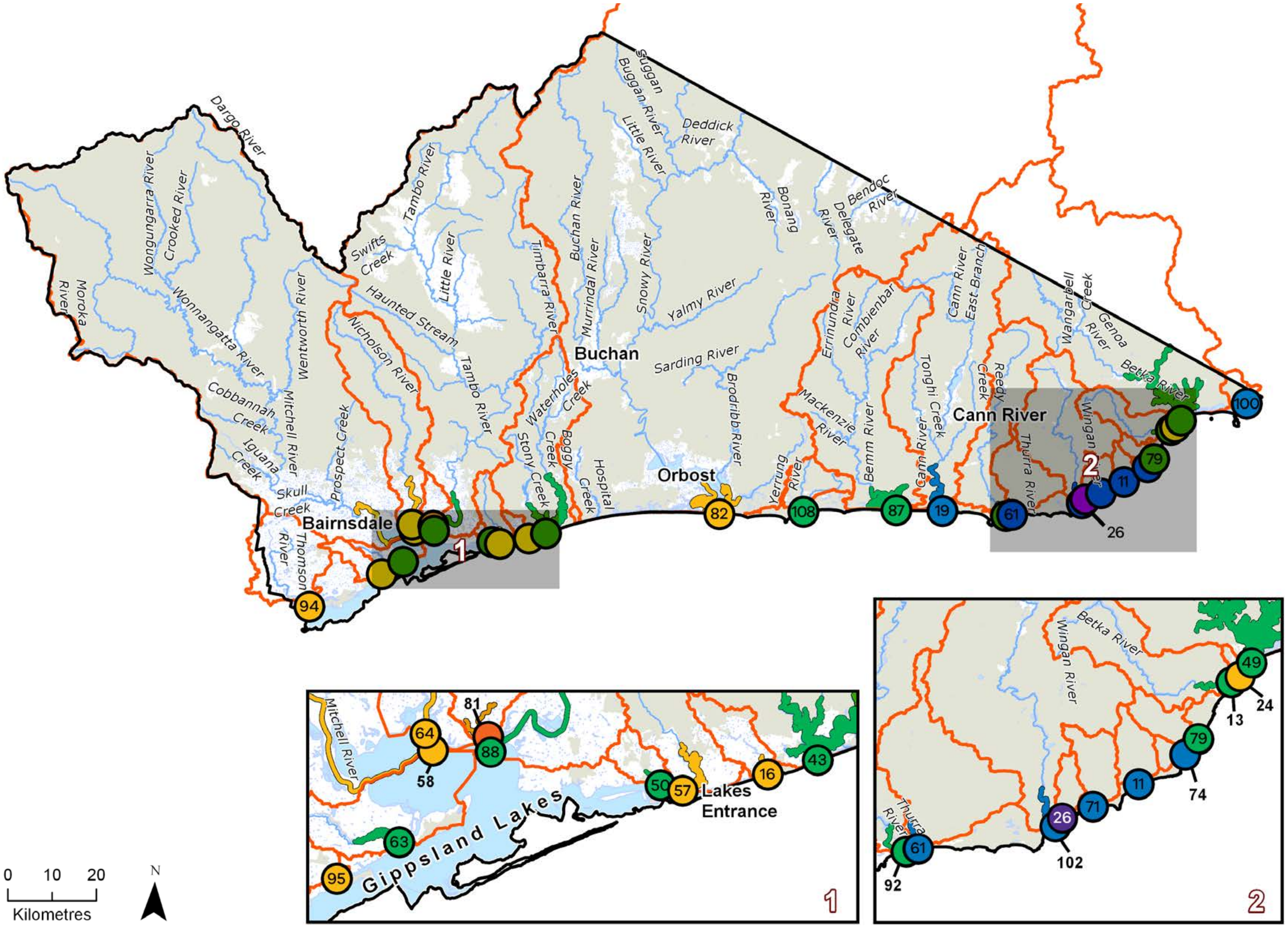


FIGURE 8

Map showing IEC condition classes for estuaries in the East Gippsland catchment region. From west to east, the estuaries are Tom Creek (94), Tom Roberts Creek (95), Newlands Arm (63), Mitchell River (58), Nicholson River (64),Slaughterhouse Creek (81), Tambo River (88), Maringa Creek (50), Mississippi Creek (57), Bunga Inlet (16), Lake Tyers (43), Snowy River (82), Yeerung River (108), Sydneham Inlet (87), Cann River Tamboon Inlet (19), Thurra River (92), Mueller River (61), Wingan Inlet (102), Easby Creek (26), Red River (71), Benedore River (11), Seal Creek (74), Shipwreck Creek (79), Betka River (13), Davis Creek (24), Mallacoota Inlet (49) and Wau Wauku Creek (100).

Table 11: Summary of IEC scores for East Gippsland region

ESTUARY (ESTUARY NUMBER)	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	Condition Class
Tom Creek (94)	9	3	8	5	7	27	Moderate
Tom Roberts Creek (95)	9	5	6	7	7	31	Moderate
Newlands Arm (63)	7	5	10	8	10	36	Good
Mitchell River (58)	9	5	9	5	9	32	Moderate
Nicholson River (64)	8	3	6	8	9	30	Moderate
Slaughterhouse Creek (81)	10	3	2	8	8	24	Poor
Tambo River (88)	8	5	10	9	7	34	Good
Maringa Creek (50)	10	4	7	10	9	36	Good
Mississippi Creek (57)	10	3	9	7	8	32	Moderate
Bunga Inlet (16)	9	5	4	8	6	28	Moderate
Lake Tyers (43)	10	6	9	8	8	38	Good
Snowy River (82)	9	1	10	8	9	31	Moderate
Yeerung River (108)	10	9	10	6	7	39	Good
Sydenham Inlet (87)	9	6	10	5	8	34	Good
Cann River - Tamboon Inlet (19)	9	8*	10	9	9	43	Excellent
Thurra River (92)	10	7	10	10†	6	39	Good
Mueller River (61)	10	10	10	9†	6	41	Excellent
Wingan Inlet (102)	10	9	7	9	9	41	Excellent
Red River (71)	10	10	N/A	10††	N/A	50	Excellent
Benedore River (11)	10	10	N/A	9††	N/A	48	Excellent
Seal Creek (74)	10	10	N/A	10††	N/A	50	Excellent
Shipwreck Creek (79)	10	10	6	N/A	7	37	Good

Table 11: Summary of IEC scores for East Gippsland region (continued)

ESTUARY (ESTUARY NUMBER)	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	Condition Class
Betka River (13)	10	9	10	7	6	39	Good
Davis Creek (24)	10	7	3	9	6	30	Moderate
Mallacoota Inlet (49)	9	5	10	10	8	37	Good
Wau Wauka Creek (100)	10	10	N/A	10††	N/A	50	Moderate

Results for the five sub-indices and the IEC condition class for the sampled estuaries (arranged west to east) within the East Gippsland catchment region. Scores for the sub-indices range from 1 (poorest condition) to 10 (best condition), whilst IEC Score ranges from 5 (poorest condition) to 50 (best condition). NA = not assessed.

*Hydrology sub-index for Cann River based solely on freshwater inflow measure as data were not available to support assessment of marine exchange.

†† Flora sub-index for marked estuaries based solely on fringing vegetation measure. These estuaries were not assessed for submerged vegetation

† Flora sub-index for marked estuaries based solely on fringing vegetation measure. Unable to apply measure for assessing submerged vegetation (i.e. the ratio of macroalgae to total vegetation) as no submerged vegetation was detected within the estuary.

BOX 8.1: REHABILITATION OF COASTAL CATCHMENTS OF EAST GIPPSLAND

Mallacoota Inlet is a large and highly valued estuary in East Gippsland. The Genoa and Wallagaraugh Rivers flow into the estuary from largely forested catchments, but floodplains are used for agriculture. The catchment experienced consecutive major floods in the early 1970's, and following these, large fires spread across the catchment in 1983. After these events, the community raised concerns about the amount of excess sediment entering Mallacoota Inlet. Informed by catchment wide investigation into the sources of the sediment, the EGCMA led a large-scale rehabilitation effort along the floodplain reach of the Genoa River to help improve the condition of waterways across the catchment down to the receiving waters in Mallacoota Inlet. Working closely with local landholders, a program of livestock exclusion fencing, revegetation, weed control and introduction of woody habitat to the river channel has helped improve the condition of the river, and trap and store excess sediment.

Following large scale fires across the Genoa and Wallagaraugh River catchments in the summer of 2019/20 and subsequent rainfall across these burnt areas, water quality deteriorated for a short period in both the rivers and the inlet. Extensive water quality testing throughout the inlet showed that there were no detectable long-lasting impacts, plus no impacts on important local fish or seagrass communities. Upstream intact riparian zones and diverse river channels have helped to protect the important receiving waters of Mallacoota Inlet.

In the East Gippsland catchment region, 27% of the estuaries sampled were in excellent condition, 38% were in good condition, 31% in moderate condition and 4% in poor condition.

8.2 Physical Form

Most estuaries in the East Gippsland catchment region had Physical Form that was unmodified or near unmodified (*Table 11*). Across the region, 59% of estuaries had unmodified Physical Form and a further 38% of estuaries had near unmodified Physical Form. Newlands Arm was the only estuary in the region that had moderately modified Physical Form.

8.3 Hydrology

The Hydrology of estuaries of the East Gippsland catchment region ranged from unmodified to extremely modified (*Table 11*). Twenty-three percent of estuaries were assessed as having unmodified Hydrology, with no interception of runoff in the catchment or alteration of marine exchange at the estuary mouth (e.g. through artificial entrance opening or entrance engineering works). Fifteen percent of estuaries had near unmodified Hydrology.

Fifteen percent of estuaries had moderately altered Hydrology, 27% had considerably modified Hydrology and 19% had extremely modified Hydrology. Estuaries with extremely modified Hydrology included tributaries to the Gippsland Lakes and the Snowy River that have water storages within their catchments that intercept a substantial percentage of runoff, interrupting freshwater inflows to the estuary, and modification of marine exchange.

Delivery of water for the environment was not incorporated into the IEC Hydrology sub-index *(see Box 4.1 on p44)*. In the East Gippsland catchment region, water for the environment is delivered in the Snowy River system.

Photos: Re-establishment of riparian vegetation along the lower Genoa River from 1989 to 2013 (EGCMA)

1989

2009

2013

Photo: Dock Inlet
(Sean Phillipson, EGCMA)

8.4 Water Quality

Water Quality in estuaries of the East Gippsland catchment region was variable, ranging from excellent to very poor, however most estuaries had good or excellent Water Quality *(Table 11)*. Forty-five percent of estuaries had excellent Water Quality and 18% had good Water Quality. Twenty-three percent of estuaries had moderate Water Quality. However, Water Quality issues were detected in some East Gippsland estuaries. Fourteen percent of estuaries in the region had poor or very poor Water Quality. Estuaries with very poor Water Quality included Slaughterhouse Creek and Davis Creek, which had elevated chlorophyll a concentrations indicating excess nutrients in the water column. Turbidity was also elevated. These results likely reflect land use within the catchments of these estuaries *(see Box 2.3 on p31)*, and possible long water residence times so water is not regularly flushed out of the estuary to counter accumulating inputs of nutrients.

8.5 Flora

The condition of Flora varied from poor to excellent among estuaries of the East Gippsland catchment region, however most estuaries had good or excellent Flora *(Table 11)*. Flora was in excellent condition at 24% of estuaries and good condition at 48% of estuaries.

Estuaries in excellent condition included those within the Croajingolong National Park and Sand Patch Wilderness Area, and Mallacoota Inlet. Flora was in good condition at the Nicholson and Tambo River estuaries.

Flora was in moderate condition at 16% of estuaries and poor condition at 12% of estuaries in the region. Estuaries with Flora in poor condition included Sydenham Inlet and two tributaries to the Gippsland Lakes: Tom Creek and the Mitchell River. At the Mitchell River, exotic species within the estuary fringe and submerged vegetation dominated by macroalgae (with little seagrass detected) contributed to the poor IEC Flora sub-index score. At Tom Creek and Sydenham Inlet, submerged vegetation dominated by macroalgae (with little seagrass detected) contributed to the poor IEC Flora sub-index score.

8.6 Fish

The condition of fish assemblages varied from excellent to moderate among estuaries of the East Gippsland catchment region: the region had the highest proportion of estuaries with fish assemblages in excellent or good condition in the state (*Table 11*). Across the region, fish assemblages were excellent in 32% of estuaries, good in 45% of estuaries and moderate in 23% of estuaries.

Estuaries with fish assemblages in excellent condition included Cann River/Tamboon Inlet, Snowy River, Wingan Inlet and some tributaries to the Gippsland Lakes (i.e. Mitchell River, Newlands Arm, Nicholson River and Maringa Creek). In these estuaries, fish assemblages included species that can complete their life cycles within estuaries, species that inhabit the bottom portion of the water column, specialist feeders, and species that migrate between freshwater and marine environments *(i.e. diadromous species - see Box 2.4 on p34)*.

Photo: Mouth of Benedore River estuary (Sean Phillipson, EGCMA)

9. References

Arundel, H.P., Pope, A.J. and Quinn, G.P. (2009). ***Victorian Index of Estuary Condition: Recommended Themes and Measures.*** Technical Report by the School of Life & Environmental Sciences, Deakin University, Warrnambool for the Department of Sustainability and Environment, Melbourne, Victoria.

Barton, J., Pope, A., Quinn, G. and Sherwood, J. (2008). ***Identifying Threats to the Ecological Condition of Victorian Estuaries.*** Technical Report by the School of Life & Environmental Sciences, Deakin University, Warrnambool for the Department of Sustainability and Environment, Melbourne, Victoria.

Cook, P.L.M., Warry, F.Y., Reich, P., Mac Nally, R.M., and Woodland, R.J. (2018). Catchment land use predicts benthic vegetation in small estuaries. PeerJ 6:e4378; DOI 10.7717/peerj.4378.

Deegan, L.A., Finn, J.T., Ayvazian, S.G., Ryder-Kieffer, C.A. and Buonaccorsi, J. (1997). Development and validation of an estuarine biotic integrity index. Estuaries 20, 601–617.

DEPI (2011). ***Index of Stream Condition: the Third Benchmark of Victorian River Condition.*** The State of Victoria, Department of Environment and Primary Industries, East Melbourne, Victoria.

DEPI (2013). ***Improving Our Waterways: Victorian Waterway Management Strategy.*** The State of Victoria Department of Environment and Primary Industries, East Melbourne, Victoria.

DELWP (2016). ***Water for Victoria: Water Plan.*** The State of Victoria, Department of Environment, Land, Water and Planning, East Melbourne, Victoria.

DELWP (2021). ***Assessment of Victoria's estuaries using the Index of Estuary Condition: Background and Methods 2021.*** The State of Victoria, Department of Environment, Land, Water and Planning, East Melbourne, Victoria.

DSE (2005a). ***Index of Wetland Condition, Conceptual Framework and Selection of Measures.*** The State of Victoria, Department of Sustainability and Environment, East Melbourne, Victoria.

DSE (2005b). ***Index of Stream Condition: The Second Benchmark of Victorian River Condition.*** The State of Victoria, Department of Sustainability and Environment, East Melbourne, Victoria.

Elliott, M., Whitfield, A.K., Potter, I.C., Blaber, S.J.M., Cyrus, D.P., Nordlie, F.G. and Harrison, T.D. (2007). The guild approach to categorizing estuarine fish assemblages: a global review. ***Fish and Fisheries*** 8, 241–268.

Frost, A.J., and Wright D.P. (2018). Evaluation of the Australian Landscape Water Balance model: AWRA-L v6. Bureau of Meteorology Technical Report.

Gillanders, B.M. and Kingsford, M.J. (2002). Impact of changes in flow of freshwater on estuarine and open coastal habitats and the associated organisms. ***Oceanography and Marine Biology: An Annual Review*** 40, 223–309.

Hallett, C.S., Valesini, F.J., Kilminster, K., Wells, N.S. and Eyre, B.D., 2019. A rapid protocol for assessing sediment condition in eutrophic estuaries. ***Environmental Science: Processes & Impacts*** 21, 1021-1037.

Harris, G.P. (2001). Biogeochemistry of nitrogen and phosphorus in Australian catchments, rivers and estuaries: effects of land use and flow regulation and comparisons with global patterns. ***Marine and Freshwater Research*** 52, 139-149.

McSweeney, S.L., Kennedy, D.M. and Rutherfurd, I.D. (2017). A geomorphic classification of intermittently open/closed estuaries (IOCE) derived from estuaries in Victoria, Australia. ***Progress in Physical Geography*** 41, 421-449.

Melbourne Water (2018). Understanding the Western Port Environment 2018. The State of Victoria, Melbourne Water, Melbourne, Victoria.

O'Brien, A.L., Dafforn, K.A., Chariton, A.A., Johnston, E.L. and Mayer-Pinto, M. (2019). After decades of stressor research in urban estuarine ecosystems the focus is still on single stressors: a systematic literature review and meta-analysis. ***Science of the Total Environment*** 684, 753-764.

Pérez-Domínguez, R., Maci, S., Courrat, A., Lepage, M., Borja, Á., Uriarte, A., Neto, J.M., Cabral, H., St Raykov, V., Franco, A., Alvarez, M.C. and Elliott, M. (2012). Current developments on fish-based indices to assess ecological-quality status of estuaries and lagoons. ***Ecological Indicators*** 23, 34–45.

Pope, A.J., Barton, J.L. and Quinn, G.P. (2015). ***Index of Estuary Condition Implementation Trial Final Report.*** Report by the School of Life and Environmental Sciences, Deakin University, Warrnambool, for the Department of Environment, Land, Water and Planning, East Melbourne, Victoria.

Scanes, E., Scanes, P. R., & Ross, P. M. (2020). Climate change rapidly warms and acidifies Australian estuaries. ***Nature communications***, 11, 1-11.

Sharley, D., Amos, C., & Pettigrove, V. (2014). Factors affecting the ecology of the Anglesea River. Final Report for the Corangamite Catchment Management Authority.

State Environment Protection Policy (Waters) (2018). ***Environment Protection Act 1970, State Environment Protection Policy (Waters)***, Victoria Government Gazette S499, pp. 1-85, State of Victoria, Melbourne, Victoria.

Stoddard, J.L., Herlihy, A.T., Peck, D.V., Hughes, R.M., Whittier, T.R. and Tarquinio, E. (2008). A process for creating multimetric indices for large-scale aquatic surveys. J***ournal of the North American Benthological Society*** 27, 878–891.

Tagliapietra, D., Sigovini, M. and Ghirardini, A.V. (2009). A review of terms and definitions to categorise estuaries, lagoons and associated environments. ***Marine and Freshwater Research*** 60, 497–509.

Warry, F.Y., Reich, P., Cook, P.L.M., Mac Nally, R. and Woodland, R.J. (2018). The role of catchment land use and tidal exchange in structuring estuarine fish assemblages. ***Hydrobiologia*** 811, 173–191.

VWMS. (2013) Victorian Waterway Management Strategy. The State of Victoria, Department of Environment and Primary Industries, East Melbourne, Victoria.

Woodland, R.J., Thomson, J.R., Mac Nally, R., Reich, P., Evrard, V., Warry, F.Y., Walker, J.P., and Cook, P.L.M. (2015) Nitrogen loads explain primary productivity in estuaries at the ecosystem scale. ***Limnology and Oceanography*** 60, 1751–1762.

10. Appendix

Details of estuaries sampled in the Index of Estuary Condition

Please visit water.vic.gov.au/waterways-and-catchments/riversestuaries-and-waterways/estuaries for a summary of Fish presence/absence and Flora maps for each region.

TABLE A:

Summary of IEC scores, estuary size and catchment land uses for all estuaries assessed for IEC. Estuary length is approximate only, and where barriers exist is the length from the mouth to the barrier. Catchment land use is from Victoria's Land Cover Time Series (2015-2019 period), which classifies the most likely land cover class for each 25m pixel over distinct time periods. Only the nine most dominant land use classes are shown (environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series). No comparable land use coverage data was available for the Tooradin Inlet catchment.

ESTUARY IDENTIFIERS			IEC Scores							Estuary size		Land use (% of catchment)								
REGION	ID	ESTUARY	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	CONDITION CLASS	Catchment area (km²)	Estuary length (km)	Urban area	Exotic pasture grassland	Dryland cropping	Hardwood plantation	Horticulture irrigated pasture crops	Native pasture grassland	Treed native vegetation	Mangrove vegetation	Saltmarsh vegetation
Glenelg Hopkins	33	Glenelg River	10	3	9	6	7	30	Moderate	11970	68.0	0.2	43.6	1.8	7.8	0.7	2.5	26.4	0.0	0.0
	99	Wattle Hill Creek	6	3	10	7	NA	28	Moderate	123	1.9	5.7	64.0	0.0	1.5	7.3	0.4	15.2	0.0	0.0
	86	Surrey River	10	8	10	6	5	34	Good	356	7.7	0.3	41.2	0.0	1.6	1.8	0.1	51.4	0.0	0.0
	30	Fitzroy River	10	7	10	7	6	37	Good	1520	9.8	0.2	52.4	0.3	11.4	1.5	1.2	27.3	0.0	0.0
	29	Eumeralla River	9	6	9	7	6	34	Good	861	8.3	0.2	75.6	0.1	12.7	1.9	1.1	3.0	0.0	0.0
	60	Moyne River	7	2	9	6	7	26	Poor	777	6.8	0.7	90.9	0.1	0.5	1.7	0.5	0.7	0.0	0.0
	52	Merri River Combined	7	6	4	5	6	26	Poor	1042	9.7	1.7	88.4	1.4	0.3	1.8	0.7	0.7	0.0	0.0
	35	Hopkins River	9	4	9	9	4	30	Moderate	8904	9.9	0.6	60.0	19.6	1.0	0.9	4.1	4.2	0.0	0.0
Corangamite	22	Curdies Inlet	10	4	10	5	7	30	Moderate	971	18.5	0.8	83.6	0.0	1.4	2.1	0.1	8.3	0.0	0.0
	18	Campbell Creek	8	7	10	6	5	32	Moderate	77	1.5	1.0	86.9	0.0	2.3	2.0	0.0	6.1	0.0	0.0
	78	Sherbrook River	9	7	10	7	4	33	Moderate	34	1.8	0.6	62.3	0.0	0.1	1.1	0.1	33.5	0.0	0.0
	32	Gellibrand River	9	6	9	6	5	31	Moderate	1150	14.9	0.2	27.9	0.0	4.8	0.7	0.1	61.1	0.0	0.0
	38	Johanna River	10	9	10	7	4	35	Good	39	1.2	0.1	28.0	0.0	11.8	1.7	0.2	51.2	0.0	0.0
	2	Aire River	10	6	6	7	7	32	Moderate	270	8.1	0.0	14.7	0.0	2.0	0.7	0.3	72.3	0.0	0.0
	8	Barham River	10	8	9	7	7	38	Good	80	3.1	0.7	19.7	0.0	0.7	2.0	0.2	71.7	0.0	0.0
	40	Kennett River	9	9	8	7	4	33	Moderate	21	0.7	0.4	0.3	0.0	0.0	0.1	0.1	98.9	0.0	0.0
	104	Wye River	7	10	10	4	NA	34	Good	24	0.5	0.4	0.3	0.0	0.0	0.0	0.1	99.0	0.0	0.0
	84	St George River	9	8	7	7	6	35	Good	34	1.2	0.3	1.7	0.0	0.0	0.0	0.0	97.7	0.0	0.0
	28	Erskine River	4	8	8	7	NA	32	Moderate	30	0.7	1.6	1.8	0.0	0.0	0.1	0.0	96.1	0.0	0.0
	67	Painkalac Creek	8	4	9	9	NA	33	Moderate	61	4.0	1.4	2.7	0.0	0.7	0.1	0.1	93.8	0.0	0.1
	5	Anglesea River	7	4	10	8	2	25	Poor	120	2.7	2.3	1.7	0.0	0.2	0.4	0.5	88.9	0.0	0.0
	83	Spring Creek	7	4	4	9	6	26	Poor	52	2.1	3.1	45.1	0.3	1.4	2.5	3.2	35.3	0.0	0.1
	91	Thompson Creek	7	4	8	8	7	31	Moderate	249	5.5	1.7	72.2	2.3	0.8	2.7	2.2	6.7	0.0	0.3
	9	Barwon River	7	5	6	8	7	31	Moderate	4450	15.1	2.6	51.6	10.1	1.3	1.3	5.3	18.1	0.0	0.1
	36	Hovells Creek Limeburners Lagoon	9	5	9	8	9	37	Good	233	4.9	3.9	21.8	32.3	2.8	1.6	24.2	7.1	0.0	0.1

ESTUARY IDENTIFIERS			IEC Scores							Estuary size		Land use (% of catchment)								
REGION	ID	ESTUARY	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	CONDITION CLASS	Catchment area (km^2)	Estuary length (km)	Urban area	Exotic pasture grassland	Dryland cropping	Hardwood plantation	Horticulture irrigated pasture crops	Native pasture grassland	Treed native vegetation	Mangrove vegetation	Saltmarsh vegetation
Port Phillip & Western Port	48	Little River	9	3	4	6	4	21	Poor	471	3.0	0.6	18.7	27.5	0.1	0.8	29.4	18.2	0.0	0.0
	101	Werribee River	8	2	2	5	6	18	Very Poor	1435	8.3	3.6	21.6	8.4	0.4	2.9	16.7	41.3	0.0	0.0
	80	Skeleton Creek	4	5	6	9	3	22	Poor	97	2.0	24.1	8.1	22.3	0.0	2.3	32.6	1.2	0.0	0.6
	47	Laverton Creek	7	3	10	6	6	27	Moderate	70	3.2	17.7	8.8	22.0	0.0	4.5	23.4	1.2	0.0	0.2
	41	Kororoit Creek	6	6	3	6	8	26	Poor	278	1.6	21.4	14.9	25.0	0.0	2.8	24.1	2.4	0.0	0.1
	107	Yarra River	6	1	10	7	6	24	Poor	5493	22.5	13.4	28.6	1.3	0.1	2.3	5.2	43.0	0.0	0.0
	27	Elwood Canal	1	7	4	NA	1	11	Very Poor	38	1.3	91.3	0.2	0.0	0.0	4.1	0.0	0.6	0.0	0.0
	59	Mordialloc Creek	6	2	8	4	4	19	Very Poor	106	2.8	53.9	10.6	0.4	0.0	16.3	1.7	3.2	0.0	0.0
	68	Patterson River	2	2	9	NA	7	19	Very Poor	580	2.9	46.0	17.2	0.4	0.1	8.7	1.8	17.3	0.0	0.0
	39	Kananook Creek	6	2	9	8	6	26	Poor	99	9.6	49.2	15.7	0.4	0.2	11.4	1.2	10.8	0.0	0.0
	7	Balcombe Creek	9	1	7	7	5	23	Poor	113	2.2	13.1	48.6	0.3	0.5	9.6	3.3	16.1	0.0	0.0
	54	Merricks Creek	8	5	2	9	2	20	Poor	48	2.6	5.1	65.0	0.0	0.6	3.1	0.1	18.6	0.0	0.1
	97	Warringine Creek	10	6	3	10	6	29	Moderate	22	1.9	8.5	51.7	0.0	0.7	10.3	0.6	19.4	0.9	0.7
	98	Watsons Creek	10	5	1	10	7	25	Poor	49	2.9	20.3	38.7	0.6	0.3	17.8	1.8	13.3	1.5	0.6
	20	Cardinia Creek	7	3	7	9	6	28	Moderate	142	5.6	6.5	34.3	0.4	0.1	7.5	2.0	37.6	0.1	0.1
	25	Deep Creek	7	4	6	9	4	26	Poor	213	7.0	8.8	59.4	0.4	0.1	8.7	0.7	17.9	0.1	0.0
	17	Bunyip River	7	3	8	9	4	26	Poor	924	4.2	1.6	49.3	0.0	0.1	2.5	0.3	44.1	0.0	0.0
	105	Yallock Creek	10	5	NA	9	NA	NA	Insufficient data	4	1.4	1.1	85.1	0.1	4.0	2.7	0.4	1.0	0.0	0.1
	106	Yallock Drain	4	4	2	NA	3	15	Very Poor	281	3.0	1.7	90.1	0.1	0.1	4.8	0.2	1.4	0.0	0.0
	45	Lang Lang River	6	4	7	NA	4	22	Poor	416	5.3	1.0	87.5	0.1	0.2	2.8	0.1	6.2	0.0	0.0
	10	Bass River	8	6	2	7	9	27	Moderate	298	8.7	0.6	90.1	0.0	0.4	2.0	0.1	4.1	0.0	0.2
	72	Saltwater Creek	10	6	NA	7	NA	37	Good	19	1.0	6.1	76.8	0.1	0.1	3.5	0.4	6.9	0.0	0.0
	111	Tooradin Inlet	6	NA	NA	9	4	NA	Insufficient data	478	7.6									
West Gippsland	14	Bourne Creek	9	3	4	7	4	22	Poor	12	0.9	0.8	93.6	0.0	0.1	2.1	0.1	0.7	0.0	0.1
	70	Powlett River	8	3	10	6	6	28	Moderate	507	9.0	1.7	89.7	0.0	0.3	2.9	0.1	3.1	0.0	0.0
	103	Wreck Creek	8	2	8	6	3	21	Poor	13	0.6	5.9	76.1	0.0	0.3	5.8	0.0	9.0	0.0	0.0
	73	Screw Creek	10	6	8	9	4	31	Moderate	47	2.1	7.5	78.8	0.0	0.1	5.6	0.2	5.9	0.0	0.0
	90	Tarwin River	7	7	6	4	7	29	Moderate	1610	14.4	0.8	80.9	0.0	1.9	2.8	0.1	9.8	0.0	0.1
	77	Shallow Inlet	8	7	10	6	8	36	Good	129	15.4	1.0	64.3	0.0	0.1	6.2	0.3	10.4	0.3	1.0
	23	Darby River	10	10	10	10	5	41	Excellent	57	1.0	0.0	0.0	0.0	0.0	0.0	1.1	90.7	0.0	0.0
	93	Tidal River	9	9	10	10	7	42	Excellent	25	2.4	0.0	0.0	0.0	0.0	0.0	0.1	98.3	0.0	0.0
	34	Growler Creek	10	10	NA	10	NA	50	Excellent	24	1.2	0.0	0.0	0.0	0.0	0.0	0.0	98.2	0.0	0.0
	75	Sealers Creek	10	10	NA	10	NA	50	Excellent	29	0.8	0.0	0.0	0.0	0.0	0.0	0.0	99.7	0.0	0.0
	56	Miranda Creek	10	10	NA	10	NA	50	Excellent	51	2.0	0.0	0.0	0.0	0.0	0.0	0.4	95.6	0.0	0.0
	21	Chinaman Creek	10	10	NA	10	8	47	Excellent	51	1.8	0.0	0.0	0.0	0.0	0.0	0.1	84.7	0.5	0.3
	66	Old Hat Creek	8	8	2	6	7	26	Poor	28	2.9	0.2	80.8	0.0	0.1	7.2	0.2	7.9	1.0	0.2
	85	Stockyard Creek	7	7	1	6	6	23	Poor	31	1.8	3.1	77.0	0.0	0.4	6.0	0.0	8.9	0.1	0.2
	12	Bennison Creek	7	8	2	6	4	22	Poor	25	2.2	1	77	0	1	4	0	12	1	0
	31	Franklin River	8	8	8	10	6	37	Good	134	6.6	0.2	43.7	0.0	6.3	1.2	0.2	37.6	1.0	0.2
	1	Agnes River	10	8	8	7	9	40	Good	95	5.4	0.1	48.1	0.0	0.7	3.0	0.3	44.0	0.4	0.1
	76	Shady Creek	7	8	2	9	7	28	Moderate	16	1.2	0.2	83.7	0.0	0.2	6.5	0.0	7.0	0.2	0.4
	65	Nine Mile Creek	8	6	10	6	7	34	Good	59	1.4	0.1	65.4	0.0	0.2	2.9	0.7	27.6	0.1	0.1

ESTUARY IDENTIFIERS			IEC Scores							Estuary size		Land use (% of catchment)								
REGION	ID	ESTUARY	Physical Form	Hydrology	Water Quality	Flora	Fish	IEC Score	CONDITION CLASS	Catchment area (km2)	Estuary length (km)	Urban area	Exotic pasture grassland	Dryland cropping	Hardwood plantation	Horticulture irrigated pasture crops	Native pasture grassland	Treed native vegetation	Mangrove vegetation	Saltmarsh vegetation
West Gippsland (cont.)	3	Albert River	8	8	6	9	7	35	Good	420	10.6	0.5	45.9	0.0	3.9	4.1	0.3	31.7	0.4	0.4
	89	Tarra River	8	7	4	7	9	32	Moderate	342	11.6	0.4	35.8	0.0	2.8	4.7	0.4	41.3	0.3	0.4
	62	Neils Creek	10	6	7	5	8	32	Moderate	3	2.2	0.5	31.6	0.1	0.0	42.6	4.2	0.7	0.4	7.1
	15	Bruthen Creek	8	8	6	8	9	36	Good	204	4.0	0.1	30.7	0.0	5.9	3.4	0.5	47.1	0.2	0.5
	37	Jack Smith Lake	6	8	6	5	NA	29	Moderate	258	0.3	0.1	32.2	0.1	4.4	3.3	1.3	50.9	0.0	0.1
	42	Lake Denison	10	6	1	7	NA	24	Poor	19	3.0	0.0	66.4	0.1	0.0	11.5	1.7	3.6	0.0	0.0
	55	Merriman Creek	8	7	9	8	7	37	Good	506	2.5	0.1	26.6	0.0	3.0	1.6	1.5	50.1	0.0	0.0
	46	Latrobe River	10	1	6	10	4	23	Poor	8550	18.9	1.2	24.7	0.2	2.1	4.7	1.6	57.7	0.0	0.1
	44	Lake Wellington Main Drain	6	3	3	8	6	22	Poor	100	5.4	0.9	49.0	0.2	0.0	40.0	3.5	0.4	0.0	0.2
	6	Avon River	7	3	2	10	4	20	Poor	2022	8.6	0.4	15.6	0.1	1.1	5.4	3.6	67.2	0.0	0.0
	69	Pound Creek	10	5	NA	6	NA	NA	Insufficient data	104	2.9	0.3	67.0	0.0	0.1	3.6	0.2	3.4	0.7	0.7
East Gippsland	94	Tom Creek	9	3	8	5	7	27	Moderate	308	2.9	0.3	64.0	0.4	0.5	8.0	7.9	12.8	0.0	0.3
	95	Tom Roberts Creek	9	5	6	7	7	31	Moderate	57	0.9	0.5	63.2	0.4	2.2	4.8	9.5	14.4	0.0	0.1
	63	Newlands Arm	7	5	10	8	10	36	Good	79	4.0	5.5	28.3	0.2	0.1	7.9	4.5	10.1	0.0	0.8
	58	Mitchell River	9	5	9	5	9	32	Moderate	4714	26.2	0.3	7.1	0.0	0.1	1.7	1.7	87.2	0.0	0.0
	64	Nicholson River	8	3	6	8	9	30	Moderate	569	16.4	0.2	8.2	0.0	0.0	1.9	1.4	86.0	0.0	0.1
	81	Slaughterhouse Creek	10	3	2	8	8	24	Poor	52	4.9	1.7	58.4	0.0	0.3	12.6	4.8	16.0	0.0	0.9
	88	Tambo River	8	5	10	9	7	34	Good	2881	17.4	0.1	11.4	0.0	0.0	1.5	4.4	80.2	0.0	0.0
	50	Maringa Creek	10	4	7	10	9	36	Good	13	1.8	1.9	40.5	0.0	0.1	12.3	5.2	33.4	0.1	0.7
	57	Mississippi Creek	10	3	9	7	8	32	Moderate	86	7.0	5.1	8.5	0.0	0.1	3.7	0.8	77.7	0.0	0.1
	16	Bunga Inlet	9	5	4	8	6	28	Moderate	22	1.7	4.0	33.2	0.1	0.1	13.0	1.9	43.0	0.0	0.1
	43	Lake Tyers	10	6	9	8	8	38	Good	577	24.5	0.3	8.6	0.0	0.1	0.9	0.8	86.1	0.0	0.1
	82	Snowy River	9	1	10	8	9	31	Moderate	15599	14.1	0.0	2.8	0.0	0.2	0.5	0.5	37.6	0.0	0.0
	108	Yeerung River	10	9	10	6	7	39	Good	118	3.2	0.0	0.9	0.0	0.0	0.3	0.1	94.8	0.0	0.0
	87	Sydenham Inlet	9	6	10	5	8	34	Good	1143	12.4	0.0	1.3	0.0	0.3	0.3	0.1	96.1	0.0	0.0
	19	Cann River Tamboon Inlet	9	8	10	9	9	43	Excellent	1176	14.4	0.1	2.6	0.0	0.0	1.0	0.1	92.9	0.0	0.0
	92	Thurra River	10	7	10	10	6	39	Good	412	6.1	0.0	0.1	0.0	0.0	0.0	0.0	98.3	0.0	0.0
	61	Mueller River	10	10	10	9	6	41	Excellent	178	5.1	0.0	0.0	0.0	0.0	0.0	0.0	98.5	0.0	0.0
	102	Wingan Inlet	10	9	7	9	9	41	Excellent	444	6.6	0.0	1.2	0.0	0.0	0.1	0.1	97.6	0.0	0.0
	71	Red River	10	10	NA	10	NA	50	Excellent	41	2.3	0.0	0.0	0.0	0.0	0.0	0.0	99.7	0.0	0.0
	11	Benedore River	10	10	NA	9	NA	48	Excellent	34	2.1	0.0	0.0	0.0	0.0	0.0	0.0	99.1	0.0	0.0
	74	Seal Creek	10	10	NA	10	NA	50	Excellent	10	0.5	0.0	0.0	0.0	0.0	0.0	0.0	89.9	0.0	0.0
	79	Shipwreck Creek	10	10	6	NA	7	37	Good	30	1.0	0.0	0.0	0.0	0.0	0.0	0.0	98.2	0.0	0.0
	13	Betka River	10	9	10	7	6	39	Good	141	8.1	0.0	0.0	0.0	0.2	0.0	0.2	97.8	0.0	0.0
	24	Davis Creek	10	7	3	9	6	30	Moderate	4	1.1	4.1	7.6	0.0	2.3	6.2	0.6	74.0	0.0	0.0
	49	Mallacoota Inlet	9	5	10	10	8	37	Good	1950	27.7	0.1	0.7	0.0	0.0	0.2	0.0	39.3	0.0	0.0
	100	Wau Wauka Creek	10	10	NA	10	NA	50	Excellent	46	1.4	0.0	0.0	0.0	0.0	0.0	0.0	63.1	0.0	0.0
	26	Easby Creek	10	10	NA	NA	NA	NA	Insufficient data	18	1.1	0.0	0.0	0.0	0.0	0.0	0.0	99.8	0.0	0.0