Victorian Index of Estuary Condition: Implementation Trial Final Report

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Deakin University, Warrnambool, Australia
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INDEX OF ESTUARY CONDITION
IMPLEMENTATION TRIAL FINAL REPORT:

DECEMBER 2015

Adam Pope, Jan Barton and Gerry Quinn

School of Life and Environmental Sciences

Deakin University

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Authors:

Dr Adam Pope

Dr Jan Barton

Prof Gerry Quinn

School of Life and Environmental Sciences, Deakin University, Warrnambool, Victoria, 3280

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ACRONYMS USED IN THIS REPORT

AHD - Australian Height Datum

AINSE - Australian Institute of Nuclear Science and Engineering

ARI - Arthur Rylah Institute, Department of Environment and Primary Industries

AWRC – Australian Water Resources Council

AVIRA - Aquatic Value Identification and Risk Assessment

CCMA – Corangamite Catchment Management Authority

CMA – Catchment Management Authority

DELWP – Department of Environment, Land, Water and Planning

DEPI – Department of Environment and Primary Industry (since 2014 DEWLP)

DSE – Department of Sustainability and Environment, Victoria (became DEPI now DELWP)

EEFAM - Estuary Environmental Flows Assessment Methodology

EGCMA – East Gippsland Catchment Management Authority

EPA – Environment Protection Authority, Victoria

EVC – Ecological Vegetation Classes

FLOWS – The FLOWS Method, for determining environmental water requirements in Victoria (Sinclair Knight Merz et al. 2002)

GHCMA – Glenelg Hopkins Catchment Management Authority

IEC – Index of Estuary Condition

ICOLL - Intermittently Closed and Open Lakes and Lagoons

ISC – Index of Stream Condition

IWC – Index of Wetland Condition

MAF –Mean Annual Flow

MW – Melbourne Water

NRM – Natural Resource Management

NTU – unit of turbidity (nephelometric turbidity unit)

OEH Office of Environment and Heritage, NSW

WGCMA – West Gippsland Catchment Management Authority

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EXECUTIVE SUMMARY

To improve the management of Victoria's estuaries there is a need for a consistent method for assessing their environmental condition to optimise resource allocation for threat mitigation and asset protection. The Index of Stream Condition (ISC) has been used for decades in flowing freshwater systems for this purpose but is not suitable for estuaries. Arundel et al. (2009), after extensive review, consultation and expert panel workshops, recommended a Victorian Index of Estuary Condition (IEC), using the approach of the ISC, based on existing knowledge and identified conceptual links between estuary assets, threats and ecological responses. The recommended IEC included six themes (physical form, hydrology, water quality, sediment, flora, and fauna) that represent different aspects of ecological condition. A range of measures within these themes were identified to ensure all aspects of ecological condition were comprehensively represented, and in total 18 measures were recommended. Based on existing knowledge these were thought to have links with current condition, changes to condition and to potential manageable threats. For estuaries, the main threats to estuarine condition are likely to be catchment land-use patterns, flow regime, urban and coastal development around the estuary, recreational and commercial use, climate change, pest species and estuary entrance management. The recommended IEC uses a referential approach to assess estuary condition, however the high degree of existing disturbance in Victoria's estuaries and lack of pre-disturbance data will mean that reference or baseline equates often to best available.

The Department of Sustainability and Environment (now Environment, Land, Water and Planning, DELWP) funded a major recommendation from Arundel et al. (2009) to trial the implementation of the recommended IEC methods. Melbourne Water contributed to additional trialling in its jurisdiction. This report presents the results of the IEC implementation trial with its three objectives of data derivation, baseline condition development, and assessment and refinement of the final measures. Data derivation focused on refining sampling protocols, including spatial and temporal replication, collecting and collating data, and refining data recording methods. Baseline condition development included calibrating the scoring ranges to establish the scoring tables which calibrate the condition of each of the measures into five condition bands. Assessment and refinement of the final measures involved developing and refining aggregation methods to calculate condition scores and index scores. In doing this the trial assesses the proposed sampling methodologies from Arundel et al. (2009) and whether the methods were applicable state-wide. It assesses and delineates zonation and subestuaries for practicality and efficiency of sampling. It also establishes or confirms score baselines, scoring methods and score confidence metrics for each measure using existing and new data. The implementation trial represents over four years of effort in collating and interpreting existing data, three intensive summer field sampling seasons across the Victorian coastline, and a number of measure-specific pilot studies. The majority of the trial was conducted by researchers at Deakin University, with the fish and bird measures in the fauna theme developed and evaluated by two research teams from the Arthur Rylah Institute. The results of the faunal research are summarised in this report.

This report presents the approaches used in determining baselines, scoring and score confidence for 16 measures in five themes (physical form, hydrology, water quality, sediment and flora). It also presents the approach used to aggregate measure scores within and between all six themes, including fauna (fish), and presents some insights into the current condition of Victorian estuaries. Score confidence is an important addition to the IEC which is not currently part of the ISC. It allows the spatial and temporal suitability of the data used to score a measure to be assessed as either high, moderate or low confidence. This allows users of the IEC to interpret the reliability of the score and relative risk of making decisions based on it.

At the beginning of the implementation trial the Deakin team visited and interviewed staff at the coastal Catchment Management Authorities (CMA's) and Melbourne Water to discuss the data needs of the trial, and to identify and locate any suitable existing data. The information gathered through this process is included as an appendix in this report. Unfortunately but not unexpectedly, there were little existing suitable data across multiple estuaries let alone across the entire coast. One of the best sources of multi-estuary data was from the now discontinued Glenelg Hopkins CMA Estuary Water Quality Monitoring Program, where the water column was sampled in multiple sites in five estuaries monthly for seven years. In addition, estuary water depth was recorded with depth loggers in these estuaries from 2005, adding considerable value to the staff and volunteer mouth-state observations. Melbourne Water also sampled surface waters within six estuaries. Estuary mouth-state observations from volunteers in the EstuaryWatch program in the Corangamite CMA were also useful along with their water quality monitoring in four estuaries.

For the implementation trial one hundred and one estuary mouths, current and natural heads, and fluvial and estuarine catchments have been spatially defined. Field sampling in 55 estuaries, and their subestuaries, allowed the definition of the upper, middle and lower estuarine zones, as well as the collection of depositional sediment size data and water depths. It also allowed the comparison of water clarity in 55; surface dissolved oxygen in 53; diurnal oxygen sags in 45; bank erosion in 48; microphytobenthos biomass in 41; and phytoplankton biomass in 44 estuaries. Data collected and collated as part of the trial allowed the comparison of modification of estuary extent in 67, modified freshwater flow in 101, sediment load in 56, and marine exchange in 85 estuaries.

Two workshops were held during the trial to help identify baseline conditions and scoring approaches. Baseline condition, also known as reference condition, is a conceptual model of how an estuary should be under realistic minimal human activity. Numerous ways were used to define baselines which reflected the level of knowledge or availability of data for a particular measure. In order of decreasing levels of knowledge or data, baselines were derived from: natural condition (pre-European); historical data; current state-wide data (best available); current individual estuary data; modelling of past conditions; and expert opinion. Identifying a baseline condition of each measure allowed condition bands or score thresholds to be identified or derived. This was done based on available data and known conceptual threat/impact models or ecological thresholds from the literature. An individual measure is scored based on deviation from the baseline into five categorical condition bands (5 = excellent, 4 = good, 3 = moderate, 2 = poor and 1 = very poor).

Thirteen measures across the six themes have been recommended for the first formal IEC program. These measures are Sediment Load, Upstream Barriers and Lateral Connectivity in the Physical Form theme with Changed Bathymetry not being recommended for the first formal IEC as it needs substantial development. Marine Exchange and Freshwater Flow modification measures are recommended for the Hydrology theme. There needs to be substantial development before there is a viable method to measure modification of the Salinity Regime throughout an estuary even though this is seen as a fundamental measure for the IEC. Both Water Clarity and Dissolved Oxygen measures were recommended for the Water Quality theme and their scoring informed by the Riverine Estuary Objectives developed by EPA. Sediment Particle Size and Bank Erosion were recommended for the Sediment theme although both need some further work. The Sediment Respiration Rate measure was trialled in four estuaries but not recommended as suitable for the IEC due to its high cost and level of expertise needed. Aquatic plants extent change and blooms are recommended together as two parts of an Aquatic Plants measure, Fringing Macrophyte extent and condition as another and Phytoplankton biomass as the final measure in the Flora theme. Microphytobenthos biomass was not recommended for the first formal IEC as substantial more work needs to be done to establish baselines and relevant scoring.

The temporal requirements for undertaking data collection or derivation for a formal IEC assessment are not arduous for most measures. Ten of the recommended measures need to be sampled or derived once every eight year assessment period. One additional measure, Aquatic Macrophytes, needs to be sampled in the late summer-early autumn twice in the eight year assessment period. It is suggested that macroalgae component of this measure could be sampled at the same time but this needs more development. Three measures need to be sampled regularly throughout the entire IEC assessment period. Both measures in the water quality theme, Turbidity and Dissolved Oxygen need to be sampled monthly at multiple sites within the estuary. This is also the case for the Phytoplankton biomass in the flora theme. One measure from the hydrology theme, Marine Exchange a) mouth openings needs to be monitored continually and depth loggers have been recommended. The other part of the Marine Exchange measure, b) structures and behaviours, in permanently open estuaries requires recording dredge volume and frequency. It is recommended that the data should be obtained through the authority that commissions the dredging through a formal arrangement.

The spatial sampling requirement within an estuary varies between measures and themes. Data are collected or derived for the head of the estuary for Sediment Load, Upstream Barriers and Freshwater Flow dam density, and for the mouth of the estuary for Marine Exchange. All lagoons and riverine sections (main channel and tributaries) require three sites each for Turbidity, Dissolved Oxygen and Bank Erosion. The latter measure needs further development so that it can be assessed for the entire estuary, as for Lateral Connectivity. All riverine sections need to be assessed for Freshwater Flow ISC hydrological modification. Particle Size is sampled in the upper and middle zones of each subestuary (tributary) and in the lower zone above the mouth. Aquatic Flora macroalgae and macroalgal blooms are tentatively suggested to be collected in the same spatial arrangement but both of these parts of the measure need further development. Phytoplankton and Fish are also recommended to be collected in the upper, middle and lower zones.

Individual theme scores are calculated by averaging the scores of the measures included in the theme. Score confidence is based on the average of the measure confidence (Low =1, Medium = 2, High = 3) with a confidence of zero included in this average for missing measures. For the physical form theme, 23 estuaries, predominately from the east of the state, could not be scored because of lack of data. The majority of estuaries scored were in excellent to moderate condition, however the score confidence was only medium to low. For the hydrology theme, all 101 estuaries could be scored, with most having good to medium score confidence. Nine estuaries, predominately in the east of the state, were scored as having excellent hydrological condition. Eighteen estuaries were scored as having very poor hydrological condition, these estuaries were spread across the state with a concentration in the central part of Victoria. Only 55 estuaries could be scored for the water quality theme, with most estuaries in the two Gippsland CMA regions lacking adequate data. Of the estuaries scored, only one, Fitzroy River, had excellent water quality with most having either good or moderate water quality. Four estuaries, spread across the coast, scored as having poor water quality. One estuary, Bass River in the central region, had very poor water quality. The majority of estuaries had poor water quality score confidence reflecting the lack of appropriate water quality monitoring in Victoria's estuaries. Forty-eight estuaries were scored in the sediment theme based on the single measure of bank erosion. The distribution of scores was reasonably even around the middle score ranges right across the coast with no estuaries scoring excellent or very poor. The majority of estuaries could be scored with high to medium confidence. Forty-four estuaries could be scored for the flora theme, mostly based on the phytoplankton measure using snapshot data. The majority of estuaries were not able to be scored because of lack of data from the central and east coast. Of the estuaries scored, only six scored as very poor, seven as poor, 16 as moderate and 11 as excellent. All estuaries were scored with low confidence for the flora theme due to lack of temporal data. Individual estuary scores for fauna were not available for incorporation into this report.

To calculate an overall IEC score for an estuary, at least four out of the possible six themes are needed, and must include water quality and at least one of the biological themes of flora or fauna. Like the individual measure and theme scores the overall IEC estuary condition score and score confidence is based on averaging the theme scores. All themes contribute equally to the overall IEC score with no weighting. The overall IEC score assigns an estuary to one of five categorical condition bands like the scoring of individual measures or themes. This enables the direct comparison of estuary condition across the state once every assessment period, which is proposed to be every eight years. From the overall IEC score it is possible to drill back down to individual theme and measure scores to identify their contributions to the overall score, which will be important for identifying appropriate management actions.

It was not possible to score all measures for any one estuary, although three estuaries, Anderson Inlet, Anglesea River estuary and Wingan Inlet were scored for nine of the ten measures as part of the implementation trial. Forty-two estuaries were scored for seven or more measures and a total of forty-one estuaries could be scored for all five themes assessed in this trial implementation. Considerable additional data (especially in the water quality and flora themes) are needed to score more estuaries across the state. Given limited resources and data, effort was made to maximise the use of all existing and collected data, even though it might be limited spatially or temporally, through developing scoring methods and associated confidence levels that allow a range of data sources and volumes to be used. Further data collection and analyses are needed before being able to determine if scoring of particular measures should be modified when applied to different ‘types’ of estuaries. While many data gaps were able to be filled during the implementation trial, the process identified further data that if collected would be valuable in extending current analyses and interpretation.

The 13 measures recommended from this implementation trial for the first formal IEC program are suitable for state-wide application, for the assessment in all Victorian estuaries. A summary of the recommendations from the implementation trial, including future research and data needs, are presented at the front of this report, with more detail given in the body of the report. Individual measures are discussed and summarised across the state by CMA region in the body of the report, individual estuary scores are included in the appendices. Individual theme scores are also summarised in the body of the report.

Figure 1. ARI fish sampling in the lower Little River 2010.

1 Recommended IEC from Implementation Trial

The following section outlines the recommended Index of Estuary Condition (IEC) for the first formal IEC program. Data collection design and methods, scoring and estimates of score confidence, and baselines (also known as reference condition) for assessing condition change have been recommended for at least two measures in each of the six themes for the first formal IEC program (Table 1 and Table 2). Detailed discussion and scoring of individual estuaries, where the appropriate data were available, is given in the body of this technical report. A summary of the estuaries with data, and the estuaries without data by Catchment Management Authority (CMA) for the thirteen recommended measures is given in Table 3. This chapter represents a standalone summary of the measures, whether they are recommended as they are, or with further development, or not recommended for the first formal IEC in priority estuaries as identified in recent regional waterway strategies.

Any tool that assesses condition of an ecosystem needs clearly defined spatial boundaries and scales at which it can be applied (Table 1). For the IEC, the head of the estuary is defined as the upper extent of bottom saline water from field assessments in low flow autumn period or from previous studies, and the mouth is the extension of the coastline from one bank to the other (Barton et al. 2008). A tributary of a main IEC estuary is included as a subestuary if it has variable salinity due to the mixing of marine and freshwaters over greater than 1km in length before it joins the estuary. An estuary can have none or numerous subestuaries. Lagoonal or riverine sections of estuaries, analogous to reaches in the ISC, are assessed independently of each other. Some of the measures can be scored for individual sections while others can only be scored for the estuary as a whole (but can then be applied to each section, Table 1). For measures where sampling along the whole estuary is necessary, estuaries were divided into three longitudinal zones (lower, middle and upper) based on geomorphology and vegetation (Table 2). Subestuaries, if present, were zoned using the same criteria, with each estuary having only one lower zone associated with its mouth. Each estuary, subestuary and section has been designated a hierarchical number. All the spatial information necessary to design sampling programs in priority estuaries is available on the updated Victorian estuary GIS.

Figure 2. Fringing macrophytes in Painkalac Creek.

Table 1. Summary of recommended measures, methods and baseline types for the first formal IEC program.

Theme	Measure	Method	Baseline
Physical Form	Sediment load	modelled proportion of pre-European sediment delivery to estuary	modelling of past conditions
	Upstream barriers	% area of estuary affected by instream barrier	natural/pristine condition (pre-European)
	Lateral connectivity	% estuary perimeter that has artificial structures & naturalness of lateral wetland connection	natural/pristine condition (pre-European)
Hydrology	Marine exchange:		
	-(a) mouth openings	% of mouth openings artificial	modelling of past condition
	-(b) structures & behaviours	history of dredging, number of training walls, presence of minor structures, artificial increase in marine exchange of 'parent system'	natural/pristine condition (pre-European)
	Freshwater flow		
	-(a) ISC Hydrology modification score	ISC hydrological modification score	modelling of past conditions natural/pristine condition (pre-European)
	-(b) catchment dam density	megalitres of storage per km^2 for the entire catchment	
Water Quality	Water clarity (surface & bottom waters)	% turbidity exceeding EPA (2010) estuary water quality median & single sample guidelines	current state-wide data (best available)
	Dissolved oxygen (surface & bottom waters)	dissolved oxygen samples exceeding EPA (2010) estuary water quality median & single sample guidelines	current state-wide data (best available)
Sediment	Particle size	% increase in fine sediment in depositional zones (<125 µm)	current individual estuary data
	Bank erosion	ISC 2004 bank erosion method	expert opinion
Flora	Aquatic flora		
	-(a) macrophytes	% change in aquatic macrophyte extent from historical	historical data/expert opinion
	-(b) macroalgae	% cover change from historical	current state-wide data (best available)
	-(c) macroalgal blooms	% of estuary with excessive macroalgal growth (blooms)	current state-wide data (best available)
	Fringing macrophytes	extent & condition	historical data/expert opinion
	Phytoplankton biomass	chlorophyll *a*	current state-wide data (best available)
Fauna	Naturalness of fish:		
	-(a) structural	guild based multi-aspect measure incorporating the proportion & number of taxa of six guilds	best available data
	-(b) functional	guild based δ15N of fish in the assemblage	best available data

Table 2. Summary of the spatial and temporal replication needed for the first formal IEC program.

Theme	Measure	Spatial scale	Temporal replication
Physical Form	Sediment load	Estuary (head)	Eight yearly
	Upstream barriers	Estuary (head)	Eight yearly
	Lateral connectivity	Section (3 validation sites)	Eight yearly
Hydrology	Marine exchange:		
	-(a) mouth openings	Estuary (mouth)	Continuous & event
	-(b) structures & behaviours	Estuary (mouth)	Event
	Freshwater flow		
	-(a) ISC Hydrology modification score	Section (tributary heads)	Eight yearly
	-(b) catchment dam density	Estuary (head)	Eight yearly
Water Quality	Water clarity (turbidity)	Section (3 sites)	Monthly
	Dissolved oxygen:		
	vertical profile	Section (3 sites)	Monthly
Sediment	Particle size	Zone (with depositional area)	Eight yearly
	Bank erosion	Section (3 validation sites)	Eight yearly
Flora	Aquatic flora		
	-(a) macrophytes	Estuary or Section (large systems)	Twice/eight years, late summer-early autumn
	-(b) macroalgae	Zone*	Eight yearly (summer or quarterly*)
	-(c) macroalgal blooms	Zone*	Monthly & event
	Fringing macrophytes	Zone *	Eight yearly
	Phytoplankton	Zone (3 sites)	Monthly
Fauna	Naturalness of fish:		Eight yearly, autumn
	-(a) structural	Zone (3 sites)	
	-(b) functional	Zone (3 sites)	

*to be developed

Table 3. Summary of estuaries with data, and estuaries without data by Catchment Management Authority (CMA) for the thirteen recommended measures. GH= Glenelg Hopkins, C = Corangamite, MW/PPWP = Melbourne Water / Port Phillip Western Port, WG = West Gippsland, EG = East Gippsland.

Theme	Measure	# of estuaries with data	# of estuaries/CMA without data				
			GH	C	MW/ PPWP	WG	EG
Physical Form	Sediment load	56	0	8	9	16	12
	Upstream barriers	67	0	1	4	18	11
	Lateral connectivity	1	8	17	22	27	26
Hydrology	Marine exchange:						
	- mouth openings (a)	37	0	5	2	4	5
	- structures & behaviours (b)	49	0	0	0	0	0
	Freshwater flow						
	- ISC Hydrology modification score (a)	59	0	2	11	16	13
	- catchment dam density (b)	42	0	0	0	0	0
Water Quality	Water clarity (turbidity)	55	2	3	8	18	15
	Dissolved oxygen:						
	vertical profile	51	3	5	12	18	15
Sediment	Particle size	43	4	8	11	20	15
	Bank erosion	48	2	3	9	20	16
Flora	Aquatic flora						
	- macrophytes (a)	4	8	15	22	28	24
	- macroalgae (b)	0	8	17	22	28	26
	- macroalgal blooms (c)	0	8	17	22	28	26
	Fringing macrophytes	1	8	17	22	27	26
	Phytoplankton	44	3	3	17	18	16
Fauna	Naturalness of fish:						
	- structural (a)	31	5	10	11	22	22
	- functional (b)	31	5	10	11	22	22

1.1A PHYSICAL FORM THEME

Alterations to estuary physical form are relatively common and can influence ecological condition both directly and indirectly, and via multiple pathways. The physical form theme addresses large scale processes such as gross changes in bathymetry and sediment loads from catchments. Alterations to the physical form of an estuary may include the removal or addition of particular habitat types and changes in the timing and rate of movement of plants and animals between habitats.

Three measures, sediment load (2), upstream barriers (3) and lateral connectivity (4) are recommended, with some minor development, for the first formal IEC. The fourth measure, changed bathymetry, needs further substantial development before it can be used.

Changed bathymetry (1): not recommended, needs improved methods

Changed bathymetry = changed bathymetry in depositional locations

Baseline = best available data

The inclusion of this measure eventually in the IEC is important, but with the current techniques for measuring it is too intensive and expensive for the IEC. It is hoped with future development of remote sensing (both aerial and water-based) that allows mapping, in often turbid environments and in both large and small systems that the bathymetry of the entire estuary could be mapped once every IEC reporting period.

Future developments:

- Assess remote sensing (both aerial and water-based) methods for mapping the entire estuary bathymetry, in often turbid environments and in both large and small systems.
- Assess if ground truth sampling for this measure could be incorporated with aquatic vegetation mapping.
- Assess if ground truth sampling could be incorporated with bank erosion and fringing macrophytes, if an improved form of LiDAR is developed.

Sediment load (2): recommended with minor development of new, higher resolution modelling

Sediment load = modelled proportion of pre-European sediment delivery to estuary

Baseline = modelling of past conditions

This measure requires modelling of natural loads, and modelling and/or measurement of current loads into the estuary from the catchment once every IEC reporting period (Table 4). This is done for the main estuary and any tributary subestuaries. Contextual information is provided by the history of sedimentation in an estuary and its catchment, which also relates to the measures of changed bathymetry and sediment particle size. The implementation trial used the modelled loads from the work of Prosser et al. (2001) for the National Land and Water Resources Audit (2002) at the estuary and sub-estuary level. Current score confidence is low due to the age of the available data, the low resolution and that the modelling was based on fluvial rather than estuary response.

Table 4. Scoring for changed sediment load.

Modelled proportion of pre-European sediment delivery to estuary	IEC Score
1	5
1 < or = 5	4
5 < or = 10	3
10 < or = 20	2
>20	1

Future developments:

- Reassess measure with sediment load data that was derived specifically for estuaries.
- Reassess measure with newer and higher resolution sediment load modelling.
- Reassess measure with sediment load modelling that is more sensitive to changed load in the smaller estuary catchments.
- Score confidence should be developed.
- Assess the effect of estuary maturity (*sensu* Roy et al. 2001) in setting score thresholds.
- Assess effects of catchment geology and estuary shape on estuary response to increased sediment load.

Upstream Barriers (3): recommended, some on ground survey needed in some small Gippsland estuaries

Upstream barrier = % area of estuary affected by instream barrier

Baseline = natural/pristine condition (pre-European)

The upstream barriers measure requires the identification of the presence of anthropogenic barriers to upstream movement of water or biota in addition to their location relative to the estimated natural upstream limit of the estuary once every IEC reporting period. This is done throughout the main estuary and any tributary subestuaries.

A subset of what were originally freshwater ecosystems are now functioning as estuaries. Where no historical head existed, its position is estimated at the likely location had there been a marine influence downstream. Similarly, where natural barriers have been removed (e.g. Yarra River estuary) the system is assessed as per other systems according to the new longitudinal extent.

Scoring is related to presence/absence, distance of the barrier downstream from the 'natural head', permanency of the barrier and to the degree to which the barrier restricts movement of biota (e.g. weir vs sand slug, Table 5). In systems with more than one subestuary, scores were aggregated using the percentage of length affected as a proportion of the combined length of all subestuaries. Score confidence relates the accuracy of the information used to assign historical and current head locations (Table 6) and the overall estuary score confidence the degree to which the estuary is covered (Table 7).

Table 5. Scoring scheme for upstream barriers used for subestuaries and estuaries.

	IEC score	
% of estuary length affected	Intermittent or selective interference with movement of biota or water	Completely blocked movement of biota or water
0%	5	
>0-5%	5	4
>5-25%	4	3
>25-50%	3	2
> 50%	2	1

Table 6. Score confidence criteria for upstream barriers at the subestuary level, associated with information used in assigning historical head location and current head location. Measured: accurately located through field observations including salinity depth profiles upstream and downstream; Estimated: located through field observations, possibly including salinity profiles but position less accurate or variable; Derived: position located using elevation and morphology but typically no field observations.

Confidence	Current position	Historical: Documentation	Historical: Elevation/morphology
High	Measured or Estimated	Accurate, clearly located position of saltwater or tidal limit, including natural barriers	Substantial natural rise in bed of waterway observed upstream of barrier. Specific geographic feature that would limiting upstream extent of estuary mapped
Medium	Measured or Estimated	Partial, (eg location approximate or degree of tidal/saltwater restriction uncertain)	Rise in bed observed but some doubt to exact location of salt water limit
Low	Derived	None or very limited	General vicinity of likely barrier identified but detail of bedform unknown
Unknown	Presence/absence of barrier not known		

Table 7. Score confidence criteria for the upstream barriers measure at the estuary level (where >1 subestuary).

Confidence	Criteria
High	>75% of subestuaries scored at medium or high confidence
Medium	<75% but >25% including major subestuaries scored at medium or high confidence
Low	< 25% of subestuaries scored OR low confidence for subestuary scores
Unknown	Presence/absence of barrier not known in any subestuary

Future developments:

- Establish the current heads of all estuaries in Victoria with an emphasis on those in west and east Gippsland CMA regions. This would require physically walking the estuary and checking the upstream extent of saline intrusion under low flow or any artificial barriers in these typically smaller systems.
- Assess the type and the % of habitat affected by altered upstream extent and the impact this may have on any critical processes or listed biota.

Lateral connectivity (4): recommended, further development of scoring & most estuaries need scores derived.

Lateral connectivity = % estuary perimeter that has artificial structures & naturalness of lateral wetland connection

Baseline = natural/pristine condition (pre-European)

Lateral connectivity is about linkages across the estuarine shoreline, the presence of fringing habitat and the natural movement of materials and biota between those habitats and the central water body. This is assessed in estuary sections, lagoon or riverine.

Lateral connectivity requires the measurement of the percentage of the estuary perimeter comprising artificial structures such as seawalls, levee banks, jetties, bridges, platforms once during the IEC reporting period (Table 8). This can be derived from two existing GIS layers, Coastal Levees and Vicmap Elevation (Coastal 1m DEM and 0.5 m Contours). These derivations need to be ground truthed with three random sites in each section, this can be done from field photos and descriptions were collected as part of the implementation trial (Table 9).

It was outside the resources of the implementation trial to derive this measure for more than one estuary, so the scoring is a simple three point system that needs to be developed further. The connectivity of artificial wetlands that have value for flora and fauna and good water quality as identified as under the Index of Wetland Condition should be included.

Table 8. Scoring for change to estuary lateral connectivity.

% estuary perimeter that is an artificial structure & wetland connectivity to estuary	IEC Score
0% artificial structures AND EITHER fully connected OR No wetlands exist.	5
1-15% artificial structures OR less than natural connection;	3
>15% artificial structures OR no longer connected	1

Table 9. Score confidence for estuary lateral connectivity.

Confidence	Criteria
High	Structures mapped throughout estuary with ground-truthing, presence & connectivity of wetlands past & present well known
Medium	Structures partially mapped, including some ground truthing. Presence & connectivity of wetlands based on limited data requiring inference.
Low	Extent & presence of structures inferred with no ground truthing. Presence or connectivity of wetlands entirely inferred.

Future development:

- Derive the percentage of the perimeter compromised by artificial structures for all estuaries from Coastal Levees and Vicmap Elevation GIS layers, ground truth or use available photos.
- Refine the measure after the scoring of more estuaries, especially compare very poor score to NSW equivalent.
- Assess the impact of altered lateral connectivity to critical estuarine processes or listed biota.
- Focus on the alteration of connectivity of wetlands to the estuary. This should be done with the revised 1750s wetlands layer and assessment of wetland connectivity alteration under the Index of Wetland Condition.
- Incorporate fringing macrophyte (extent) and the types of structures present.
- Assess remote sensing methods that might improve resolution or decrease costs for assessing changes in lateral connectivity. In particular LiDAR remote sensing methods developed for stream banks, whole of estuary video surveys and or mapping or aerial photo validation with small remote controlled drones with a camera.

1.1B HYDROLOGY THEME

Alterations to hydrology of estuaries are common. Changes to both freshwater and marine inputs alter many aspects of the physical and chemical environments of estuaries. Key changes are to the salinity regimes and biological connectivity. Changes in the relative amounts and timing of freshwater and marine waters entering an estuary can alter the fundamental nature of an estuary.

Two measures, marine exchange (5) and freshwater flow (6), are recommended for the first formal IEC. Although the third measure, salinity regime (7), is not recommended for use as it needs substantial further development, this development should be a high priority as it is a fundamental characteristic of estuaries with great importance for estuarine organisms.

Marine exchange (5)

To assess the condition of estuaries in relation to modification of marine exchange, data needs to be collected at the estuary mouth, with different methods used for intermittently and permanently open estuaries.

Marine exchange 5a) intermittently open mouths: recommended with minor development to improve scoring

Marine exchange (5a) for intermittently open estuaries = % of mouth openings artificial

Baseline = modelling of past condition

This measure requires the recording of all openings, whether natural or artificial, over the entire eight year IEC reporting period for the calculation of the percentage of artificial openings for this period (Table 10). Score confidence relates to accuracy of all openings being recorded (Table 11).

Should an artificial opening take place primarily for the benefit of the estuarine ecosystem following an EEMSS-based assessment it may be disregarded in scoring.

Table 10. Scoring for % of estuary mouth openings that are artificial over the eight year reporting period.

% openings artificial	IEC Score
0%	5
0<50%	3
>50%	1

Table 11. Score confidence criteria for the IEC mouth opening score.

Confidence	Criteria
High	Artificial openings & water height before opening recorded, water depth logged. Regular site visits record the three estuary mouth states & have been related to logged water height. OR System never artificially opened.
Medium	Artificial openings & water height before opening recorded. Regular site visits record estuary open or closed mouth state.
Low	Artificial openings recorded
Unknown	Unable to establish if data exist

Future development:

- Install depth loggers in artificially opened estuaries: Hopkins, Merri, Barham, Kennett, St George, Erskine, Painkalac, Anglesea, Thompson Balcombe, Powlett, Merriman, Lake Tyers, Snowy and Mallacoota Inlet.

- Improved recording of both artificial and natural mouth opening durations is needed for a large number of intermittent estuaries to be able to improve scoring.
- Simplify and standardise the field based collection of mouth state data (open, perched or closed) to minimise inter-operator variability.
- Incorporate estuary water height (measured as Australian Height Datum, AHD) prior to both artificial and natural opening into this measure. Currently, this is best done by installing telemetric water depth data loggers to allow assessment of all mouth openings and states.
- Compare and assess the AHD water level at artificial vs natural openings to derive more specific scores. These should be combined in a matrix that weights artificial openings at low elevations as worse for estuarine condition.
- Identify natural opening regime for each artificially opened estuary. Assess whether this could be done with modelling of natural mouth opening frequency to determine the percentage time the entrance is artificially opened compared to natural.
- Assess the applicability of remote sensing techniques for determining the frequency and duration of marine exchange for estuaries that are not artificially opened.

Marine exchange (5b) for permanently open estuaries: recommended with minor development of scoring

Marine exchange (5b) for permanently open estuaries = history of dredging, number of training walls, presence of minor structures, artificial increase in marine exchange of 'parent system'

Baseline = natural/pristine condition (pre-European)

This measure requires the identification of structures and collection of data from dredging events that increase marine exchange to be collected throughout the IEC reporting period. At present the scoring proposed is a simple three point system (Table 12). The score confidence changes with the level of knowledge about the presence or occurrence of mouth modification and its effectiveness. The score confidence changes with the level of knowledge about the presence or occurrence of mouth modification and its effectiveness (Table 13).

Table 12. Scoring for mouth exchange in permanently open estuaries.

Criteria	IEC Score
Essentially natural marine exchange: Entrance not dredged & no training walls or other structures AND entrance not artificially constructed AND no major modification to marine exchange of 'parent' estuary where applicable	5
Some modification: No dredging of entrance BUT minor structures at entrance OR artificially constructed entrance OR major increase in marine exchange of 'parent' system	3
Entrance dredged OR training walls present	1

Table 13. Score confidence criteria for of mouth exchange in permanently open estuaries.

Confidence	Criteria
High	Presence of structures/dredging documented & effective in maintaining marine connectivity. Absence of minor structures & lack of dredging documented.
Medium	Score reduction based on major increase in marine exchange at 'parent' estuary mouth. Absence of minor structures based on map layer only.
Low	Structures known to be ineffective. Possible undocumented dredging.
Unknown	Unable to establish if data exist

Future development:

- Develop scores related to the frequency and degree of increased exchange through the scale of dredging activity or alteration through built structures.
- Quantify of the degree of increased marine exchange with dredging. Implement information agreements with the responsible port authority or dredging agent so that quantitative data (frequency and volume, or number of days of operation and capacity of the dredge, or how much has been spent on dredging) are collected and able to be analysed.
- Increase resolution by including temporal components.
- Specific research into the ecological effects of increased marine exchange, how important are the amount, frequency and duration of change as well as the sensitivity of existing biota to that change.

Freshwater flow modification

Where available the Victorian Estuary Environmental Flows Assessment Methodology (EEFAM) for determining flow requirements for estuaries should be used to assess modification to freshwater flow (Lloyd et al. 2012). However EEFAM has only be applied to three estuaries so the preferred method for most Victorian estuaries is (a) the ISC hydrology sub-index score immediately upstream of the estuary (Arundel et al. 2009). Where this is not available, the degree of hydrological change needs to be determined by (b) determining dam volume in the catchment. The use of the extraction licences (c) proved to be unfeasible as a further source of information in lieu of ISC hydrology assessments. The freshwater flow modification measure is assessed for each estuary section, riverine and lagoon, and needs to be assessed once every IEC reporting period.

Freshwater flow modification (6a) ISC hydrological modification score: recommended

Freshwater flow modification (6a) = ISC hydrological modification score

Baseline = modelling of past conditions

To achieve an IEC hydrological modification measure score out of 5, the raw ISC standardised seasonally weighted score from 0 to 10 are categorised (Table 14).

Table 14. Scoring for freshwater flow modification (measure 6a).

ISC hydrology sub-index score	IEC Score
>8 - 10, no flow stress	5
>6 - 8, some flow stress	4
>4 - 6, moderate flow stress	3
>2 - 4, flow stress	2
0 - 2, high flow stress	1

Where a section had multiple tributaries with different ISC hydrological modification scores (DEPI 2013) the IEC score was derived from the average of the raw ISC scores (weighted by catchment area of each tributary) and treated as above. Estuary sections below the ISC-scored reach have the same IEC score unless another ISC-scored tributary enters the system. When this was the case and the ISC score was different for each tributary, the IEC score below their junction was derived from the weighted average of the raw ISC scores. Tributaries or sections without ISC scores did not contribute to the IEC score but resulted in a lower score confidence. Score confidence was based on whether the ISC 2010 freshwater modification (DEPI 2013) was derived from gauged flow or modelled (Table 15). It also considered if the catchment of the estuary was fully covered in the assessment and included all subestuaries (Table 15).

Table 15. Score confidence criteria for freshwater flow modification (measure 6a).

Confidence	Criteria
High	Gauged, >75% catchment coverage, all subestuaries included
Medium	Gauged or modelled. Incomplete catchment coverage (25-75%). If gauged subestuaries missing
Low	No gauge, modelled only, incomplete catchment coverage, subestuaries missing. If gauged, catchment coverage <25%.
Unknown	Unable to establish if data exist

Future development:

- For each estuary that has EEFAM compare compliance with IEC hydrology modification to help improve this measure.
- Assess the relationship of ISC hydrology scores to estuarine condition.

Freshwater flow modification (no ISC upstream reach) (6b): recommended with minor development of scoring & score confidence

Freshwater flow modification (with no ISC reach) (6b) = megalitres of storage per km^2 for the entire catchment

Baseline = natural/pristine condition (pre-European)

This catchment dam density measure is required where no EEFAM or ISC hydrology score is available, which is currently 42 estuaries (Arundel et al. 2009). The volume of dams in the entire catchment are quantified (Table 16), following the work of Lowe et al. (2005) and the State Government-commissioned mapping project in the ‘Farm Dam Boundaries (FARM_DAMS/)’ layer in 2013 (metadata ANZLIC ID: ANZVI0803005037). Score confidence is based on the understanding of that impact on estuarine condition (Table 17).

Table 16. Scoring of freshwater flow modification (no ISC upstream reach) (measure 6b).

Catchment farm dam density (volume per km^2)	IEC Score
Less than 0.63 ML/km^2	5
0.63 ML/km^2< dam density < 17.98 ML/km^2	3
Greater than 17.98 ML/km2	1

Table 17. Score confidence criteria for freshwater flow modification (no ISC upstream reach) derived from the dam density (measure 6b).

Confidence	Criteria
Medium	Variability of relative impact of measure on estuarine condition

Future development:

- Assess the relationship between overall reductions in flow and total dam density with soil type and catchment configuration.
- Take into account stream or groundwater extraction.
- Improve sensitivity of score confidence.

Number of extraction licences (no ISC upstream reach) (6c): not recommended

This measure requires the number and volumes of fresh water extraction licences in the catchment to determine the extraction volume relative to the mean annual flow (MAF) immediately above the estuary. Mean annual flows (MAF) were not available for the small systems that this measure would be needed for. Data on licensed offtakes for stock and domestic use were not easily collated. Water extraction in the catchments of the smaller systems without ISC scores is poorly known. Ground water extraction is poorly documented and is known to play an important role in the hydrology of freshwater and estuarine systems.

Salinity regime (7): not recommended, needs substantial further development. To be collected as contextual information in the interim

Salinity regime = % change in axial salinity gradient from baseline (length of estuary) & vertical salinity stratification

The salinity regime measure aimed to assess whether the head of the estuary had moved upstream and the degree of vertical stratification had changed. Data from throughout the estuary based on different tides throughout the IEC reporting period were required. No suitable data met the recommended criteria.

Future development:

- Utilise the extensive salinity data from the Surry River collected by GHCMA, and from salinity studies in Mitchell River estuary. The salinity regime measure could be similar to the ISC hydrology measure and incorporate some of the different processes identified in EEFAM.
- Assess the value of knowing that salinity regime change happened and the cost benefit of knowing the change in the condition of the estuary.

1.1C WATER QUALITY THEME

This theme considers the impact of characteristics of water quality on ecological condition. Water clarity is influenced by the condition of inflowing river and marine water as well as factors such as tidal flow, sediment type, estuary depth and orientation. Oxygen levels within an estuary are a balance of oxygen input from photosynthesis, aeration and inflow and reduction from respiration and nitrification. Dissolved oxygen levels, particularly in bottom waters of stratified estuaries are often depleted through decomposition of organic matter by microbial activity. Anthropogenic activities resulting in increased input of nutrients and organic matter to estuaries are likely to accelerate the process. In addition, limited tidal input in wave-dominated estuaries makes them more prone to hypoxic events. Anoxic bottom waters can trigger release of sediment-bound nutrients which may lead to algal blooms and large diel variations in dissolved oxygen.

Two measures, water clarity and dissolved oxygen are ready for the first formal IEC.

Water Clarity (turbidity) (8): recommended

Water clarity = % turbidity exceeding EPA (2010) estuary water quality median & single sample guidelines

Baseline = current state-wide data (best available)

Water clarity, as measured by turbidity (NTU), is recommended to be recorded mid-channel in top and bottom waters monthly in each estuary section over the entire IEC reporting period, avoiding high flow events. Three sites are randomly chosen, within each riverine and lagoonal section in the estuary at the start of the monitoring program. Tidal flow, depth and channel width are also recorded when sampling to assist with data interpretation. The measure is assessed by water year (July to June). EPA (2010) guidelines (Table 18) and the exceedance of them are used for scoring (Table 19).

Table 18. EPA (2010) estuary water quality guideline trigger values for turbidity (NTU) in surface and bottom waters.

Parameter		Surface	Bottom
Turbidity (NTU)	Annual Median*	5	7
	Single sample	18	26

*calculated from a minimum of 10 samples collected at a monthly frequency

Table 19. Scoring for water clarity (turbidity) (measure 8) against EPA (2010) guidelines for exceedance of annual median thresholds and % of single sample. Annual medians require at least 10 samples in a water year.

Exceedance of EPA guidelines (EPA 2010): annual median threshold & % single sample	IEC Score
Neither exceeded	5
Annual median not exceeded AND single sampled exceeded OR No annual median BUT single sample not exceeded	4
Annual median < 110 % of guideline OR single sample exceedances < 25%	3
Annual median 5.5 <40 NTU (surface) or 7.7<8.8 NTU (bottom) OR single sample exceedances 25<50%	2
Annual median >40 NTU (surface) or >8.8 NTU (bottom) OR > 50% of single samples above guideline	1

Scores are calculated at the estuary section level, then averaged up to an estuary score. To score a section, the data from each site in a section are incorporated. The median and % single sample exceedances are then calculated separately for the top and bottom waters for each water year. All section scores for top and bottom for each water year are averaged to give an estuary score. To ensure problem sections can be identified, the individual scores need to be retained.

Score confidence considers how many years of data were available, the percentage of estuarine sections sampled, whether both surface and bottom waters were sampled and the degree of temporal and spatial replication within years and sections (Table 20). Score confidence falls when the sampling is not monthly, as medians cannot be calculated with less than 10 samples per year, also when there are less than three sites per section and when not every section is sampled or sampled in the recommended way. This method of defining score confidence allows scores to be calculated from limited data but clearly acknowledges the level of confidence that should be placed on that score.

Table 20. Score confidence criteria for the water clarity (turbidity) measure (8).

Confidence	Years sampled (out of 6) ** to be revised for an 8 year period in future*	Sections sampled (in any year)	% Top and bottom sampled (of year & section combinations)	Annual median for sections?	3 or more sites in any section?
High	4-6	>50%	>75%	All	Yes
Medium	4-6	>50%	>75%	All	No
Medium	4-6	>50%	>75%	Some	
Low	4-6	>50%	>75%	None	
Medium	4-6	>50%	<=75%	All or some	
Low	4-6	>50%	<=75%	None	
Medium	4-6	<=50%	>75%	All or some	
Low	4-6	<=50%	>75%	None	
Low	4-6	<=50%	<=75%		
Medium	2-3	>50%	>75%	All or some	
Low	2-3	>50%	>75%	None	
Low	2-3	>50%	<=75%		
Low	2-3	<=50%			
Low	1				

Future development:

- Establish monthly water monitoring programs in estuaries, particularly in the Gippsland region to allow further refinement of the water clarity measure with higher data confidence.
- Assess how the EPA (2010) guidelines apply to the entire estuary, to both river and lagoonal sections with multiple sites.
- Include the EPA (2010) six additional parameters (bottom water pH, top and bottom water conductivity and stratification status, and average daily flow over the previous week) to enable EPA’s control charting method to be used. This would contribute to the further development of scoring distributions.
- Examine a more suitable approach to thresholds to allow a small proportion of single sample exceedances (eg <5%) that reflects the number of samples used to develop a score.
- Investigate pristine but unstudied estuaries in the east of the state to further develop the baseline associated with natural (vs best available) turbidity regimes as highlighted by the difference of Victorian guidelines to NSW trigger levels.
- Assess the effect of estuary section size, length and area, for potential bias and optimum number of sample sites.
- Research to understand the ecological consequences of high turbidity to fish and seagrass in Victorian estuaries.

Dissolved oxygen (9): recommended

Dissolved oxygen = dissolved oxygen samples exceeding EPA (2010) estuary water quality median & single sample guidelines

Baseline = current state-wide data (best available)

The dissolved oxygen measure is based on monthly mid-channel surface and bottom % saturation measurements taken over the eight year IEC reporting period and assessed by water year. In each estuary section, sampling occurs at three randomly chosen sites. In addition, vertical daytime (late afternoon) dissolved oxygen profiles are taken at the same sites to detect anoxic bottom waters and algal blooms. The measure is assessed against EPA (2010) riverine estuary guidelines (Table 21) and exceedance of them is used for scoring (Table 22). Additional contextual data need to be collected at the same time, including temperature and salinity.

Table 21. Dissolved oxygen (%) trigger levels for surface and bottom waters from EPA (2010) estuary water quality guidelines.

Parameter		Surface	Bottom
Dissolved Oxygen (%)	Annual Median*	<90	<65
	Single sample	70-110	15-110

*calculated with a minimum of 10 samples collected at approximately monthly frequency

Table 22. Scoring criteria for dissolved oxygen (measure 9) for sections per water year using EPA (2010) guidelines for exceedance of annual median thresholds and % of single sample.

Criteria	IEC Score
Neither median nor single sample trigger value exceeded AND annual median <110% saturation	5
Annual median not exceeded AND <110% saturation AND single sample guideline exceeded No annual median BUT single sample not exceeded	4
Annual median: either 81 < 90 or 110 < 115 % (surface); either 58.5 < 65 or 110 < 115 % (bottom) OR IF single sample only: <25% exceedances	3
Annual median 62.5 < 81% (surface); 25.1 < 58.5 % (bottom) OR > 115% IF single sample only: 25-50% exceedance	2
Annual median < 62.5% (surface);or < 25.1% (bottom) IF single sample only: > 50% exceedance	1

Score confidence considers how many years of data were available, the percentage of estuarine sections sampled, whether both surface and bottom waters were sampled and the degree of temporal and spatial replication within years and sections (Table 23). Score confidence falls when the sampling is not monthly, as medians cannot be calculated with less than 10 samples per year, also when there are less than three sites per section and when not every section is sampled or sampled in the recommended way. This method of defining score confidence allows scores to be calculated from limited data but clearly acknowledges the level of confidence that should be placed in that score.

Table 23. Score confidence criteria for the dissolved oxygen (measure 9).

Confidence	Years sampled (out of 6) * to be revised for an 8 year period in future	Sections sampled (in any year)	% Top and bottom sampled (of year & section combinations)	Annual median for sections?	3 or more sites in any section?
High	4-6	>50%	>75%	All	Yes
Medium	4-6	>50%	>75%	All	No
Medium	4-6	>50%	>75%	Some	
Low	4-6	>50%	>75%	None	
Medium	4-6	>50%	<=75%	All or some	
Low	4-6	>50%	<=75%	None	
Medium	4-6	<=50%	>75%	All or some	
Low	4-6	<=50%	>75%	None	
Low	4-6	<=50%	<=75%		
Medium	2-3	>50%	>75%	All or some	
Low	2-3	>50%	>75%	None	
Low	2-3	>50%	<=75%		
Low	2-3	<=50%			
Low	1				

Future development:

- Establish monthly water monitoring programs in estuaries, particularly in Gippsland to allow further refinement of the water clarity measure with higher data confidence.
- Assess how well the EPA (2010) guidelines apply to the entire estuary, to both river and lagoonal sections with multiple sites.
- Assess how well the EPA (2010) guidelines apply to Gippsland estuaries.
- Assess the seasonal and temporal variability of surface water diurnal oxygen changes. Subsample existing and future dissolved oxygen data from the permanent loggers in GHCMA (Glenelg, Surry, Fitzroy and Lake Yambuk estuaries) and CCMA (Gellibrand).
- Incorporate diurnal oxygen measurement, with dissolved oxygen surface measurements logged over 24 hours (15-20 minute intervals) at the most vulnerable site of each estuary section. This 24 hour log should be collected once in a water year and incorporated into scoring this measure.
- Examine a more suitable approach to thresholds to allow a small proportion of single sample exceedances (eg <5%) that reflects the number of samples used to develop a score.
- Assess the effect of estuary section size, length and area, for potential bias and optimum number of sample sites.
- Review the five condition bands considering changes relative to ecological effects. It may be possible to relate the condition bands to the extent of the water column deoxygenated, i.e. amount of aerobic habitat. It also may be advisable to take 1 off the IEC dissolved oxygen score if both top and bottom are deoxygenated.
- Include the EPA (2010) six additional parameters (bottom water pH, top and bottom water conductivity and stratification status, and average daily flow over the previous week) to enable EPA's control charting method to be used. This would contribute to the further development of scoring distributions.

1.1D SEDIMENT THEME

Sediments play a key role in the ecology of estuaries and comprise an important habitat as well as being involved in processes such as nutrient cycling, light attenuation, transport and storage of toxicants. The theme links to other themes and considers aspects of the physical properties, movement and biota of sediments.

Two measures, sediment particle size and bank erosion are ready, with some further minor development, for the first formal IEC. The third measure, sediment respiration rate, is not recommended for inclusion in the IEC.

Sediment particle size: recommended with further development of scores and score confidence

Sediment particle size (10) = % increase in fine sediment (<125 µm)

Baseline = current individual estuary data

The sediment particle size measure assesses the change in the proportion of sediment in the top 10cm of the estuary bed that is <125 µm in diameter (i.e. clays, silts and very fine sands) as a measure of sedimentation (Table 24). The sample design is eight replicate cores at depositional locations in the upper, middle and lower zones of the estuary. Sampling is done once an IEC reporting period. A moderate level of skill and specialised equipment is required for particle size analyses but this can be done by commercial laboratories. Australian Standards have been published regarding measurement of sediment particle sizes and for this measure wet sieving after organic matter removal (with hydrogen peroxide) is recommended. Score confidence is based on adequate sampling and still needs further development (Table 25). Contextual information for this measure should include major flooding, extended droughts, presence of large dams and the existence of riverine sand slugs.

Table 24. Scoring for sediment particle size change.

% increase in proportion of fines	IEC Score
0% OR decrease of fines	5
<5%	4
>5%	3
>10%	2
>20%	1

Table 25. Score confidence criteria for the sediment particle size change.

Confidence	Criteria
High	Areas sampled have low potential for scouring and represent a substantial proportion of potential estuarine habitat. All possible subestuaries sampled. Statistically significant change in proportion of fines.
Medium	*To be developed*
Low	*To be developed*
Unknown	Unable to establish if data exist

Future development:

- Repeat sampling of the depositional locations from the implementation trial estuaries to determine responsiveness of measure in IEC timeframe.
- Assess, using the repeat sampling data, if different ranges of scoring scales will be required for differing groups or of estuaries, particularly with respect to the availability and type of depositional areas and the frequency of scouring.
- Improve score confidence criteria using the repeat sampling data.
- Finalise stable isotope component and assess integration with % change in fines.

Bank erosion (ISC method): recommended with some further development

Bank erosion (11) = ISC 2004 bank erosion method

Baseline = Expert opinion

Bank erosion in estuaries is assessed as per the ISC 2004 (DSE 2005) method for bank stability in which three sites within each riverine and lagoon section are assessed. The score for an estuary section is based on the rounded average score for all three sites and replicates combined (average of a maximum of six scores) as done in the ISC (Table 26). If not every bank was scored, this is captured in data confidence (Table 27). Estuary scores are calculated as shoreline-proportional averages of section scores (Table 26). Unrounded section scores were multiplied by the proportion of the total estuary perimeter represented in that section and added together. Where not all sections in an estuary were scored, a standardised estuary score was calculated by dividing the summed scores from sections where scores were available by the proportion of the total estuary represented by those sections. Summed proportional section scores were then rounded to the nearest integer. Armoured banks are given a score of 4 to reflect that they were not a natural bank but probably are contributing little sediment to the estuary if they were functioning as designed.

Table 26. Scoring for bank erosion.

Banks: stability; toe; slope >45^{o} & undercut; cover of vegetation; >33% exposed woody roots; livestock damage	IEC Score
Good stable & intact; no toe; not >45^{o}; continuous cover; <33% roots; no damage	5
Limited/isolated erosion; no toe; not >45^{o} & undercut, near continuous cover; <33% roots, no damage	4
Moderate erosion; instabilities toe, gentle OR >45^{o} slope, discontinuous cover, >33% roots, no damage	3
Extensive erosion; mostly unstable toe OR >45^{o} slope with toe, minimum cover, >33% roots, obvious damage	2
Extreme erosion, very recent bank movement; unstable toe; cover >45^{o} slope; no vegetation, >33% roots, obvious damage	1

The ISC 2004 bank erosion method (DES 2005) was developed for freshwater rivers and, because of that, the score was uniformly given a low data confidence where it was assessed in an estuarine lagoon section. The data confidence for sections in the more riverine part of estuaries was determined from the number of sites and number of samples scored, based on three size categories of the zone perimeter (<5, 5 to 17 & >17km). The estuary score confidence is a proportional average of the zone score confidences (Table 26).

Table 27. Score confidence criteria for bank erosion for estuaries of different size.

Confidence	Criteria: Perimeter <5km
High	> 2 sites or 3 to 6 samples
Medium	1 site or < 3 samples; or Lagoon section
Low	
Unknown	Unable to establish if data exist
Confidence	Criteria: Perimeter 5 to 17 km
High	3 sites & 5 to 6 samples
Medium	2 sites or 4 to 3 samples
Low	1 site or < 3 samples; or Lagoon section
Unknown	Unable to establish if data exist
Confidence	Criteria: Perimeter >17 km
High	
Medium	3 sites & 5 to 6 samples
Low	< 3 sites or < 4 samples; or Lagoon section
Unknown	Unable to establish if data exist

Future development:

- Review of the rankings developed and rate for potential sediment contribution by an estuarine geomorphologist. The importance of bank erosion as a measure of estuarine condition will vary between estuaries in response to reduced fluvial sediment supply, geomorphology and proportional contribution to suspended sediment concentrations and loads. Does the measure need to be scaled for this?
- Further adapt the ISC 2004 scoring method (DSE 2005) for estuaries, particularly for large lagoons and low lying fringing sand and mudflats and assess its applicability to non-channelised sections. Refine methodology to cope with high water levels (tidal or mouth state) or for low relief sandy shores (beaches and berms).
- Evaluate the changes in the ISC method for bank erosion (DSE 2005), would they would improve this measure?
- Evaluate the ISC LiDAR erosion assessment method. Would it give whole estuary coverage, what would be needed to field validate the automatic classification in estuaries, what are the errors associated with high water and dense fringing vegetation? Is it appropriate to make develop a measure integrating the stream and coastal LiDAR with the existing *in situ* bank erosion assessments?
- Assess mapping or aerial photo validation with a camera on a remote controlled drone.
- Geolocate implementation trial photos and publish online in a photo library.

Sediment respiration rate: not recommended

This measure was too resource intensive to undertake and currently the interpretation of the results for scoring are not straightforward. It is not recommended that this measure be implemented as part of the initial IEC. NSW also does not routinely use sediment respiration rate to assess estuary condition, although it is used in specific intensive studies. It is a useful tool for understanding the complex biogeochemistry and the sediments' role as a source or sink of nutrients in estuaries when results outside of expectations for other measures are found. As such it is a secondary intensive tool for assessing estuary condition.

1.1E FLORA THEME

This theme considers the condition of the flora that occurs in and around estuaries. It includes macrophytes such as saltmarsh, reedbeds, seagrass and macroalgal beds, and microphytes such as phytoplankton in the water column or microphytobenthos associated with the sediment. Seagrass is affected by a range of anthropogenic influences, particularly those that alter the light availability, sediment deposition, water movement and salinity regime. Excessive growth of opportunistic macroalgae can result because of excessive nutrients and high water residence times. Riparian macrophytes provide important faunal habitat and reduce bank erosion. Development pressure around estuaries can often result in physical destruction of macrophyte beds and other riparian vegetation. Altered freshwater flows, entrance opening frequency and lateral connectivity can detrimentally change riparian inundation frequency. Both microphytobenthos and phytoplankton are important components of aquatic food webs.

Three measures, aquatic flora (macrophyte change and macroalgal cover), fringing macrophytes and phytoplankton, are recommended for the first formal IEC, although all need some further development. In particular the aquatic flora measures of macroalgal cover (bi) and blooms (bii) need some further research. The fourth measure, microphytobenthos, needs more substantial development before it is suitable for the formal IEC.

Aquatic flora (a, b1 & b2): recommended with further development

Aquatic macrophyte extent (a): recommended with further development of sampling design, methodology and scoring

Aquatic macrophyte extent (a) = % change in aquatic macrophyte extent from historical

Baseline = historical data/expert opinion

This measure is based on the percentage change in the extent of seagrasses from historical to present.

For the IEC a relatively simple and efficient method of monitoring aquatic vegetation is required to allow sampling across a large number of systems. Where broad coverage remote sensing methods are not viable, a form of spot or transect method is required. Sidescan sonar can cover a large area most efficiently but requires a ground truthing with another method. Use of remote underwater cameras is sometimes possible in intermediate water clarities where the presence of seagrasses cannot be identified from above the surface. Diver observations can be used in extremely low visibility and allow for samples to be taken for identification purposes. Seasonal variability should be addressed by sampling in late summer-early autumn when macrophyte extent and density is often highest. Sampling should be done at least twice during an IEC assessment period, due to interannual variability.

Due to uncertainties associated with natural variability and measurement accuracy, a three-level scoring method is recommended, using the combined extent of all seagrass species and densities (Table 28).

Table 28. Scoring for aquatic macrophyte extent (13a), % change in aquatic macrophyte extent and cover.

% decrease from historical	IEC Score
<20%	5
20% to 40%	3
>40%	1

Confidence in this score depends on having a reliable baseline, accounting for natural variability in extent and composition of aquatic macrophytes in a given estuary (Table 29). Given the large, unpredictable and short term changes in extent of *Ruppia* and *Lepilaena*, confidence in scores is decreased when changes in extent have large contributions from saline aquatic meadow species.

Table 29. Score confidence criteria for aquatic macrophyte extent (13a), % change of macrophyte extent.

Confidence	Criteria
High	Seagrasses mapped multiple times previously to provide a baseline & determine locations for IEC assessment. Assessment based on at least 2 sampling times during the assessment period. Proportion of saline aquatic meadow species in total extent estimates varies < 20% between baseline & assessment estimates.
Medium	Baseline may be based on expert opinion but is guided by prior mapping. Assessment based on >1 sampling in the assessment period. Proportion of saline aquatic meadow species in total extent estimates is between 20% & 75%
Low	Baseline based on expert opinion with no prior mapping OR Assessment based on a single sampling occasion OR Proportion of saline aquatic meadow species in total extent estimates varies by more than 75%.
Unknown	Unable to establish if data exist

Future development:

- Review applicability of Woodland et al. (2015) habitat mapping with aerial photography and video field survey.
- Collect data from a wider range of estuaries and review the thresholds.
- Incorporate species composition into measure to account for changes in more/less ephemeral species.
- Incorporate estimates of percentage cover into the scoring. This could be done by the assessment of cover at known sites of major beds within estuaries using remote sensing in conjunction with spot or transect surveys in estuaries where this is possible.
- Use models incorporating bathymetry and likely light and salinity conditions to determine potential seagrass habitat to enhance baselines.

Macroalgal cover (b1): recommended with further development of sampling design, methodology, score thresholds and score confidence

Aquatic macroalgal cover (b1) = % cover change from historical

Baseline = current state-wide data (best available)

This method is based on the future change in percent cover of macroalgae.

Sampling protocol is still to be determined and will depend on available resources. Temporal and spatial variability of macroalgae mean that the protocol may need to be more intensive than that proposed for aquatic macrophytes. This measure will probably involve remote sensing (such as aerial photography or multispectral scanning) in addition to field assessment requiring diving, video survey and taxonomic expertise. Summer sampling to quantifying percent cover is tentatively recommended (Table 30).

Table 30. Scoring for aquatic macroalgal cover (13b1).

% cover (summer)	IEC Score
<5%	5
5–15%	4
15–25%	3
25–50%	2
>50%	1

Score confidence criteria have not been developed and need to be done so in conjunction with the monitoring and reporting system that is developed.

Future development:

- Review applicability of Woodland et al. (2015) habitat mapping with aerial photography and video field survey.
- Sample macroalgal cover in Victorian estuaries for the refinement of the scoring thresholds, score confidence and measurement frequency.
- Sample macroalgal cover in Victorian estuaries to assess spatial and temporal variability.

Number of macroalgal blooms (b2): recommended with further development of design, methodology, scoring and score confidence

Aquatic macroalgal blooms (b2) = % of estuary with excessive macroalgal growth (blooms)

Baseline = current state-wide data (best available)

Documenting macroalgal blooms requires regular observations and at least monthly monitoring over the warmer spring to autumn months is recommended. This measure could be developed so that it is suitable for community monitoring through EstuaryWatch.

There has been no systematic reporting of macroalgal blooms in Victorian estuaries so the proposed scoring is very preliminary (Table 31).

Table 31. Scoring for aquatic macroalgal blooms (13b2).

% estuary with excessive macroalgal growth	IEC Score
<1%	5
1-25%	3
>25%	1

Score confidence criteria have not been developed.

Future development:

- Monitor and report aquatic macroalgal blooms in Victorian estuaries, potentially by developing methods to be incorporated with the EstuaryWatch and other regular water quality monitoring programs.
- Use monitoring data to refine scoring thresholds and measurement frequency, spatial and temporal variability of blooms and to develop score confidence criteria.

Fringing macrophytes: recommended with further development of score confidence

Fringing macrophytes = extent & condition

Baseline = historical data/expert opinion

This measure considers the extent and condition of fringing macrophytes, including mangroves (Table 32). The measure for assessing fringing macrophytes is from the detailed mapping methods of the Victorian Saltmarsh Study, which provides an overview of the current ecological condition of fringing macrophytes, suitable for regional planning and investment processes. It assessed the distribution, condition, threats and management of fringing macrophytes in Victoria. To be able to compare to pre-European extent mapping is aggregated to coastal marsh, which consists predominately of coastal saltmarsh and estuarine wetland. The fringing macrophyte measure would be remapped once every eight years in the IEC reporting period.

Table 32. Scoring for fringing macrophytes, extent and condition.

Fringing macrophytes extent and condition	IEC Score
Intact, no discernible impacts	5
Detrimental impact discernible with close inspection or measurement but essentially intact. Impact in relatively small, localised places, < ~5% of original area	4
Visibly structurally modified and of reduced biological diversity. Impact in relatively small, localised places (~5% of original area)	3
Visibly structurally modified and of reduced biological diversity. Impact affecting > 5% of original area	2
Largely destroyed or lost, massive visual and ecological impact	1

Score confidence criteria have not been developed.

Future development:

- Review the coastal wetlands included in the Index of Wetland condition to ensure that they are not within the estuary, as defined by the estuary head (GIS layer).
- Assess remote sensing such as LiDAR mapping at a coarser scale.
- Assess using a small remote controlled drone with a camera for field validation.
- Score confidence criteria need to be developed when scores for more estuaries are derived.
- Review Victorian Saltmarsh Study (2011) measure of extent and condition to maximise applicability on a broad scale.

Microphytobenthos: not recommended, needs substantially more development

All microphytobenthos chlorophyll *a* data collected across Victoria, including the four incubated core estuaries, were extensively plotted and examined. There were no obvious breaks or slope changes that indicated different thresholds. There was some suggestion of higher biomass with possible mild eutrophication as would have been expected. However, many estuaries had low biomass with medium land use intensity and across all population densities. There was no obvious relationship with phytoplankton biomass from the same sites.

These results and some other preliminary investigations of the data indicated that a lot more research is required before microphytobenthos biomass, as assessed with chlorophyll *a* and/or phaeophytin *a,* can be used as a measure for the IEC. The lack of established monitoring or scoring protocols, and problems differentiating natural changes in microphytobenthos biomass from anthropogenic induced change make their inclusion in the IEC at this stage difficult.

Future development:

- Detailed analysis of all collected benthic chlorophyll *a* data in relation to other driving factors such as water depth, water clarity and colour, sediment redox, organic matter and grain size, and estuary characteristics and type.
- Determine which pigments or combinations of pigments best differentiate estuary condition.
- Determine how to best deal with measurement interference from other pigments or compounds.

Phytoplankton: recommended

Phytoplankton biomass = Chlorophyll *a*

Baseline = current state-wide data (best available)

The phytoplankton measure involves the collection of monthly surface water samples for chlorophyll *a* determination. Three replicates of two litres of surface water are collected in the mid-channel of one site in each of the upper, middle and lower estuary zones. Monthly sampling, at least in the warmer spring to autumn months, is recommended. The majority of estuaries require boating access to be able to collect the samples. Water samples are filtered within 8 hours, the filter paper frozen and the sample analysed within 30 days as per standard protocol. Techniques and collection methods for phytoplankton biomass as measured by chlorophyll *a* are well established and laboratory analysis can be outsourced to commercial laboratories. Chlorophyll *a* is assessed for each water year in the IEC assessment period for the estuary as a whole.

Chlorophyll *a* concentration is assessed against exceedance of EPA (2010) guidelines for scoring (Table 33 and Table 34). For each estuary zone (upper, middle, lower) the three replicates per site are summarised as % exceeded, minimum value, maximum value and number of samples for each water year. At least ten samples per year are necessary to assess against the annual median guidelines (Table 34).

Table 33. Scoring for phytoplankton biomass using single samples.

% single samples exceeding guidelines	IEC Score
0%	5
1-19%	4
20-50%	3
51-85%	2
>85%	1

Table 34. Scoring using both annual median thresholds and % of single sample for chlorophyll a for exceedance of EPA (2010) guidelines for. Annual medians require at least 10 samples in a water year.

Exceedance of EPA guidelines (EPA 2010): annual median threshold & % single sample (SS) – surface only	IEC Score
Neither exceeded or SS exceedances <10%	5
Annual median not exceeded AND SS exceedances >10% OR No annual median BUT single sample not exceeded	4
Annual median < 1.1µg/L OR single sample exceedances < 25%	3
Annual median 1.1µg/L<90th percentile threshold (value to be determined) OR single sample exceedances 25<50%	2
Annual median >90th percentile threshold (value to be determined) OR > 50% of single samples above guideline	1

Score confidence considers how many years of data are available, the percentage of zones sampled, and the degree of temporal and spatial replication within years and zones (Table 35). Score confidence falls when the sampling is not monthly, as medians cannot be calculated with less than 10 samples per year (Table 35). This method of defining score confidence allows scores to be calculated from limited data but clearly acknowledges the level of confidence that should be placed in that score.

Table 35. Score confidence criteria for phytoplankton biomass taking into account the number of years, zones and replicates sampled.

Confidence	Years sampled (out of 6)	Zones sampled (in any year)	% sampled (of year and zone combinations)	Annual median for zones?	3 or more replicates?
High	4-6	>50%	>75%	All	Yes
Medium	4-6	>50%	>75%	All	No
Medium	4-6	>50%	>75%	Some	
Low	4-6	>50%	>75%	None	
Medium	4-6	>50%	<=75%	All or some	
Low	4-6	>50%	<=75%	None	
Medium	4-6	<=50%	>75%	All or some	
Low	4-6	<=50%	>75%	None	
Low	4-6	<=50%	<=75%		
Medium	2-3	>50%	>75%	All or some	
Low	2-3	>50%	>75%	None	
Low	2-3	>50%	<=75%		
Low	2-3	<=50%			
Low	1				

Future development:

- Explore the potential for use of seasonal chlorophyll maxima in Victorian estuaries as has been done in NSW.
- Refine thresholds for median scores when more monthly data are collected.
- Assess how well the EPA (2010) guidelines apply to the entire estuary, and to all estuary zones.
- Assess the effect of estuary section size, length and area, for potential bias and optimum number of sample sites.
- Analyse the relationship between *in situ* fluorometry and spectrophotometric laboratory based chlorophyll *a* from the implementation trial.

1.1F FAUNA THEME

The condition of the flora and fauna is the ultimate gauge of how well an estuary is functioning. The composition, distribution and abundance of faunal species, particularly those at higher trophic levels, will be affected directly and indirectly by components of all other themes.

Only fish, both structural and functional naturalness, is recommended as for the first formal IEC. The naturalness of bird populations are not recommended.

Naturalness of fish (17a) structural: recommended

Naturalness of fish (17a) structural: guild based multi-aspect measure incorporating the proportion and number of taxa of seven guilds

Baseline = best available data.

Fish as a measure for the IEC (Figure 1) was assessed separately by ARI and is reported in detail in a separate report (Warry and Reich 2014). Warry and Reich (2014) recommended a structural and a functional measure for assessing fish naturalness based on specific aspects of the guilds of the sampled fish assemblage.

Estuaries are surveyed using a rapid catch and release assessment methodology that can be completed within twelve hours. Surveys are conducted in autumn and all upper, middle and lower zones in the estuaries and subestuaries are sampled. A core sampling protocol of fyke (3 each zone) and mesh (1 each zone) nets is conducted in depths < 2 m. Trawls and seines are also conducted opportunistically in the lower estuary zone, where the substrate, tidal currents and estuarine geomorphology permit effective gear use. Contextual information, including water depth (m), tidal amplitude category (0m, <1m, 1-1.5m, >1.5m, derived from nearest tidal gauge) and estuary area (km^2), is also recorded.

The fish assemblage data are then categorised into ecological guilds: demersal-associated species; freshwater migrant species; detritivores; miscellaneous opportunists; zoobenthivores; and zooplanktivores (Elliott et al. 2007). The proportion of the seven structural aspects (or metrics) are then calculated for either taxa (five aspects) or individuals (two aspects) in those guilds in the fish assemblage sample.

Each aspect of the fish assemblage sample was scored out of 1, 3 or 5, the fish naturalness structural measure is calculated by summing the scores of the aspects and dividing by seven to get an overall score between 1 and 5 (Table 36). Score confidence has not yet been developed for this measure.

Table 36. Scoring for the seven specific structural aspects of six guilds of the fish assemblage

Structural aspect: guild, proportion of	5	3	1
Demersal Species, taxa	> 44.6	44.6 - 36.0	< 36.0
Freshwater Migrants, taxa	> 12.9	12.9 - 6.1	< 3.1
Detritivores, taxa	> 13.0	13.0 - 8.5	< 8.5
Zoobenthivores, taxa	> 43.1	43.1 - 34.5	< 34.5
Zooplanktivores, taxa	< 13.0	13.0 - 19.1	> 19.1
Detritivores, individuals	> 21.0	21.0 - 4.3	< 4.3
Opportunists, individuals	< 5.6	5.6 - 20.5	< 20.5

Naturalness of fish (17b) functional: recommended

Naturalness of fish (17b) functional: guild based δ15N of fish in the assemblage

Baseline = 'best available' sample data.

This measure consists of the summation of two functional aspects based on δ15N stable isotope ratios of nitrogen to determine the functional naturalness of fish assemblages, as direct measures of ecosystem function. The two aspects are a mean δ15N value of zoobenthivore fish and an estimate of trophic niche position of detritivore fish. The sampling methodology is the same as for the structural naturalness except that five fish from two functional guilds in each estuary zone are collected and sacrificed for stable isotope analysis. Each of the two aspects was given a score of 1, 3 or 5. The functional fish naturalness measure was calculated by summing the two scores and dividing by two to get an overall score between 1 and 5 (Table 37). The physical nature of individual estuaries or estuary types did not need to be taken into account when allocating scores. Score confidence has not yet been developed for this measure.

Table 37. Scoring for the two specific function aspects of two guilds of the fish assemblage

Functional aspects	5	3	1
Zoobenthivores - Mean δ15N	< 12.0	12.0 - 15.0	> 15.00
Detritivores - δ15N Standard ellipse area -	> 4.0	4.0 - 2.5	< 2.05

Future development for both structural and functional fish measures:

- Investigate co-variance between disturbance gradients and sources of natural variation in the landscape for better interpretation of the data, aspect values and scores, and measure values.
- Include the sampling of consistent, local environmental data, such as in-stream habitat, for assessing measure responsiveness to disturbance and potential threats to estuaries.
- Use local environmental data to assist in developing additional stable isotope measures of the roles of different autotrophs in supporting fish nutrition, this will provide further insight into estuarine trophic function and relationships with landscape scale disturbance.
- Collect fish assemblage and stable isotope data from other estuaries, and at previously sampled estuaries to help understand patterns and variability in fish assemblage structure, how these relate to estuarine condition and which measures best represent the condition of an estuary.

Naturalness of birds (18): not recommended

Naturalness of birds (18) = observed/expected estuarine bird guilds

Birds as a measure for the IEC were assessed separately by ARI. The utility of birds as a component of an IEC needs substantial further assessment.

1.1G THEME AND OVERALL IEC SCORES

As per the ISC, each theme contributes equally to the final IEC score and there is no weighting of themes. Any consideration of weighting themes requires more data and may be considered in future development of the IEC. Within themes, measures contribute equally and there is no weighting of measures. The measure scores and score confidence within a theme is averaged across the theme. All score confidences are used when combining measures, including low score confidences, in the future when more data become available excluding low score confidences should be assessed.

An overall estuary IEC score involves adding up all six theme scores and taking the average, for both the score and score confidence. We recommend that an overall estuary condition score needs to have at least four themes out of the possible six to be able to score an estuary. At least one biological theme of flora or fauna, and water quality, needs to be included. In the future with more data the number of measures within a theme can be assessed for redundancy.

Like the ISC, the IEC methodology will be reviewed over time to ensure it remains up to date, incorporates recent advances in science and technology, and provides the best possible information for estuary planning and management (DEPI 2013). Future testing and periodic revision of the IEC are recommended to continue to develop it as a robust and credible method for the rapid assessment of estuaries. Continued development of the IEC method, information management and training programs will ensure that the IEC provides the most practical and scientifically defensible means of assessing estuarine condition in Victoria.

General recommendations:

- Reguarly review the IEC methodology to ensure it incorporates recent advances in science and technology, and provides the best possible information for estuary planning and management.
- Continued development of the IEC information management and training programs.
- Further research to establish the importance of certain estuarine characteristics for indicating vulnerability to given threats.
- Produce an overall IEC summary report after each IEC assessment that combines elements of inventory, condition and risk reports for a wider audience, including national reporting.
- Produce individual estuary status reports that provide a summary of physical information and provide context for other elements such as: IEC scores as a summary of the ecological condition and condition targets; key assets and threats including environmental, social and economic values; and critical and high risks for the estuary.
- Address the lack of appropriate water quality and phytoplankton monitoring in Victoria’s estuaries
- With more data assess excluding low score confidences from an IEC assessment.
- With more data the number of measures within a theme can be assessed for redundancy.
- With more data the weighting of individual themes could be considered.
- With more data assess if individual measures need to be modified when applied to different ‘types’ of estuaries.

2 BACKGROUND

2.1 OBJECTIVES OF THE INDEX OF ESTUARINE CONDITION

There is currently no consistent method available for assessing the environmental condition of Victorian estuaries to optimise resource allocation for threat mitigation and asset protection. This inability to adequately and comparatively assess estuarine condition is an impediment to effective management of Victoria's estuaries and the implementation of Regional Catchment Strategies (Arundel et al. 2008). The development (Arundel et al. 2009) and trialling of the Index of Estuary Condition aims to address this and improve the monitoring, evaluation and reporting of the condition of Victorian estuaries using a suite of six themes, each of which contains a number of specific measures (or indicators). The IEC will form part of the Victorian 8 year water strategy period. Results from the IEC will contribute to Catchment Management Authority (CMA) waterway health programs, inform priorities and funding decisions. The IEC is intended to assess the condition of Victorian estuaries at specific points in time, every eight years (although an interval of six years was anticipated during the preparation of this report and so has been used for the trial implementation where integration over an assessment period was needed). The multi-metric IEC for Victorian estuaries was recommended following an iterative process of expert workshops and comparison of a wide range of measures with existing knowledge, information and monitoring and assessment tools (Arundel et al. 2009). The IEC was developed to be consistent with the Index of Stream Condition (ISC, Ladson and White 1999) and the recently developed method for Aquatic Value Identification and Risk Assessment (AVIRA). The ISC has been used widely across Victoria, fitting into an existing and successful structure for managing aquatic natural resources. The IEC is consistent with this approach of assessing assets, threats and condition (Condition Indicators) to enable adaptive management of natural resources (Arundel et al. 2008).

The approach undertaken by Arundel et al. (2009) for the development of the draft Index of Estuary Condition was comprehensive and included reviews of the international estuary research and knowledge, and Australian and international measures for determining estuarine condition. Key aspects of estuaries that were considered essential to the ecological function of an estuary were identified as themes. An overall conceptual model of estuary processes represented by the themes and relationships between them was developed (Figure 3). An estuary in good condition ('healthy') is defined as one which retains the major ecological features and functioning of the estuary prior to European settlement and can sustain these features in the future (Lloyd et al. 2012). In keeping with the ISC, in which each sub index consists of several measures, each theme in the IEC includes several measures that represent aspects of ecological condition. This formed a discussion paper that was the basis of a workshop of national and international estuarine scientists and managers who debated all aspects of the preliminary draft method and refined the list of recommended measures. Criteria used to assess measures during this process were:

- cost;
- effectiveness;
- conceptual relevance;
- measurement variability;
- responsiveness to management actions/stressors; and
- interpretability.

The feedback received during the workshop and subsequent internal reviews led to the refinement of the draft method for trial in Victoria (Arundel et al. 2009).

The IEC themes and measures were developed around estuary assets identified in Arundel (2007). Threats to these assets were broadly identified in Barton *et al.* (2008). The main threats to estuarine condition are likely to be catchment land-use patterns, flow regime (including environmental flows as a restoration tool), urban and coastal development around the estuary, recreational (e.g. fishing, boating) and commercial (e.g. industry) use, climate change, pest species and estuary entrance management. The IEC was developed based on existing knowledge, identifying conceptual links between assets, threats and responses (Arundel et al. 2008; Arundel et al. 2009).

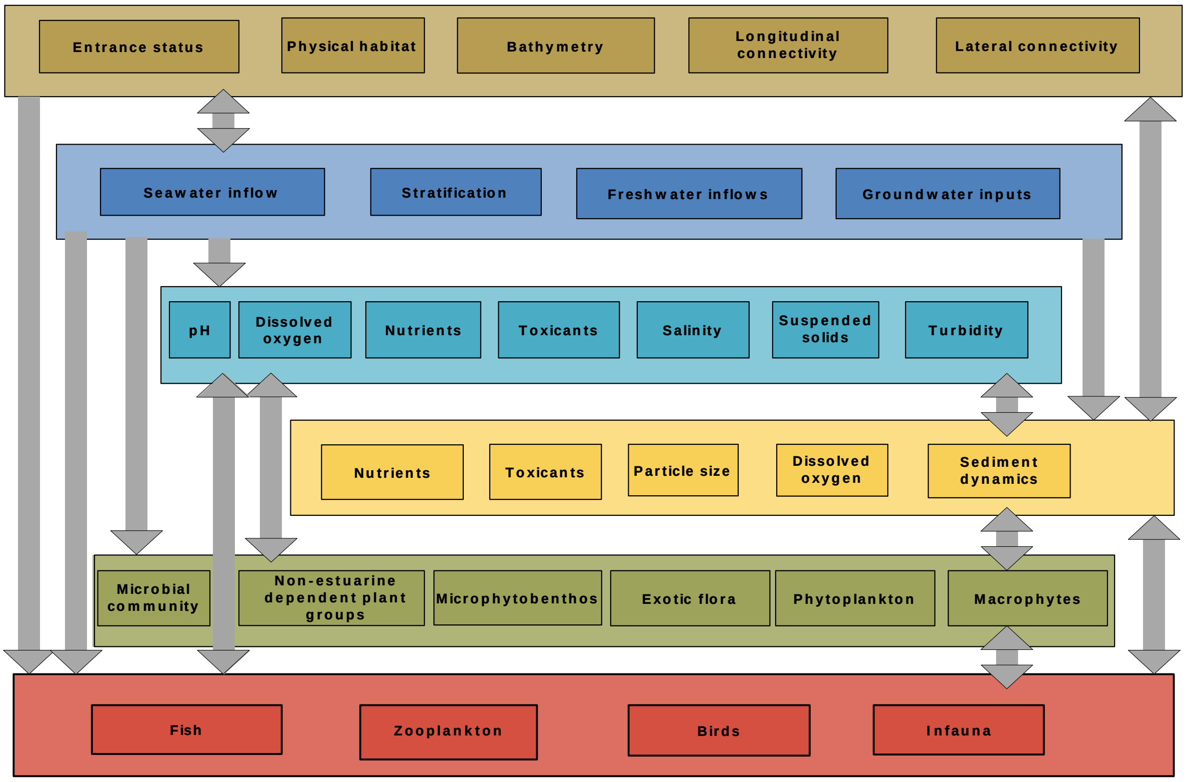

Figure 3. Conceptual model showing main themes (from top physical form, hydrology, water quality, sediment flora and fauna), content and direction of influence (Arundel et al. 2009).

In keeping with the framework of the ISC, in which five sub-indices (or Themes) are used to group measures, six themes were identified for use in the IEC: Physical form, Hydrology, Water quality, Sediment, Flora and Fauna (Table 38). The themes represent the key components of estuaries (Figure 3) that contribute to their ecological condition (Arundel et al. 2009). As per the ISC, it is proposed that each theme contributes equally to the final IEC score. Therefore each theme will ideally be of equal importance to ecological condition of an estuary and be applicable across Victorian estuaries as a whole. Several specific measures within each theme were recommended to assess estuary condition based on current conceptual understanding of the response to threats or pressures.

The IEC, like the ISC, requires its measures to be transparent, intuitive and an appropriate balance of cost, speed, accuracy and scientific rigour (DEPI 2013). The measures need to be suitable for state-wide application and therefore suitable for assessment in all Victorian estuary types (Arundel et al. 2009). Scoring of particular measures could be modified when applied to different 'types' of estuaries. A measure should be conceptually linked to the condition of the estuary (Arundel et al. 2008). Where possible a direct measure should be used but it is acknowledged that measures may need to be included that have an indirect link to condition. Measures are most valuable when we can link current condition, and changes in condition, to potential manageable threats (Arundel et al. 2009). Measures need to be assessed in a cost-effective manner. Costs associated with assessment programs include staff time and expenses associated with the field and/or laboratory, staff expertise and /or training required, establishing data collection protocols and any further development that may be required to relate a measure to ecological condition (Arundel et al. 2009). The availability of existing data influences cost effectiveness and therefore choice of measures. Existing data can also provide measures of variation which are required when designing sampling programs to detect temporal and spatial patterns. Measures need to be assessed over temporal and spatial scales that reflect their natural variability and the scale of their responses to threats of interest. Multiple measures may be needed to detect short-term responses to threats but also longer-term trends in characteristics with slower turnover times. For each measure, a range of scores that represent improving ecological condition needs to be assigned. These scores must be directly comparable across Victoria's estuaries.

The final IEC should include measures that:

- Are applicable state-wide;
- Are influenced by management decisions;
- Characterise the condition of the estuary;
- Are cost effective;
- Are scientifically defensible;
- Have established reference conditions and;
- Are measures of condition (state) rather than pressure (threats).

Using pre-established criteria, Arundel et al. (2009) selected eighteen measures (Table 38) from a more extensive list in consultation with scientists with expertise in a broad range of aspects of estuarine ecology (2008 IEC workshop, Appendix 1). The selected measures varied from those feasible for immediate implementation to others that required some further development to guide data collection and/or data interpretation (Arundel et al. 2009). Like the ISC, the IEC methodology will be reviewed over time to ensure it remains up to date, incorporates recent advances in science and research, and provides the best possible information for estuary planning and management (DEPI 2013).

Arundel et al. (2009) identified that the practical application of the recommended IEC needed to be tested, baseline conditions identified and scoring thresholds developed through a trial implementation across the full range of Victorian estuary types. This would also allow necessary refinement of sampling protocols and data recording methods, thereby enabling a more accurate assessment of the feasibility of implementing the IEC and its component measures across the State. The IEC will provide a method for consistent state-wide assessment of the environmental condition of estuaries. This will enable better:

- Condition reporting for Victorian estuaries at regional, state and national levels;
- A consistent state-wide picture of estuarine condition;
- A consistent approach to the identification of estuary values and threats (pressures);
- State-wide data for incorporation into the CMA regional Waterway Health Strategies;
- A standardised interpretation of estuary condition that allows communities to understand and get involved in discussions of regional waterway health and;
- A way to assess the long-term effectiveness of estuary management programs.

Table 38. Summary table of initially recommended IEC themes, possible measures, methods and baselines (Arundel et al 2009). Numbers assigned to measures are consistent with those used throughout the report. For some measures there are several components. Fauna is not assessed in this report.

Theme	Measure	Method	Baseline
Physical Form	1. Changed bathymetry	Cross-sectional transects of depositional sites	Individual estuary baseline
	2. Sediment load	Modelled catchment load	Modelled natural load
	3. Upstream barriers	% of estuary area affected & degree of blockage	Natural (pre-European)
	4. Lateral connectivity	% of estuary perimeter artificial	Natural (pre-European)
Hydrology	5. Marine exchange:		
	a) mouth openings	% artificial openings	Natural (pre-European)
	b) structures & behaviours	Training walls & dredging	Natural (pre-European)
	6. Freshwater flow a) ISC Hydrology modification score	ISC Hydrology modification score	Modelled natural
	b1) catchment dam density	# of dams standardised by catchment area	Natural (pre-European)
	b2) number of licences	Extraction volume relative to Mean Annual Flow	Natural (pre-European)
	7. Salinity regime	Net movement upstream, fixed sites along estuary, spring & neap tides, high & low flows	Natural (pre-European) or baseline
Water Quality	8. Water clarity	Turbidity (NTU) monthly	current state-wide data (best available)
	9. Dissolved oxygen	% dissolved oxygen, monthly surface & bottom waters	current state-wide data (best available)
Sediment	10. Particle size	% <125 µm in top 10cm depositional areas	current individual estuary data
	11. Bank erosion	ISC 2004 method	Expert opinion
	12. Sediment respiration rate	NSW incubated core method	Expert opinion
Flora	13. Aquatic flora		
	a) macrophytes	% seagrass extent change	historical data/expert opinion
	b1) macroalgae	% cover of macroalgae	current state-wide data (best available)
	b2) number of macroalgal blooms	% of estuary with excessive growth	current state-wide data (best available)
	14. Fringing macrophytes	% change in extent or condition	historical data/expert opinion
	15. Microphytobenthos biomass	phaeophytin &/or chlorophyll a concentration	current state-wide data (best available)
	16. Phytoplankton biomass	chlorophyll a concentration	current state-wide data (best available)
Fauna	17. Naturalness of fish	Observed to expected	best available
	18. Naturalness of birds	Observed to expected	best available

2.2 OBJECTIVES OF THE IMPLEMENTATION TRIAL OF THE IEC

The primary focus of the implementation trial was to refine data collection and interpretation. For each measure this included:

- Developing or refining sampling methods including spatial and temporal replication required within and/or between estuaries and estuary types;
- Developing or refining field data sheets;
- Establishing baseline condition;
- Developing condition scoring methods for each measure and;
- Developing weighting methods that provide an accurate and representative overall IEC score.

The recommended IEC measures (Arundel et al. 2009) were developed from research generally undertaken in other states or countries, and it has been assumed that they will also indicate estuarine condition in Victorian estuaries. The trial implementation project was not designed to test the validity of this assumption, although substantial information on the validity of this assumption is an outcome of the trial. In the trial an assessment was also made as to whether it should be included in the final IEC method.

The IEC trial consisted of identifying and using the available data on Victorian estuaries and some targeted field sampling to generate data to evaluate the selected measures where existing data were inadequate. The trial was initially funded for one year (2009/2010) which was extended to 2010/11 and 2011/12 with additional funding. Assessment of the measures in the Fauna theme (Fish and Birds) were outside the scope of this trial because of the high level of development required for both data collection and interpretation, and associated costs. Melbourne Water funded the Arthur Rylah Institute to trial the Fauna measures in six Port Phillip Bay and Western Port Bay estuaries, and DSE (now DELWP) extended this across the state in 2011 and 2012. Melbourne Water supported the full IEC trial in the 6 additional estuaries in 2010, this was continued for fish and birds for the trial period. The results of trials of the Fauna theme are presented in reports separate to this one, with only the recommendations included here.

The selection of estuaries for the trial varied with different measures. Principles that guided selection were:

- Presence of existing data of the quality and type required;
- Representation of estuaries from each CMA region;
- Representation of estuaries in each estuary type (*sensu* Barton 2003) and;
- Estuaries representing different levels of threat (land use intensity and population density, Barton et al. 2008).

Data collection and cost

Implementation of a particular measure depends on the investment required to both collect and interpret the required data. The time and cost associated with data collection primarily depend on whether there is an established sampling procedure, how frequently data need to be collected and the level of expertise required for collection. While existing data for some measures were available it was important that a standardised protocol was used for broad scale programs to enable valid and accurate comparisons between estuaries. For some measures, sampling procedures were available from previous studies of specific estuaries or interstate and overseas programs. Generally protocols used in the IEC trial were decided at the workshop and recommendation stage (Arundel et al. 2009). The implementation trial did modify some protocols to increase their applicability across Victoria. This included identifying critical times of the year in which sampling can be focussed for particular measures.

2.3 BASELINE CONDITION

Two workshops were held to help the trial teams identify baseline, or reference, conditions and scoring approaches during the implementation trial. In 2011 a large workshop was held with a range of scientists, including estuarine experts and those involved in developing the ISC (see Appendix 2). A second smaller workshop, of just the trial teams, was held in mid-2012.

Interpreting ecosystem condition data relies on the establishment of baseline condition. Condition as measured in the IEC is an assessment of deviation in the ecology of the system away from reference, be it natural or best available, related to anthropogenic stress. Baseline condition is not a restoration target but rather a conceptual model of how an estuary should be under realistic minimal human activity. The way a baseline is defined needs to be consistent so that condition can be compared across regions or the state although the value of the baseline does not need to be the same for all estuaries. Waterway condition assessment in Victoria is moving away from using reference conditions towards assessing against management target condition (DEPI 2013). It is envisaged that the IEC will adopt that way in the future but was developed using deviation from reference condition.

While some biotic condition measures were recommended for the IEC, all required considerable further work to establish the baseline condition and develop descriptions and scores which reflect the extent of deviation from that condition. For many other measures, descriptions and associated scores have been developed for estuary assessment programs used elsewhere and their suitability for use in Victorian estuary assessments required testing. The implementation trial aimed to identify the type of baseline for each measure and how it was derived. From the derivation of a baseline, thresholds could then be identified or derived. These baselines and thresholds are reflected in the scoring and condition bands for each measure.

There are numerous ways of defining baseline, the use of which reflects the level of knowledge and availability of data for a particular measure. The list below includes ways of defining baseline condition that are used with decreasing levels of existing data and/or knowledge of a particular measure:

- Natural/pristine condition (pre-European);
- Historical data;
- Current state-wide data (best available);
- Current individual estuary data;
- Modelling of past conditions; and
- Expert opinion.

Workshop members in 2011 agreed that the specificity of a baseline will relate to the amount of information available. Where little data exist, only one baseline may be able to be developed for all estuaries, more data will allow multiple baselines to be developed (where appropriate) that can reflect regional differences. A combination of baselines is possible, incorporating any information on true reference (natural/pristine) with ‘best-available’ (both based on independent measures of pressures and response(s)), to produce a "modelled" baseline. The use of best available as a baseline in a region needs to be undertaken with caution as the condition of the baseline system/s may be quite low, making it difficult to equitably compare condition across the state. If a measure’s baseline is identified from the current individual estuary data, then the data from the first visit are used to create the baseline. For this type of baseline the first sampling (current condition) is compared to next sampling event. This is not a preferred way of setting a baseline, as this represents a temporal trend rather than variation from natural/reference. In the ISC, most baselines are a combination of approaches. The 2011 workshop concluded that there is no single correct approach to be applied across measures for baselines. Any approach needs to be guided by the shape of the data and use the opinion of the experts involved in developing the IEC (2008 workshop participants, Appendix 1).

Baselines can change over time as more data become available, or as conditions change in ‘best-available’ systems (e.g. using data quartile approach). This is not an issue in meeting the basic IEC aim, to benchmark estuary condition state-wide or regionally every eight years. The IEC, like the ISC, will be adaptive and able to incorporate improved methodology and new science and research over time (DEPI 2013).

Condition bands are the range or band width for each of the five scoring categories that are used to translate data into scores on a scale that is ecologically meaningful. The thresholds for each band for scoring each measure are based on the available data and known conceptual threat/impact models or ecological thresholds from the literature. The relationships between condition and independent threat measures are unlikely to be linear. Thresholds can be even (e.g. based on quintiles to create five categories), or can be a combination of these approaches that reflects the shape of a measures distribution and knowledge regarding meaningful thresholds. Quintiles can be used where there is a broad trend with land use and no obvious cut offs. The 2011 workshop concluded that there is no single correct approach to be applied across measures for scoring thresholds.

The 2011 workshop suggested that for categorical variables, it was important to assess not only non-compliance with a guideline or trigger value but also the deviation from non-compliance, i.e. small numerous or large few occasions. This adds a layer of sensitivity.

It was agreed at the 2011 workshop that scoring thresholds for condition bands:

- Must make sense and be ecologically defensible;
- Use relationships independent of measures of threats;
- Use distribution of data across a large numbers of estuaries;
- Use distribution of scores of deviation from baseline; and
- Use expert opinion and "modelled" thresholds.

For each measure the justification of how and why each threshold decision was made is given. Sometimes arbitrary decisions were made where data or tested models or ecological knowledge were insufficient. Arundel et al. (2009) gave condition descriptions for excellent (5) and very poor (1) scores for most measures, however assigning intermediate scores (2 to 4) in most cases required further data collection and analysis. Based on current human activities there are some estuaries that can never be scored as excellent for some measures.

The implementation trial design allowed for the application of different baselines and scoring thresholds between different types of estuaries, but for simplicity of use and interpretation, the IEC aimed for the same baseline and thresholds across all of Victoria’s estuaries where possible.

Overall IEC score

The overall IEC score is used to put an estuary into a condition band compared to all assessed estuaries state-wide. Condition bands do not have to be all the same width. As with the ISC, the theme (subindex) score is worked out and then adjusted for missing measures.

Consideration was given in the 2012 workshop (Appendix 2) as to whether there were critical themes/measures that need to have scores in order to derive an overall score. Should ecological themes be weighted higher in score integration than the physical and hydrological themes? For example, do we weight fish and birds highly, along with seagrass? Other recent waterway condition assessments like the Sustainable Rivers Audit weight biota more highly than physical and hydrological themes (Davies et al. 2012). Consideration was also give to the within-theme weighting of individual measures. The ISC only explicitly does this for hydrology and for the 2010 Streamside Zone, but the ISC has a different number of measures in different themes so actually ends up weighting the measures between themes (i.e. weight of measure overall is inverse to number of measures in its theme). Confidence in data could be considered as a variable that is combined with the importance of a measure to derive a weighting for theme scores – e.g. for water quality; weight a water clarity measure with high confidence so that it influences the theme score more than an associated low-confidence dissolved oxygen measure for the same location rather than giving both measures equal weight. With the sparse amount of data available for Victorian estuaries it was decided that weighting should not be considered at this stage between or within themes and that this should be revisited when more data has been collected.

The implementation assessment for each measure varied depending on the particular measure and its current stage of development. Scores and estimates of their distributions were required for all measures before it was possible to combine measures within themes, or to combine themes into overall condition categories. All scoring processes in the IEC are transparent, with overall score, theme and measure scores, and raw data, all publicly available.

The trial implementation of the recommended IEC measures (Arundel et al. 2009) in a selection of estuaries provided the opportunity to:

- Assess the suggested sampling methodologies, including the delineation and assessment of reaches, for practicality/ efficiency of collection;
- Establish/confirm baseline conditions;
- Assign and/or refine scores from 1-5 to reflect the condition of the measure;
- Ensure measures provide a spread of values to allow adequate discrimination between estuaries and also reflect the potential range of estuary condition;
- Determine if there are ambiguities in interpreting data;
- Consider options for combining scores (if multiple measures are recommended) in a way that best reflects the condition of the theme content; and
- Investigate aggregation and integration methods which best reflect overall estuary condition,

2.4 PURPOSES OF THIS REPORT

This report summarises the findings of the implementation trial of the recommended IEC (Arundel et al. 2009), providing detailed analyses of results and recommendations for inclusion of measures for the first formal IEC.

Aims specifically addressed in this report are to:

- Refine protocols proposed in the recommended IEC (Arundel et al. 2009), to refine field techniques, scoring and develop field sheets as necessary;
- Undertake targeted sampling for measures where existing data were not adequate;
- Assess the measurability of the recommended IEC measures (Arundel et al. 2009); and
- Develop and assess baselines, scoring distributions, response and sensitivity of individual measures and make recommendations for the rollout of the IEC.

3 METHODS AND BACKGROUND

3.1 VICTORIAN ESTUARIES

The selection of estuaries to be included in the trial was guided by those estuaries considered in Barton et al. (2008), which was originally based on estuaries identified by local and regional managers as systems of interest (OSRA 2001). This list was updated following discussions with each of the CMAs and Melbourne Water in 2009 (Appendix 3). A consistent definition of IEC estuaries is that they:

- Have substantial variation in salinity due to the mixing of marine and fresh waters;
- Are at least 1km long, or have lagoonal lengths of at least 300m;
- Include riparian, animal and plant communities that are affected by waters of the estuary; and
- Include tributary estuaries that run into Corner Inlet, Gippsland Lakes, Western Port and Port Phillip bays and fulfil the above length criterion.

This definition captures the majority of the Victorian estuaries that the community recognises, values and uses. Ninety-nine Victorian estuaries met the criteria and are considered suitable to assess using the IEC (Table 39). An additional two estuaries (Watsons and Warringine Creeks) that, based on available information, did not meet these criteria were included in the trial due to their regional importance to Melbourne Water who funded their trial along with an additional four estuaries in their region. Barton et al. (2008) delineated, through digital elevation and stream flow models, the freshwater and estuarine catchments of most of the IEC estuaries and determined the threat levels from land use and population density patterns. In this trial, these derivations were reviewed and with new catchments and attributes derived for the Gippsland Lakes estuaries.

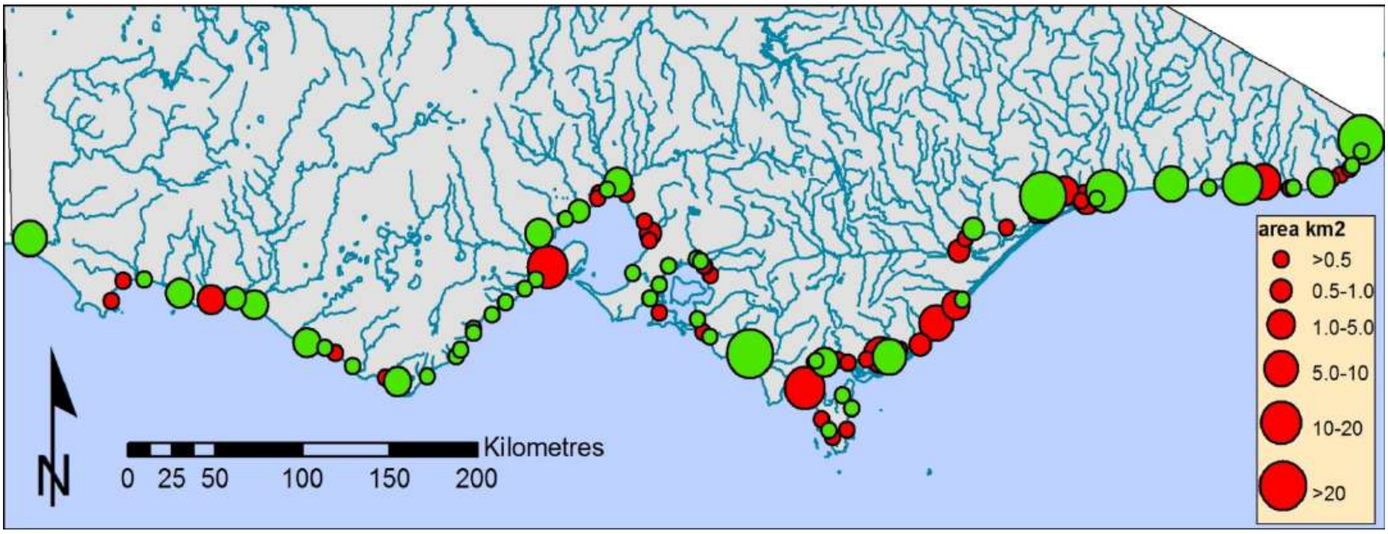

Figure 4. IEC estuaries along the Victorian coast. Symbol size indicates estuary water area. The locations of the estuaries sampled in the trial are in green.

Table 39. List of Victorian estuaries for which the recommended IEC is applicable. Waterway names have been abbreviated, R = River, Ck = Creek.

NRM Region	IEC Estuaries
East Gippsland	Toms Ck, Forge Ck/Newlands Arm, Mitchell/Nicholson complex, Slaughterhouse Ck, Tambo R, Stock Ck, Mississippi Ck, Lake Bunga, Lake Tyers, Snowy R, Yeerung R, Sydenham Inlet, Tamboon Inlet, Thurra R, Mueller R, Wingan Inlet, Easby Ck, Red R, Benadore R, Seal Ck, Shipwreck Ck, Betka R, Davis Ck, Mallacoota Inlet
West Gippsland	Powlett R, Anderson Inlet, Shallow Inlet, Darby R, Tidal R, Growler Ck, Sealers Ck, Miranda Ck, Chinaman Ck, Old Hat Ck, Stockyard Ck, Bennison Ck, Franklin R, Agnes R, Shady Ck, Nine Mile Ck, Albert R, Tarra R, Neils Ck, Bruthen Ck, Jack Smith Lake, Lake Denison, Merriman Ck, Latrobe R, Lake W main drain, Avon R
Melb. Water/ Port Phillip & Westernport	Little R, Werribee R, Skeleton Ck, Laverton Ck, Kororoit Ck, Yarra R, Elwood Canal, Mordialloc Ck, Patterson R, Kananook Ck, Balcombe Ck, Merricks Ck, Cardinia Ck, Deep Ck, Bunyip R, Yallock Ck, Yallock drain, Lang Lang R, Bass R
Corangamite	Curdies Inlet, Campbells Ck, Sherbrook R, Gellibrand R, Johanna R, Aire R, Barham R, Kennett R, Wye R, St George R, Erskine R, Painkalac Ck, Anglesea R, Spring Ck, Thompson Ck, Barwon R, Hovells Ck
Glenelg Hopkins	Glenelg R, Wattle Hill Ck, Surrey R, Fitzroy R, Eumeralla R, Moyne R, Merri R, Hopkins R

Various studies have identified the lack of adequate Victorian estuary data sets for assessing changes in environmental condition (Barton 2003; Sherwood et al. 2003; Barton and Sherwood 2004; GHD 2005; Molloy et al. 2005; Arundel and Barton 2007; Arundel et al. 2008; Barton et al. 2008; Sherwood et al. 2008). To try and address this issue, Coastal Natural Resource Managers in CMAs and Melbourne Water were visited and interviewed in late 2009 to establish what data existed for each IEC measure (Appendix 3). This built on the findings of Barton et al. (2008) and helped inform the choice of estuaries for further data derivation. It was established that limited data sets existed for the recommended methods, especially at the recommended sampling frequency (Arundel et al. 2009). In general terms, more estuaries had existing data in the west of the state than in the east, and larger systems were more likely to have been studied than smaller systems.

3.2 EXPERIMENTAL DESIGNS

3.2A FUNCTIONAL TYPES

To ensure the measures and condition scores were applicable to all Victorian estuaries, Arundel et al. (2009) recommended that trials be conducted on estuaries that represent the range of possible responses to particular threats. Barton et al. (2008) assessed current estuary classifications for Victorian estuaries and developed a classification of four Victorian estuary types based on their broad physical characteristics in the absence of extensive ecological data (Table 40). These broad physical attributes of estuaries and their estuarine and fluvial (freshwater) catchments encompass most of the state-wide variability in the major drivers (e.g. catchment size and steepness, and orientation with regard to wind and coastal current direction) that are likely to influence their ecological functioning. Estuary and fluvial land use intensity and population density based threat levels were identified for each estuary (Barton et al. 2008). Arundel et al. (2009) recommended that the trial of the IEC measures should include estuaries from each of the four types exposed to high and low levels of threat. The design of the trial implementation included type as an upper level factor to reduce variability in threat-response relationships and allow assessment if separate baselines and scoring methods were needed.

Table 40. Descriptions of functional types of Victorian estuaries (Barton et al. 2008).

Type	Description
West	Run to open, west facing coasts. Large to moderate size estuaries & catchments. Intermittent mouth often with lagoon. Sandy, high energy coast facing major weather patterns.
East	Run to open, east facing coasts. Small, intermittent estuaries with steep catchments. Rocky, moderate energy coast at angle to major weather patterns.
Bay/Sheltered	Run to embayments, sheltered coasts. Small to moderate, generally permanently open estuaries without lagoons. Flat small to moderate catchments. Muddy, low energy coast, some with large tides.
South	Run to open, south facing coasts. Large to moderate size estuaries & catchments. Intermittent mouth often with lagoon. Limited seasonal difference in rainfall. Sandy, moderate energy coast facing major weather patterns.

3.2B ESTUARY SECTIONS AND ZONES

Any tool that assesses condition of a natural ecosystem should have clearly defined spatial boundaries and scales at which it can be applied. The mouth and head of the majority of IEC estuaries were defined by Barton et al. (2008). The head of the estuary was defined as the upper extent of bottom saline water from field assessments in low flow autumn periods or from previous studies and the mouth as the extension of the coastline from one bank to the other (Barton et al. 2008). For the purpose of the IEC it was necessary to:

- Determine the size and type of subestuary to be included in assessments;
- Establish protocols for dividing the estuary into sections (lagoonal and riverine); and
- Establish protocols for dividing the estuary into zones (upper, middle and lower).

A tributary of the main IEC estuary was included as a subestuary if it had variable salinity due to the mixing of marine and freshwaters over greater than 1km in length before it joined the IEC estuary. An estuary could have none or numerous subestuaries. It was suggested (Arundel et al. 2009) that the IEC should include sections of estuaries, analogous to reaches in the ISC, that can be assessed independently of each other. Two types of section were proposed, either riverine or lagoonal (Figure 5). An individual estuary may consist of either of these or a combination of (usually) one lagoonal section and one or more riverine sections. Some of the measures can be scored for individual sections while others can only be scored for the estuary as a whole (but can then be applied to each section). For measures where sampling across the whole estuary was necessary, estuaries were divided into three longitudinal zones (lower, middle and upper) based on geomorphology and vegetation (Figure 5). Subestuaries, if present, were zoned using the same criteria, with each estuary having only one lower zone associated with its mouth. While estuaries can have an influence on nearshore marine environments, the IEC does not attempt to assess the condition of these regions.

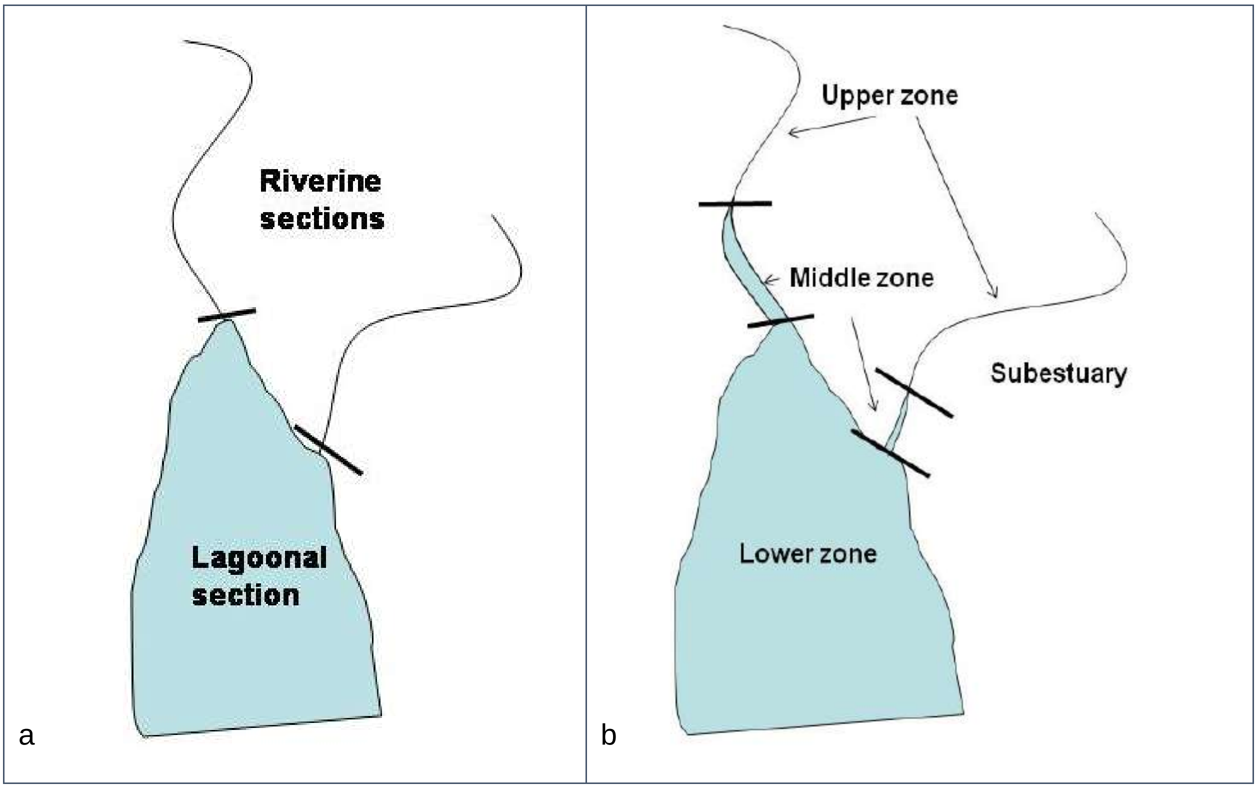

Figure 5. A schematic example of the estuarine sections and zones used in the implementation trial: a) two riverine sections are shown attached to a lagoonal section with boundaries shown in heavy lines; b) an estuary with zones and a subestuary entering the lower zone.

Each estuary, subestuary and section is numbered hierarchically (eg Figure 6, Table 41), with numbering consisting of:

- Its Australian Water Resources Council basin (AWRC Basin) number and secondary AWRC basin number if the estuary spans two basins (4 digits);
- An estuary code (Estuary_ID) based on its position along the coast from the South Australian border (3 digits);
- A subestuary code (SE_ID) where the primary estuary or mainstem is subestuary one, and subsequent subestuaries are numbered from west to east along the shoreline of the primary estuary starting from the western side of the entrance to the sea (1 digit); and
- A section code (Section_ID) that uniquely identifies a section within an estuary, ordered from the mouth upstream and in order of subestuary (2 digits).

Table 41. Yarra River estuary as an example of individual numbering of estuaries, subestuaries and sections.

Full_ID	AWRC Basin	AWRC 2nd Basin	Estuary ID	System	Subest. ID	Subestuary	Section ID	Section type	Section name
2930_031_1_01	29	30	031	Yarra River	1	Yarra River	01	Lagoon	Yarra Port Area
2930_031_1_02	29	30	031	Yarra River	1	Yarra River	02	Riverine	Yarra River
2930_031_2_03	29	30	031	Yarra River	2	Stony Creek	03	Riverine	Stony Creek
2930_031_3_04	29	30	031	Yarra River	3	Maribyrnong River	04	Riverine	Maribyrnong River
2930_031_4_05	29	30	031	Yarra River	4	Moonee Ponds Creek	05	Riverine	Moonee Ponds Creek

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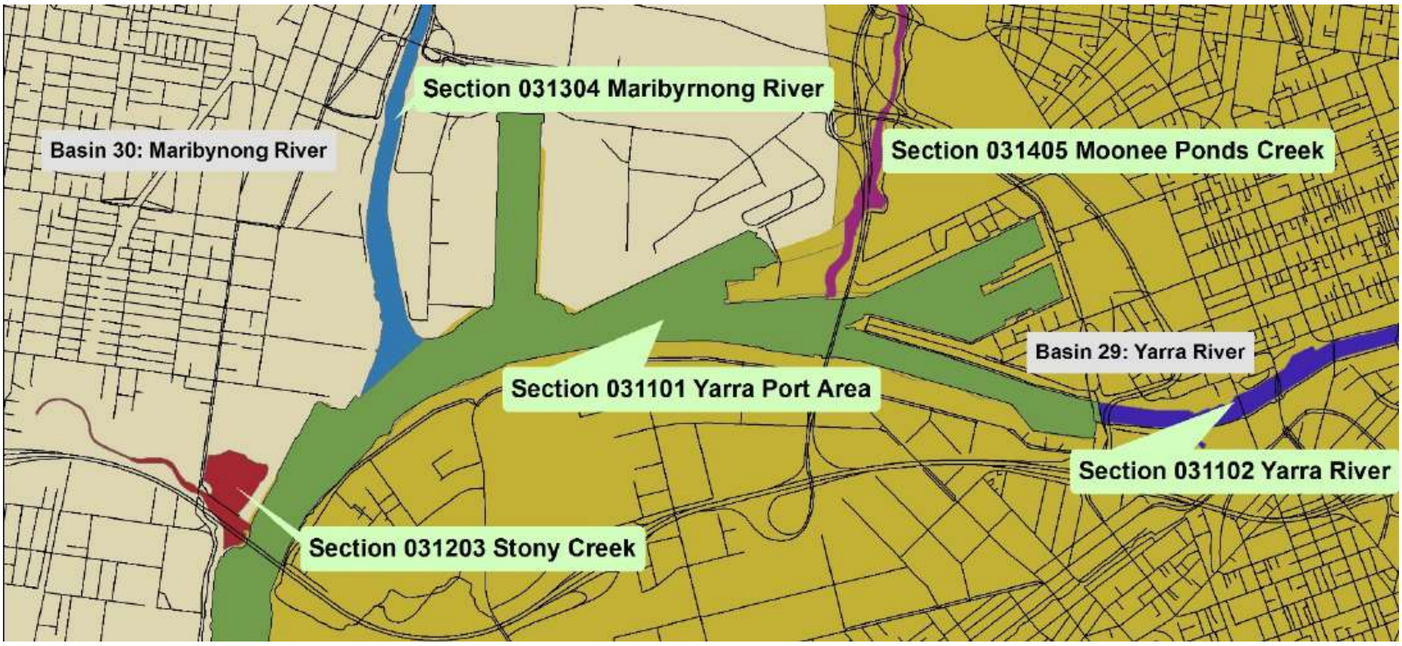


Figure 6. Numbering of sections in the Yarra estuary which crosses 2 basins and includes a number of subestuaries and sections. The Primary basin is Yarra (29) and the secondary basin is Maribyrnong (30) hence Basin ID is 29_30. Estuary ID is 031 and four subestuaries are shown (1-4: 1 is mainstem, 2-4 are numbered west to east). Of all the subestuaries only the Yarra has more than one section (Sections 01 and 02), other sections are numbered from west to east as per the subestuaries.

3.2C SAMPLING

Only a subset of measures (Table 42) required, or were practical for, trialling over a large number of estuaries. These measures were (with numbering from Table 38):

Physical Form theme
- Upstream Barriers (3) (presence, type & location)
- Lateral Connectivity (4) (# & type of artificial structures on foreshore)

Hydrology theme
- Marine Exchange (5)-
  - 5a) mouth opening (observations only)
  - 5b) structures and behaviours (dredging & training walls)
- Salinity Regime (7)

Water Quality theme
- Water Clarity (8) (turbidity)
- Dissolved Oxygen (9) (mg/L & %)

Sediment theme
- Sediment Particle size (10)
- Bank Erosion (11) (ISC method)

Flora theme
- Microphytobenthos biomass (15) (Phaeophytin &/or Chlorophyll *a*)
- Phytoplankton biomass (16) (Chlorophyll *a*)

Table 42. Summary of the spatial and temporal replication needed for trialled IEC measures (Arundel et al. 2009).

Theme	Measure	Spatial scale	Temporal replication
Physical Form	Upstream barriers (1)	Estuary	Eight yearly
	Lateral connectivity (2)	Section	Eight yearly
Hydrology	Marine exchange:		
	mouth intermittent (5a)	Estuary	Continuous & event
	mouth permanent (5b)	Estuary	Event
	Salinity regime (7)	Estuary	Defined tides
Water Quality	Water clarity (8)	Section	Monthly
	Dissolved oxygen:		
	Profile (9)	Section	Monthly
	Overnight decrease	Section	Monthly
	Additional parameters		
	Bottom pH	Section	Monthly
	Bottom salinity	Section	Monthly
	Top salinity	Section	Monthly
	Stratification status	Section	Monthly
	Daily flow	Section	Week before sampling
Sediment	Particle size (10)	Zone	Eight yearly
	Bank erosion (11)	Section	Eight yearly
Flora	Microphytobenthos (15)	Zone	Monthly
	Phytoplankton (16)	Zone	Monthly

Three different sampling designs with different spatial replication (Table 42), and with measures taken at the whole estuary longitudinal, section or zone, were used depending on the measure being assessed (Arundel et al. 2009). In field sampling each design overlayed the other two, with efficiencies of sampling made by combining sites where possible. Six measures, changed bathymetry (1), sediment load (2) (Physical Form theme), freshwater flow (6) (Hydrology theme), sediment respiration rate (12) (Sediment theme), aquatic macrophyte (13) extent and macroalgal cover, and fringing macrophyte (14) extent and condition (Flora theme) (Arundel et al. 2009), were assessed from existing data or from small focussed studies using a smaller number of estuaries than the larger field trial. A proforma field sheet was developed and refined through the three sampling summers (Appendix 5 Proforma field sheet for implementation trial). Sampling was conducted under a Department of Sustainability and Environment (now DELWP) permit number 10005760.

Over three summers of sampling (2010, 2011 and 2012), 50 estuaries (including the 6 Melbourne Water targeted estuaries) were sampled across the state from Glenelg River in the west to Mallacoota Inlet in the east (Figure 4, Table 43 & Table 44). This included 119 riverine or lagoonal sections and 74 subestuaries (tributaries and lagoon complexes). A list of these subestuaries and sections is given in Appendix 4. Estuaries were sampled across the entire state in the 2010 sampling period. In 2011 the sampling focus was on western Victorian estuaries and in 2012 eastern Victorian estuaries were sampled. In each sampling season the order of sampling was allocated haphazardly to avoid confounding longitude with any event/season-related changes in the estuaries. Two teams with two or three staff each worked in parallel throughout the three field programs, which involved sampling between February and early April. During field sampling staff from East Gippsland, West Gippsland, and Corangamite Catchment Management Authorities (CMA's) and Melbourne Water Authority participated in making observations and collecting samples as well as providing further local information and commenting on the field recording sheets and methods (Appendix 5). Ten estuaries were sampled twice over the three summers. Glenelg, Aire, Powlett and Tidal Rivers and Anderson Inlet were sampled in 2010 and 2011. Tarra and Mitchell/Nicholson Rivers, Lake Bunga, Shipwreck Creek and Wingan Inlet were sampled in 2010 and 2012.

The assessment of the implementation of each measure is presented by theme. For each measure, a brief introduction and overview, derived and updated from the recommended IEC (Arundel et al. 2009), is given describing the measure and processes it relates to. Then the data and estuaries used to test the implementation are identified and discussed. The scoring method used to derive the five categories is then described followed by the data confidence, and the baseline type and rationale. An overview of the scores for the estuaries that had data is given with the individual scores presented in the appendices. Lastly the implementation and further development needed to improve the measure is discussed.

Table 43. The fifty estuaries sampled as part of the IEC implementation trial over three summers, listed from west to east across Victoria. Abbreviations in the table are for functional types, W = West facing coast, E= East facing coasts, B = Embayment, S = South facing coast, threat level, L = low, M = moderate, H = high, and for region, GH = Glenelg Hopkins, C = Corangamite, MW = Melbourne Water, WG = West Gippsland, EG = East Gippsland. Estuaries in brackets were Melbourne water funded.

IEC estuary #	Estuary	functional type	threat level	CMA/ management region	2010	2011	2012
1	Glenelg River	W	L	GH	1	1	
4	Fitzroy River	W	M	GH		1	
5	Lake Yambuk	W	L	GH		1	
7	Merri River	W	H	GH	1		
8	Hopkins River	W	H	GH		1	
9	Curdies Inlet	W	M	C		1	
10	Campbell Creek	W	H	C		1	
12	Gellibrand River	W	L	C		1	
14	Aire River	W	L	C	1	1	
15	Barham River	E	M	C	1		
16	Kennett River	E	L	C	1		
17	Wye River	E	L	C		1	
19	Erskine River	E	H	C		1	
20	Painkalac Creek	E	M	C	1		
21	Anglesea River	E	H	C		1	
22	Spring Creek	E	H	C	1		
23	Thompson Creek	E	L-M	C		1	
25	Limeburners Lagoon	B		MW			1
26	(Little River)	B	L	MW	1		
27	(Werribee River)	B	H	MW	1		
30	Kororoit Creek	B		MW	1		
31	Yarra River	B		MW	1		
36	(Balcombe Creek)	B	H	MW	1		
37	Merricks Creek	E	H	MW	1		
998	(Watsons Creek)	B	H	MW	1		
999	(Warringine Creek)	B	M	MW	1		
38	Cardinia Creek	B		MW	1		
40	(Bunyip River)	B		MW	1		
44	Bass River	B	L	MW	1		
47	Powlett River	W	H	WG	1	1	
49	Anderson Inlet	W	H	WG	1	1	
52	Tidal River	W	L	WG	1	1	
55	Miranda Creek	E	L	WG	1		
56	Chinaman Creek	B	L	WG			1
59	Bennison Creek	B	M-H	WG			1
60	Franklin River	B	H	WG			1

IEC estuary #	Estuary	functional type	threat level	CMA/ management region	2010	2011	2012
65	Tarra River	B	H	WG	1		1
70	Merriman Creek	E	M-H	WG			1
73	Avon River	B	H	WG			1
77	Mitchell/Nicholson	B	M	EG	1		1
82	Lake Bunga	S	H	EG	1		1
83	Lake Tyers	S	M-H	EG	1		
84	Snowy River	S	M-H	EG	1		
85	Yeerung River	S		EG	1		
86	Sydenham Inlet	S		EG			1
89	Mueller River	S		EG			1
90	Wingan Inlet	S	L	EG	1		1
95	Shipwreck Creek	S	L	EG	1		1
97	Davis Creek	S	H	EG			1
98	Mallacoota Inlet	S	M	EG			1

Table 44. Summary of the number of estuaries sampled for the IEC implementation trial, including the number of subestuaries and sections.

Year	# IEC estuaries	# subestuaries	# sections
2010	24 (6)	36 (6)	59 (8)
2011	15	20	33
2012	15	26	40

( ) Melbourne Water funded

4 RESULTS OF IMPLEMENTATION OF PHYSICAL FORM MEASURES

The Physical theme (Figure 7, Table 45) considers modifications to the physical environment of estuaries that are important to ecological condition (Arundel et al. 2009). It relates to the naturalness of the physical environment within the estuary. The physical structure of an estuary includes its depth, bed, banks and the presence of structures that alter connectivity to adjacent marine and freshwater ecosystems, and connectivity of the estuary to riparian areas and any associated wetlands (Arundel et al. 2009). The physical elements of the estuary combine to define the types of habitat available. Alterations to physical form are relatively common and can influence ecological condition both indirectly and directly and via multiple pathways (Arundel et al. 2009).

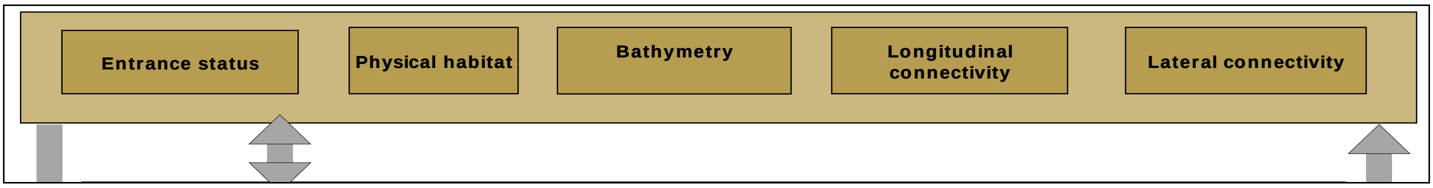


Figure 7. Physical Form components of conceptual model. (Full model shown in Figure 1).

Table 45. Recommended measures within Physical Form theme from Arundel *et al*. (2009).

PHYSICAL FORM	HYDROLOGY	WATER QUALITY	SEDIMENT	FLORA	FAUNA
1. Changed bathymetry 2. Sediment load 3. Upstream barriers 4. Lateral connectivity					

Physical Form includes the overall morphology of an estuary as well as the physical characteristics of its littoral region. Measures included in this theme relate to altered sedimentation rates and physical barriers that reduce connectivity to lateral and upstream environments (Arundel et al. 2009). Downstream, or marine, connectivity is included as a measure (5) in the Hydrology theme. There is some overlap between Physical Form and the Sediment theme, the distinction being that physical form addresses larger scale processes such as gross changes in bathymetry and sediment loads from catchments, whereas the Sediment theme focuses on processes at finer scales (Arundel et al. 2009).

Measures in this theme address aspects of the physical environment of an estuary that can fundamentally alter the nature of estuarine ecosystems (Arundel et al. 2009). Such alterations may include the removal or addition of particular habitat types and changes to the timing and rate of movements of plants and animals between habitats (Arundel et al. 2009). The recommended Physical theme (Arundel et al. 2009) consisted of four measures, changed bathymetry (1), sediment load (2), upstream barriers (3) and lateral connectivity (4) (Table 38).

4.1 CHANGED BATHYMETRY (1)

Changed bathymetry (1): not recommended, needs improved methods

Over geological time the bathymetry of estuaries typically decreases (Arundel et al. 2009). The sedimentation/erosion rate in estuaries is naturally variable because of the variability in natural processes causing it (e.g. water current/ flow patterns, climate (rainfall, seasonality), geology, slope (or topography), etc.) (Scheltinga and Moss 2007; Ganju et al. 2011). In recent times, some Australian systems have filled at an accelerated rate in association with anthropogenic increases in fluvial sediment supply. Other human-influenced changes in bathymetry include increases in landward infilling with marine sediments, particularly in artificially-opened estuaries, and accumulation of sediments associated with water extraction and reductions in scouring flows. Increased sediment within an estuary can have many causes, such as increased coastal erosion due to loss of vegetation, catchment run-off (rural and urban), episodic and large scale events (drought, floods, storms, bushfires), and point source discharge (Scheltinga et al. 2004; Ganju et al. 2011; Madricardo et al. 2012). Combined with ongoing sea-level rise this implies a constant modulation of hydrodynamic energy and sediment transport behaviour (Ganju et al. 2011). Conversely, human activities such as upstream dams and coastal engineering works can decrease sediment supply to estuaries. Changed sedimentation rates can result in important changes to the form and function of waterways (e.g. they may cause: changed shoreline and mudflats area, channel infilling, habitat/benthic community smothering or removal, increased turbidity levels, and the burial or resuspension of nutrients, trace elements, toxicants and organic matter) (Scheltinga and Moss 2007; Ganju et al. 2011; Mied et al. 2013). Increases in the supply of sediment can cause increased deposition (10) and water turbidity (8), habitat and biota loss (13A) through smothering and decreased depth (Scheltinga and Moss 2007). The net result of enhanced sedimentation rates are an increase in the maturity of coastal waterways, and a decrease in their overall lifespans (Scheltinga and Moss 2007). Reductions in the biodiversity, health and integrity of coastal ecosystems may also occur (Scheltinga and Moss 2007; Ganju et al. 2011).

Changed bathymetry (1) = changed bathymetry in depositional locations

Baseline = current individual estuary data

The baseline for changed bathymetry would need to be based on current individual estuary data as modelling natural bathymetry to a degree of accuracy suitable for assessment of short term changes is not possible.

Data used

The changed bathymetry measure was proposed as an accurate measurement of change in bathymetry, occurring along cross-sectional transects in depositional locations (Arundel et al. 2009). Depositional sites include fluvial and flood tide deltas, the areas of maximum turbidity, and tidal flats and basins. The immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to require substantial work and be hard to achieve. This measure also relates to those of sediment load (measure 2) and particle size (measure 10) (see Sections 4.2 and 7.1). During the implementation fieldtrips, depositional sites were identified for the sediment particle size measure (10) and GPS located (Appendix 5).

Little pre-existing data were identified (Appendix 3). Although there are a few well surveyed estuaries (such as Werribee and Gellibrand), the resources needed to resurvey them with existing technology were outside the scope of the implementation trial. Some relevant contextual information is available through modelled sediment deposition (Prosser et al. 2001; Section 4.2) and observations of sand slug incursions (Section 4.3).

Accurate mapping of the bathymetry and sedimentation history of estuaries often represents a serious technological challenge due to both navigational and instrumental issues (Madricardo et al. 2012). Aerial remote sensing, primarily LiDAR, for deriving data for this measure has had issues with turbid water in estuaries although it is highly effective for measuring elevation in parts of estuaries where it can be used. High resolution sounder or surveys are promising for collecting fundamental data of the depth and change in depth. Single beam echosounders are easy and relatively cheap to implement in extremely shallow water (less than 1 m) environments while multibeam units are effective in covering larger and deeper areas. Use of historical surveys can reveal overall trajectories of change in estuarine morphology but are associated with numerous sources of error which can be on a par with depth changes on decadal scales (Van der Wal and Pye 2003).

The reliability and utility of estuarine geomorphic models can be maximised by applying models to problems on management timescales (i.e., one decade), and testing the sensitivity to the tidal and annual forcing interactions (Ganju et al. 2011). Efforts to extrapolate historical or current conditions to simulations of future geomorphology can be fraught with error (Ganju et al. 2011). Modelling and field verification should investigate the interaction between estuarine processes, idealised forcings and boundary conditions, and morphological acceleration in depth (Ganju et al. 2011).

In the second stage of the implementation trial, cores to depths pre-dating European settlement were taken and dated using nuclear techniques in a few targeted estuaries to help inform current day bathymetric mapping. This work was undertaken in collaboration with Ballarat University (now Federation University) and some additional funding from the Australian Institute of Nuclear Science and Engineering (AINSE) for dating in cores taken from estuaries running into Port Phillip Bay. This assessment will be reported in a separate document.

Scoring Method

There has been some development in scoring this measure since the recommendations of Arundel et al (2009) but thresholds cannot be recommended at this stage. It is proposed to add the criterion of whether there has been a large historical reduction in estuary bathymetry. The scoring system in Table 46 was developed at the IEC 2008 workshop and modified in the scoring workshop of 2012. There was some debate as to whether changed bathymetry scoring should specify the volume of reduction but this may be going too far with the current data and understanding. Future development should consider whether the thresholds should also incorporate estuary type and/or maturity as both are associated with different rates of change in bathymetry. In addition, some estuaries are highly and continuously modified (e.g. Yarra), some have been substantially modified in the past (e.g. Western Port tributaries) and some are routinely modified with entrance opening (intermittent artificial opening). Rises in sea level and flood frequency and magnitude will also affect estuarine morphodynamics. Both should be considered in further development of this measure.

Table 46. Proposed scoring for changed bathymetry as developed in workshops. Thresholds for 8 year reduction in volume and prior reductions need further development.

	IEC score	
reduction in volume (8 year period)	No large change from historical	Prior reduction in historical volume greater than threshold (TBD)
Threshold to be determined	2	1
Thresholds TBD	4	2
Threshold TBD/detectable	5	3

Score confidence

Score confidence has not been developed yet.

Scores

No estuaries were scored.

Discussion

The inclusion of this measure eventually in the IEC is important, but with the current techniques for measuring it is too intensive and expensive for the IEC. In future it is hoped that the bathymetry of the entire estuary could be mapped once every IEC assessment period.

Future development:

- Assess remote sensing (both aerial and water-based) methods for mapping the entire estuary bathymetry, in often turbid environments and in both large and small systems.
- Assess if ground truth sampling for this measure could be incorporated with aquatic vegetation mapping.
- Assess whether ground truth sampling could be incorporated with bank erosion and fringing macrophytes if an improved application of LiDAR is developed.

4.2 SEDIMENT LOAD (2)

Sediment load (2): recommended with minor development of new, higher resolution modelling

The amount of sediment carried by rivers in Australia is thought to have increased many times over in response to land use change and associated erosion (Arundel et al. 2009). Modelled sediment supply to Victorian streams has increased by between three (in the Mitchell Basin) to over 1000 times (in the Bunyip and Portland Coast basins) compared to modelled pre-European inputs on a regional basis (Marston et al. 2001). This pressure can affect ecological condition by changes in the depth (measure 1) and sediment particle size (measure 10) of the estuary bed, transport of nutrients and toxicants, by smothering fauna and by reducing light penetration (Arundel et al. 2009). In some cases, sediment loads to estuaries may also be decreased, where sediments are trapped by instream structures or where transport of sediments is reduced in association with a reduced flow regime.

Sediment load (2) = modelled proportion of pre-European sediment delivery to estuary

The sediment load measure requires modelling of natural loads and modelling and/or measurement of current loads into the estuary from the catchment (Arundel et al. 2009). Contextual information is provided by the history of sedimentation in an estuary and its catchment which also relates to the measures of changed bathymetry (measure 1) and sediment particle size (10) (Arundel et al. 2009). The immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be moderately achievable. Assessment of this measure was identified primarily as needing derivation of data through modelling.

Baseline = modelling of past conditions

The baseline for sediment load is modelled natural sediment load from catchment sediment type and pre-European land use.

Data used

No estuary specific modelled sediment load was located through literature searches or interviews with coastal managers (Appendix 3). Modelled loads from the work of Prosser et al. (2001) for the National Land and Water Resources Audit (2002) were available for 56 estuaries (Appendix 7) and results for matching sections were also compiled at the sub-estuary level (Figure 8).

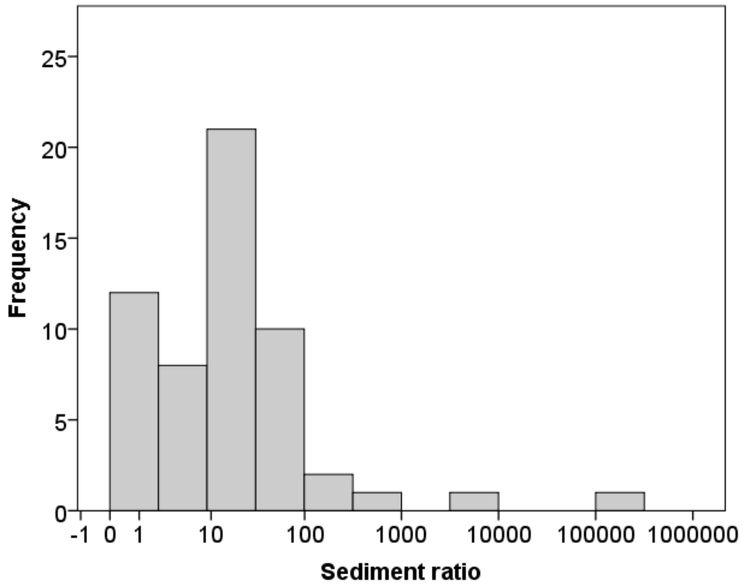


Figure 8. Distribution of proportional increases in modelled sediment load for Victorian estuaries (figure from Prosser et al. 2001).

Scoring Method

The scoring method has been refined from that originally proposed in Arundel et al (2009). The scoring system in Table 47 was developed at the IEC 2008 workshop and modified in the 2012 scoring workshop. It was based on both the distribution of modelled loads and opinion regarding potential effects on estuary condition. Modelled values for some systems are two or three orders of magnitude greater than the threshold for a score of 1 (Figure 8) but resolution between values higher than this threshold was considered to be unlikely to be relevant to condition and, for extremely high values, less certain in terms of the model's predictive capacity.

Table 47. Scoring for sediment load.

Modelled increase in sediment delivery to estuary (as a proportion of pre-European sediment delivery)	IEC Score
1	5
1 < or = 5	4
5 < or = 10	3
10 < or = 20	2
>20	1

A similar measure of changed sediment load is used in other states. In NSW a scoring method based on percentage increase in sediment load from natural is used (Roper et al. 2011), while in Queensland a scoring method based on absolute load has been suggested (Scheltinga and Moss 2007). In both these methods poor condition is a large change from natural (NSW>483% increase; Qld>10kg/year/m^3); and good condition is small or no change from natural (NSW <12% increase; Qld <5kg/year/m^3).

Score confidence

Despite some differentiation between estuaries based on the proportion of tributaries with modelled loads, confidence in all scores for this measure was considered low. Modelling was based on fluvial sediment supply introducing one source of uncertainty for predicting estuarine loads. The low resolution of the model which used regional and coarse scale datasets introduced more uncertainty into the score confidence particularly when applied to smaller estuaries and catchments. In addition the link between specific score thresholds and estuarine response was based on existing score distributions and expert opinion.

Scores

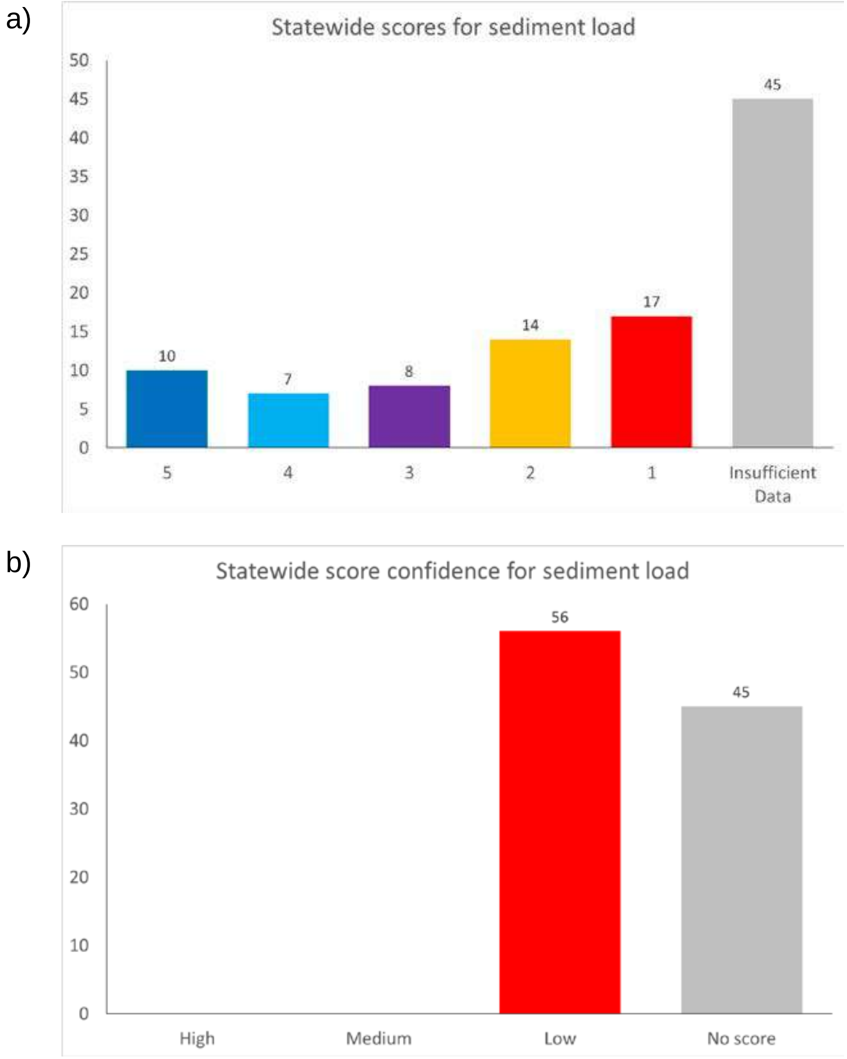


Figure 9. Statewide estuary a) scores and b) score confidence for the sediment load measure.

From the national data set NLWRA (2002), sediment load scores were able to be derived for 56 estuaries (Figure 9, Table 47), 45 estuaries did not have sufficient data for scores to be derived. The majority of estuaries that were scored, 31, had low scores of 1 or 2 indicating the modelled increase of sediment delivered was >10 times the baseline. Ten estuaries were scored as 5, these were predominately in the West and East Gippsland CMA regions. These were Jack Smith Lake, Lake Wellington Main Drain, Mississippi Creek, Lake Tyers, Yeerung River, Mueller River, Wingan Inlet and Betka River. Only two estuaries in the west of the state had low modelled sediment load and these were Lake Yambuk and Moyne River in the Glenelg Hopkins CMA region (Table 49, Appendix 7).

All scores were of low confidence because of the low resolution and coarse scale of the modelled datasets they were derived from (Figure 9b, Table 49).

Table 48. Numbers of estuaries by score and score confidence for the sediment load measure.

Score Confidence	IEC Score				
	5	4	3	2	1
High					
Moderate					
Low	10	7	8	14	17

Table 49. Sediment load scores and data confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH	2				6				8
C		3	1	1	4	8			9
MW/PPWP			1	7	5	9			13
WG	2	4	2	4		16			12
EG	6		4	2	2	12			14

Discussion

The available modelled data for sediment load to estuaries are over a decade old, of low resolution and gave a coarse measure of changed sediment load delivered to estuaries. The sediment load data were derived for rivers and needs to be reassessed specifically for estuaries. For Victorian estuaries increased resolution in the downstream links is a priority for this measure as assumptions about the proportion of floodplain deposition in lowland rivers can have a large effect on modelled transport to the estuary. The Moyne River is an example of this where the river link immediately above the estuary has a high sediment load (up to 807 times pre-European) but the link that takes in the estuary has a modelled sediment load equivalent to pre-European settlement. An updated sediment load model could also provide information of benefit for several other measures. For example, the model of Prosser et al. (2001) gives estimates of nutrient loadings and deposition of coarse sediment which, at the appropriate resolution, could be used for deriving future scores for altered bathymetry and interpreting data for aquatic flora measures.

Future developments:

- Reassess measure with sediment load modelling specifically for estuaries.
- Reassess measure with newer and higher resolution sediment load modelling.
- Reassess measure with sediment load modelling that is more sensitive to changed load in the smaller estuary catchments.
- Score confidence should be developed.
- Assess the effect of estuary maturity (sensu Roy et al. 2001) in setting score thresholds.
- Assess effects of catchment geology and estuary shape on estuary response to increased sediment load.

4.3 UPSTREAM BARRIERS (3)

Upstream barrier (3): recommended, some on ground survey needed in small Gippsland systems

Artificial upstream barriers both prevent movement of biota, particularly fish, up and downstream and can also reduce the diversity of estuarine habitat by preventing upstream movement of salt water (Arundel et al. 2009). Common barriers are weirs, and sand slugs from large upstream erosion events.

Upstream barrier (3) = % area of estuary affected by instream barrier

The upstream barriers proposed measure required the identification of the presence of anthropogenic barriers to upstream movement of water or biota in addition to their location relative to estimated natural upstream limit of the estuary (Arundel et al. 2009). The immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be very achievable (Arundel et al. 2009). Assessment of this measure was identified primarily as needing to collate and derive field measured data.

As part of the process of incorporation of this measure into AVIRA, the measure was further developed to specifically take into account the degree of blockage caused by a barrier as reflected in the scoring system (Table 50).

Baseline = natural/pristine condition (pre-European)

Baseline for this measure is natural (pre-European) condition of no upstream barriers.

Data used

A combination of existing data and new field assessments (Appendices 3 & 5) was used to identify existence of barriers to water and biota as well as the degree of intermittency of blockage. The heads of 52 estuarine tributaries were located as part of this project (e.g. Figure 10). Barton et al (2008) recorded features and compiled available data identifying the upstream limits and the presence of barriers for 46 estuaries. Other estuary heads were identified using information from a range of grey literature (GHD 2005; Pope 2006; Aquatic Systems Management 2007; Arundel 2007; Becker 2007; Lind and Sherwood 2007; Wealands et al. 2007; Lloyd et al. 2008a; Water Technology hydrographic survey of LaTrobe River estuary 2011, AECOM 2012; Information on sites of geomorphological significance (various reports by N. Rosengren et al) at Department of Environment and Primary Industries Victoria 2014). Assessments of the degree of blockage also used information from the fishway survey of O’Brien et al. (2010). For relevant locations in the Corangamite region the degree of blockage for fish cited in Ryan et al (2010) was used (fish passage through drownout score <3 was classified as an intermittent blockage).

A particular challenge of assessing and implementing this measure was developing a method to derive the natural heads of estuaries. Where artificial barriers existed, locations of historical estuary heads were derived from historical documents, field observations, remotely sensed elevation data and waterway morphology. The degree of confidence in the estimate varied according to the available evidence, as summarised in Table 51.

A subset of originally freshwater systems are now functioning as estuaries. Where no historical head existed the position was estimated at the likely location had there been a marine influence downstream. Similarly, where natural barriers have been removed (e.g. Yarra River estuary) the system was assessed as per other systems according to the new longitudinal extent. Estuaries where the above applies include the ‘child’ estuaries of the Gippsland Lakes, where downstream salinities have increased through the dredging of a permanent connection to the sea; the Yarra, where the original upstream barrier near Queen Street has been removed and systems such as Elwood Canal and Patterson River, which were created largely as a result of drainage schemes.

Figure 10. Examples of artificial and natural estuary heads, a) Tidal River, b) Moonee Ponds Creek (Yarra River), c) Bass River and d) Wingan Inlet.

A total of 61 estuaries were fully assessed for this measure, with six for which the presence of barriers was only assessed for some tributaries and 34 for which the presence of upstream barriers is unknown. Of the 139 subestuaries across the state, 97 were assessed and 42 were not. Of the assessed tributaries, 25 had some kind of artificial barrier which tended to be found in more central regions of the state (Figure 11).

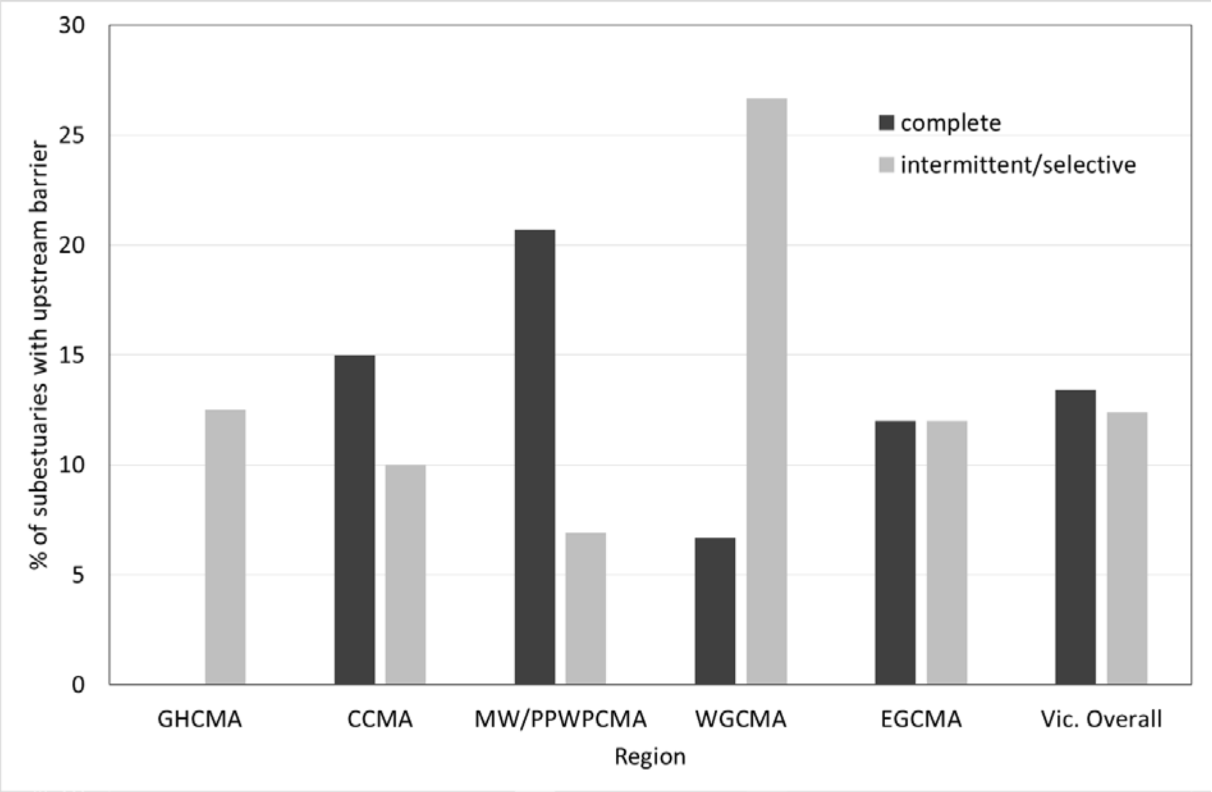


Figure 11. The percentage of assessed subestuaries with upstream barriers by region and degree of blockage to water or biota. Complete is a barrier that completely blocks, and intermittent/selective is a barrier that intermittently or selectively blocks movement of water or biota.

Scoring method

Scoring is related to presence/absence, distance of the barrier downstream from the 'natural head', permanency of the barrier and to the degree to which the barrier restricts movement of biota (e.g. weir vs sand slug). Scores were derived for subestuaries, representing the major estuarine tributaries of each system using the schema in Table 50.

Table 50. Scoring for upstream barriers used for subestuaries and estuaries.

% of estuary length affected	IEC Score	
	Intermittent or selective interference with movement of biota or water	Completely blocked movement of biota or water
0%	5	
>0-5%	5	4
>5-25%	4	3
>25-50%	3	2
> 50%	2	1

In systems with more than one subestuary/major tributary scores were aggregated using the percentage of length affected as a proportion of the combined length of all subestuaries. An average of the degree of blockage was also used, for example a system with one unconstricted subestuary and one completely blocked subestuary would be considered as one with intermittent or selective interference as a proportion of upper estuarine habitat that would still be available in the estuary.

Score confidence

Score confidence for barriers in subestuaries was based on information used to locate current and historical heads (Table 51). Where necessary (i.e. where an estuary had multiple subestuaries) the overall score confidence was related to the percentage of subestuaries with scores and the score confidence for those subestuaries (Table 52).

Table 51. Score confidence criteria for upstream barriers in subestuaries associated with information used in assigning historical head location and current head location. Measured: accurately located through field observations including salinity depth profiles upstream and downstream; Estimated: located through field observations, possibly including salinity profiles but position less accurate or variable; Derived: position located using elevation and morphology but typically no field observations.

Confidence	Current position	Criteria	
		Historical: Documentation	Historical: Elevation/morphology
High	Measured or Estimated	Accurate, clearly located position of saltwater or tidal limit, including natural barriers	Substantial natural rise in bed of waterway observed upstream of barrier. Specific geographic feature that would limit upstream extent of estuary mapped
Medium	Measured or Estimated	Partial, (e.g. location approximate or degree of tidal/saltwater restriction uncertain)	Rise in bed observed but some doubt to exact location of salt water limit
Low	Derived	None or very limited	General vicinity of likely barrier identified but detail of bedform unknown
Unknown	Presence/absence of barrier not known		

Table 52. Score confidence criteria for the upstream barriers measured at the estuary level (where >1 subestuary).

Confidence	Criteria
High	>75% of subestuaries scored at medium or high confidence
Medium	<75% but >25% including major subestuaries scored at medium or high confidence
Low	< 25% of subestuaries scored OR low confidence for subestuary scores
Unknown	Presence/absence of barrier not known in any subestuary

Scores

A large proportion of estuaries scored for this measure did not have substantial upstream barriers, reflected in the large number of high-scoring systems (Figure 12a, Table 53). Only 34 estuaries did not have sufficient data to be scored and the majority of these estuaries were in west and east Gippsland CMA regions (Figure 12b, Table 54). The three estuaries with the low upstream barrier score of 1 (Figure 12b, Table 54) were the Barwon River in Corangamite CMA with the complete blockage by a weir, and, due their extensive modification, Elwood Canal and Patterson Rivers in Melbourne Water/Port Phillip Western Port CMA. Confidence in upstream barrier scores was typically high (Figure 12b, Table 53 & Table 54). Details of scores for individual estuaries are found in Appendix 7.

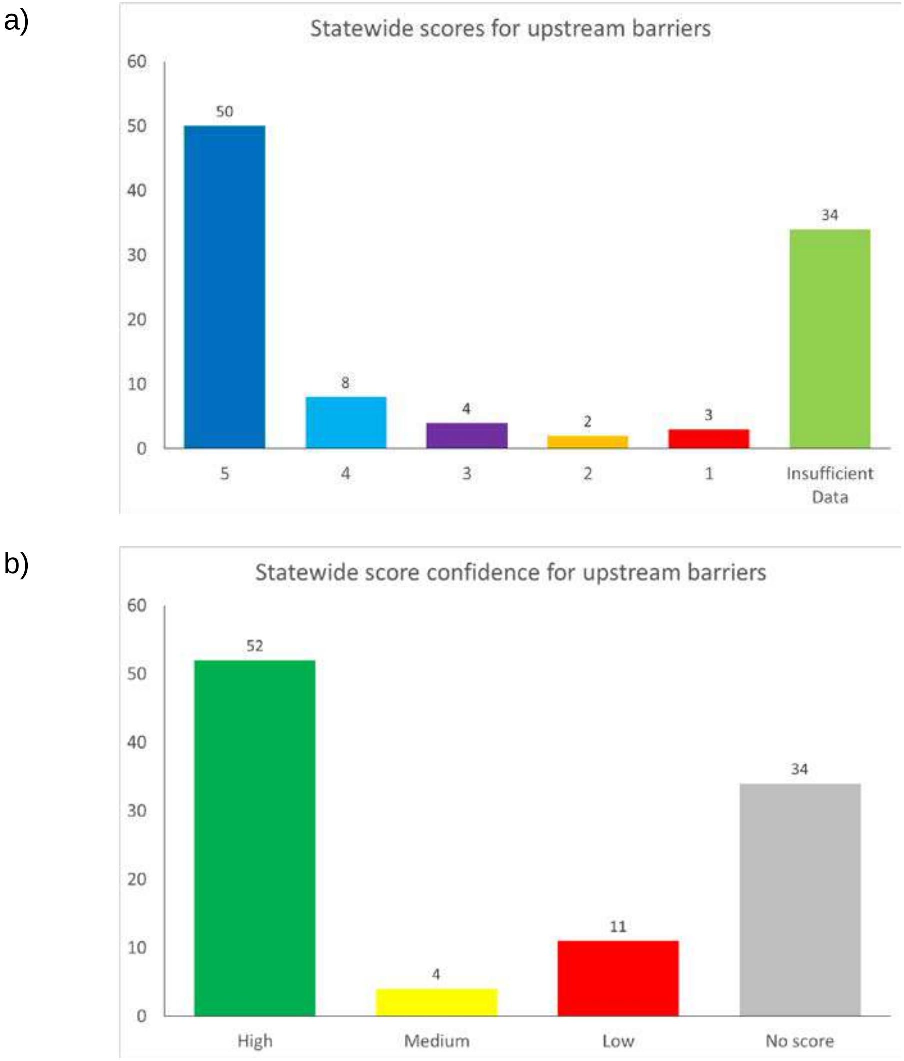


Figure 12. Statewide estuary a) scores and b) score confidence for the upstream barriers measure.

Table 53. Numbers of estuaries by score and data confidence for the upstream barriers measure.

Score Confidence	IEC Score				
	5	4	3	2	1
High	44	2	3		3
Moderate	4				
Low	2	6	1	2	

Table 54. Upstream barrier scores and data confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH	7	1					6	1	1
C	12	2		1	1	1	13		3
MW/PPWP	13	1	1	1	2	4	16	1	1
WG	7	1	2			18	9		1
EG	11	3	1			11	8	2	5

Discussion

Identification of barriers for this measure is relatively simple, especially when combined with other sampling such as water quality profiling or bathymetric surveys. Updating the presence, removal or alteration of artificial barriers should be possible through reviews of CMA permits. This measure also has the potential to change over time with the removal or modification of artificial upstream barriers as well as the movement of sand slugs downstream. Assessing the degree of connection in some locations more accurately would require monitoring of salinity through time above and below a given barrier. Although the upstream limits of all estuaries were located in this project some remain estimates. There was a high confidence associated with scores of 5 where it could be established that the upstream extent of the estuary had not been altered. Many of the estuaries that could not be scored were in the West and East Gippsland CMA regions and it would take a relatively small investment to establish their current heads.

Future development:

- Establish the current heads of the estuaries that could not be scored, with an emphasis on those in West and East Gippsland CMA regions. This would require physically walking the estuary and checking the upstream extent of saline intrusion or any artificial barriers in these typically smaller systems.
- Assess the type and the % of habitat affected with altered upstream extent and the impact this may have on any critical processes or listed biota.

Figure 13. Yarra River estuary, entrance to Moonee Ponds subestuary showing substantial lateral connectivity modification.

4.4 LATERAL CONNECTIVITY (4)

Lateral connectivity (4): recommended, further development of scoring and most estuaries need scores derived.

Lateral connectivity is about linkages across the estuarine shoreline, the presence of fringing habitat and the natural movement of materials and biota between those habitats and the central water body. This measure focuses on artificial structures along the perimeter of the estuary including levees, infilling, and seawalls (Figure 13) (Arundel et al. 2009). It is linked to other littoral measures such as bank erosion (11) and fringing macrophytes (14) (Arundel et al. 2009).

Lateral connectivity (4) = % estuary perimeter that has artificial structures & loss of lateral wetland connection

The lateral connectivity measure requires the measurement of the percentage of the estuary perimeter comprising artificial structures such as seawalls, levee banks, jetties, bridges, platforms (Arundel et al. 2009). The implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be reasonably achievable (Arundel et al. 2009). Assessment of this measure was identified primarily as needing to collate, derive and collect field measured data.

Baseline = natural/pristine condition (pre-European)

The baseline for this measure is natural (pre-European) condition as there would have not been any artificial structures that would have reduced the lateral connectivity of estuaries.

Data used

Field assessment of lateral connectivity was carried out over the three IEC trial field seasons while trialling other proposed measures. Three random sites were assessed in each estuary section (lagoon or riverine) of 50 estuaries (Figure 14, Appendix 5). These field assessments serve as ground truthing for determining lateral connectivity from existing GIS data layers. Two GIS data layers are particularly relevant to determining the modification in lateral connectivity. The first is Coastal Levees, published January 2014, derived from 2011 aerial imagery and LiDAR Digital Elevation Models as part of the Future Coasts Program. The second data layer used was the Vicmap Elevation, Coastal 1m DEM and 0.5 m Contours, published December 2009, from LiDAR data acquired between 2007 and 2009. For demonstration of the method for the implementation trial, artificial structures that alter lateral connectivity have been mapped for Anderson Inlet (Figure 15). There were not sufficient resources for the trial to map all Victorian estuaries.

Scoring method

The scoring method has been refined from that originally proposed in Arundel et al (2009). The scoring system in Table 55 was developed at the IEC workshop, modified at the RiVERS(II)/AVIRA workshop in November 2008 and scoring workshop 2012. Due to the lack of data on which to base thresholds, the scoring proposed is a simple three point system that is consistent with ISC (Table 55). This could be used pending refinement of this measure for Victorian estuaries. From the 2012 scoring workshop it was discussed whether only the alteration of connectivity of natural wetlands should be used. It was decided that artificial wetlands that have value for flora and fauna and good water quality should also be included, if they are identified as wetlands under the Index of Wetland Condition.

Table 55. Scoring for change to estuary lateral connectivity.

% estuary perimeter that is an artificial structure & wetland connectivity to estuary	IEC Score

0% artificial structures AND EITHER fully connected OR no wetlands exist.	5
1-15% artificial structures OR less than natural connection;	3
>15% artificial structures OR no longer connected	1

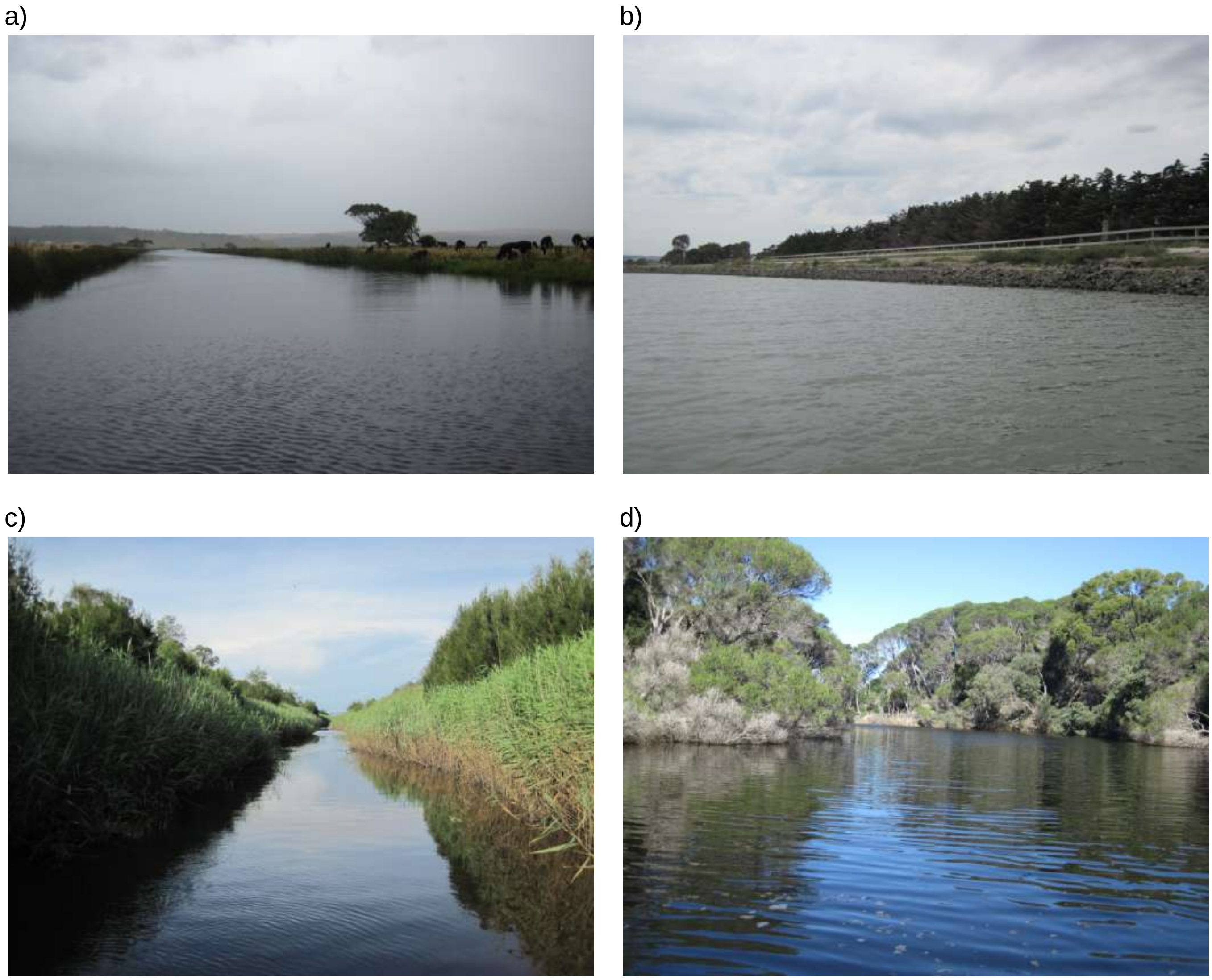


Figure 14. Examples change in lateral connectivity in Victorian estuaries, a) levees Aire River estuary, b) bank armouring Tarwin River (Anderson Inlet), extreme channelization Bunyip River estuary, c) natural banks Shipwreck Creek estuary.

NSW scores its estuaries' lateral connectivity very poor if >25% of the perimeter is compromised, and they used the distribution of their data to develop a five categories at equal intervals for scoring (P. Scanes pers. com). The scoring proposed for the lateral connectivity measure for Victorian estuaries has a higher expectation with >15% as very poor (Table 55) and this should be further examined. Australian expectations of lateral connectivity are considerably higher than in other countries, Portuguese estuaries' scoring of the perimeter affected by sea walls is good 0, <5, <30, <60, <90, very poor >90% (Neto et al. 2013).

Score confidence

Table 56. Score confidence criteria for estuary lateral connectivity.

Confidence	Criteria
High	Structures mapped throughout estuary with ground truthing, presence & connectivity of wetlands past & present well known
Medium	Structures partially mapped, including some ground truthing. Presence & connectivity of wetlands based on limited data requiring inference.
Low	Extent & presence of structures inferred with no ground truthing. Presence or connectivity of wetlands entirely inferred.

Scores

Anderson Inlet has extensive levy banks built along the shoreline of the upper Inlet and along the lower Tarwin River. These artificial structures that decrease the lateral connectivity of the estuary far exceed 15% of the entire estuary's perimeter. So, Anderson Inlet would be scored 1 for the lateral connectivity measure based on levy walls alone (Table 55Table 55). No assessment has been made of the degree of alteration of connectivity of wetlands adjacent to Andersons Inlet.

Discussion

The built shoreline structures that interfere with lateral connectivity have only been mapped for Anderson Inlet for the implementation trial. GIS data layers have been identified that should allow the lateral connectivity modification mapping of at least the large to medium estuaries. It is unclear if the resolution will be sufficient for small estuaries with low topography coastal catchments. Field photos and descriptions collected as part of the implementation trial could be used to ground truth the mapped structures. Difficulties were encountered in the field in assessing lateral connectivity from the water, as fringing vegetation can obscure the presence of levees which were also sometimes difficult to distinguish from natural banks. Currently lateral connectivity can be only scored in three categories, more individual estuaries need to be scored to allow this to be expanded to five categories.

There are a few remote sensing or other methods that might improve resolution or decrease costs for assessing changes in lateral connectivity. LiDAR remote sensing with targeted ground truthing in the field has been trialled for stream banks. It should be assessed for estuaries. Another proposed method is to use whole of estuary video surveys to identify impediments to lateral connectivity. This may be a valuable supplementary method of assessing the % of the estuary perimeter that is artificial if there are difficulties with water level or vegetation when the LiDAR is flown. Alternatively mapping or aerial photo validation could be done with a small remote controlled drone with a camera.

Future development:

- Derive the percentage of the perimeter compromised by artificial structures for all estuaries from Coastal Levees and Vicmap Elevation GIS layers, ground truth or use available photos.
- Refine the measure after the scoring of more estuaries, especially compare very poor score to NSW equivalent.
- Assess the impact of altered lateral connectivity to critical estuarine processes or listed biota.
- Focus on the alteration of connectivity of wetlands to the estuary using the revised 1750s wetlands layer and assessment of wetland connectivity alteration under the Index of Wetland Condition.
- Incorporate fringing macrophyte (extent) and the types of structures present.

- Assess remote sensing methods that might improve resolution or decrease costs for assessing changes in lateral connectivity. In particular LiDAR remote sensing methods developed for stream banks, whole of estuary video surveys and or mapping or aerial photo validation with small remote controlled drones with a camera.

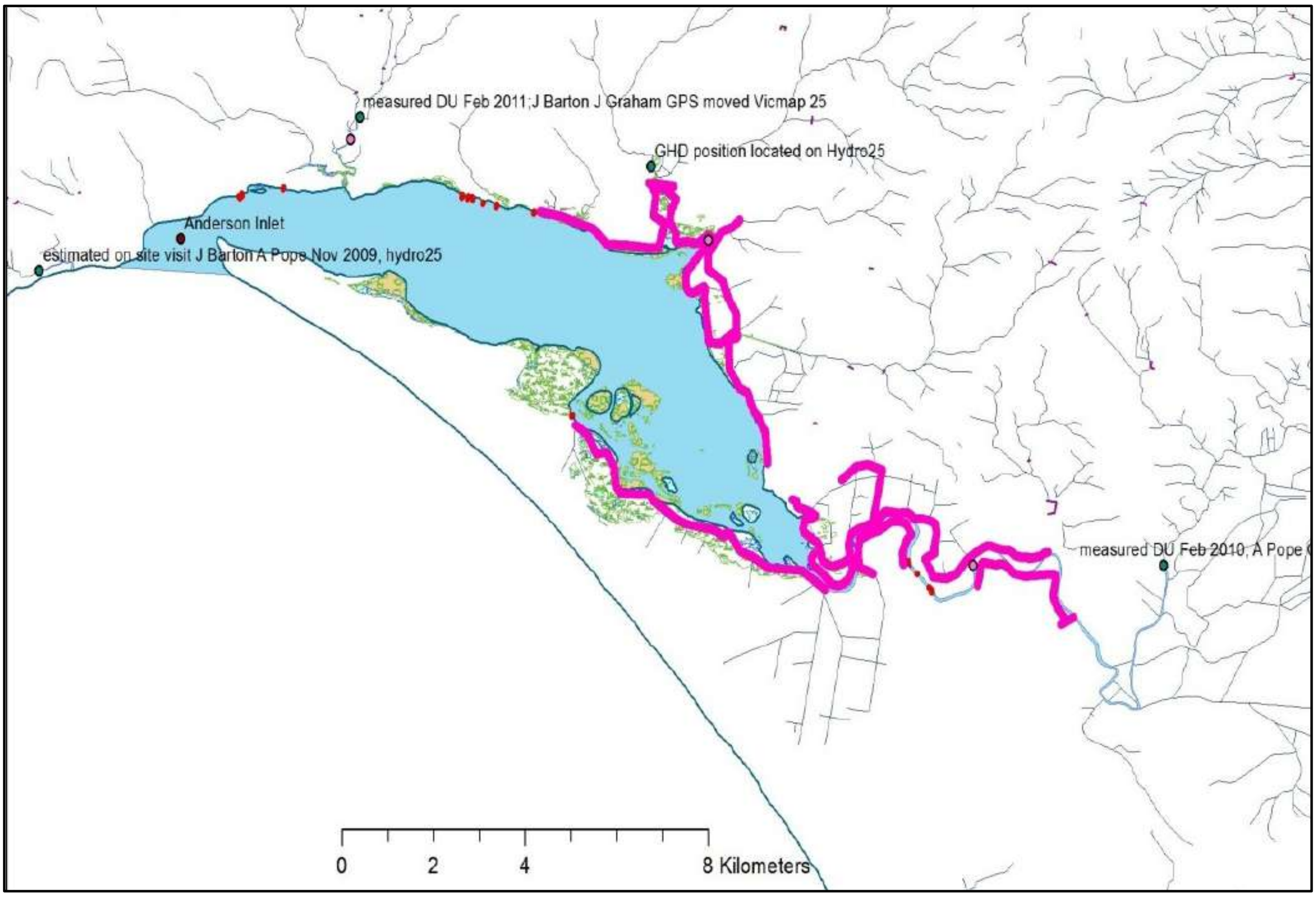


Figure 15. Artificial structures on the banks and in the catchment of Anderson Inlet. Pink indicates levy banks and red boat ramps or other structures.

Figure 16. Wetlands adjacent to the Gellibrand River estuary.

5 RESULTS OF IMPLEMENTATION OF HYDROLOGY MEASURES

Estuaries are broadly defined as places where fresh and marine waters meet, and the resulting salinity regime is a dominating physical factor on estuarine ecology. The hydrological regime of an estuary (Figure 17, Table 57) includes timing and volume of freshwater, marine and groundwater inputs, which in turn affect patterns of salinity distribution, including stratification, in the estuary (Arundel et al. 2009). Changes to the relative amounts and timing of these waters entering an estuary can alter the fundamental nature of an estuary (Chuwen et al. 2009; Taljaard et al. 2009a; Morris and Turner 2010; Schallenberg et al. 2010; Gillanders et al. 2011; Lawrie and Stretch 2011; Terörde and Turpie 2013).

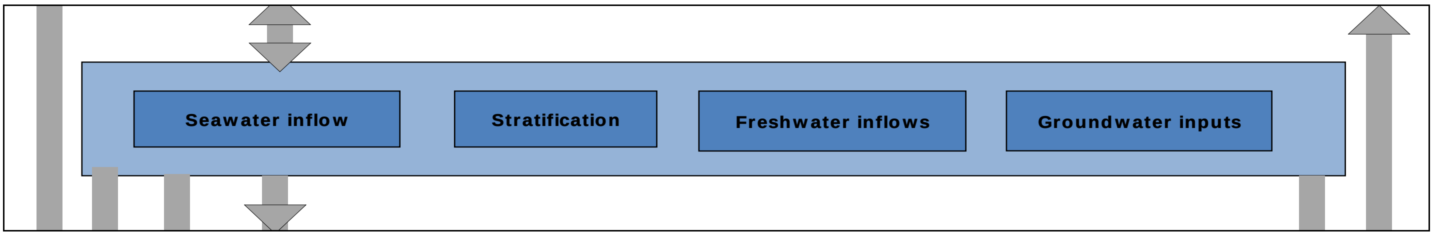


Figure 17. Hydrology components of conceptual model. (Full model shown in Figure 1).

Table 57. Recommended measures within Hydrology theme from Arundel *et al*. (2009).

PHYSICAL FORM	HYDROLOGY	WATER QUALITY	SEDIMENT	FLORA	FAUNA
	5. Marine exchange a) mouth openings b) structures & behaviours 6. Freshwater flow a) ISC Hydrology mod index b1. # of structures b2. # of licences 7. Salinity regime				

Alterations to the hydrology of estuaries are common. Changes to both freshwater and marine inputs alter many aspects of the physical and chemical environment of estuaries not only through salinity but also inputs and dynamics of sediment and nutrients (Gillanders et al. 2011; McLean and Hinwood 2011; Vinagre et al. 2011; Spohn and Giani 2012; Teixeira et al. 2013). The degree of biological connectivity across salinity gradients and physical structures both within and bounding estuaries is often strongly influenced by adjoining water bodies, both upstream and downstream (Arundel et al. 2009). The hydrology theme considers modifications to the hydrology and hydrodynamics of estuaries that are important to ecological condition (Arundel et al. 2009). The recommended Hydrology theme (Arundel et al. 2009) consisted of three measures, marine exchange (5), freshwater flow (6) and salinity regime (7) (Table 38).

5.1 MARINE EXCHANGE (5)

Marine exchange for intermittently open estuaries (5a): recommended with minor development to improve scoring

Marine exchange measure for permanently open estuaries (5b): recommended with further development

The exchange of water with the marine environment is related to the cross-sectional area of an estuary's mouth through which water can move (Arundel et al. 2009). This area is often altered (usually increased) by various human changes to the natural dynamics of estuary mouths (EEMSS 2006). Changes in freshwater flows, incidence of storms and storm waves due to climate change are all also likely to alter marine connectivity of estuaries (Gillanders and Kingsford 2002; Haines and Thom 2007). To assess the condition of estuaries in relation to modification of marine exchange data need to be collected at the estuary mouth, with different methods used for intermittently and permanently open estuaries (Table 42) (Arundel et al. 2009). Detail on each sub-measure are presented in sections below with the combined scores of 5a and 5b presented at the end.

5.1A MARINE EXCHANGE (5A)

Intermittently open estuaries

The scouring effect of freshwater flow (6) is an important determinant of whether an estuary mouth remains open (Haines and Thom 2007; Whitfield et al. 2008; van der Molen and Perissinotto 2011; Whitfield et al. 2012). Other factors that may influence mouth state include changes in astronomical tidal amplitude during the spring-neap tidal cycle, changes in sea level due to atmospheric pressure (known as the meteorological tide), wind speed and direction, and wave height (Haines and Thom 2007; Lloyd et al. 2009). These all directly affect the amount and direction of oceanic energy that can shift sand along the coast (Lloyd et al. 2009; McLean and Hinwood 2011). High wave energy is able to suspend sand in the water column and currents then transport it. Once the water velocity drops (e.g. when seawater enters an estuary entrance or travels up a beach face as wave swash) its capacity to hold sand in suspension decreases and the sand is deposited (Lloyd et al. 2009; Morris and Turner 2010; Whitfield et al. 2012). On Southwest Victoria's micro-tidal coast even small changes in sea level or wave height can cause significant changes in the location of sand deposition zones (Sherwood et al. 2003).

The entrances of 29 of Victoria's 53 intermittent estuaries are artificially opened to prevent inundation of low-lying land, structures and ecological assets (Barton and Sherwood 2004; EEMSS 2006; Arundel et al. 2008; Sherwood et al. 2008). This can cause major changes to the ecology of a system over both the short and long term (Becker et al. 2009; Lill et al. 2012; Milbrandt et al. 2012; Ribeiro et al. 2013). Reduction in freshwater flow (6) can lead to an estuary mouth being closed more frequently and for longer periods, leading to increased backflooding of adjacent low-lying developments and increase the pressure to artificially open the estuary (Pope 2006; Van Niekerk and Turpie 2012). Artificial opening at levels below natural water levels can lower the frequency of inundation of peripheral vegetation (14) such as saltmarsh and other macrophytes such as reeds (Taljaard et al. 2004; Roper et al. 2011; Whitfield et al. 2012). Repeated low-level artificial breaching will almost certainly lead to a gradual shallowing of the estuary due to sediment accumulation (1), particularly in the lower reaches (Whitfield et al. 2012).

In Victoria, the Estuarine Entrance Management Support System (EEMSS 2006) was developed as a decision support tool that guides estuary managers when making the decision whether or not to artificially open an estuary. It requires the collation of information on the individual estuary's environmental, cultural and socioeconomic assets that are potentially impacted by the opening decision and then gives rules for scoring both the importance of, and threats to, those assets (EEMSS 2006).

The IEC measure of modification of marine exchange for intermittently open estuaries (5a) requires the recording of all openings, whether natural or artificial, over the entire eight year assessment period to allow the calculation of the percentage of artificial openings for this period (Arundel et al. 2009). To assess long term changes due to artificial opening the water height (measured as Australian Height Datum, AHD) within the estuary before artificial, and natural opening needs to be recorded. There was insufficient AHD data collected to allow it to be incorporated into this measure at this time.

Marine exchange for intermittently open estuaries (5a) = % of mouth openings artificial

Baseline = modelling of past condition

The baseline is suggested as being natural (pre-European no artificial openings) but taking into account the amount of land and water use change since European settlement, the baseline may have to be derived from modelled data.

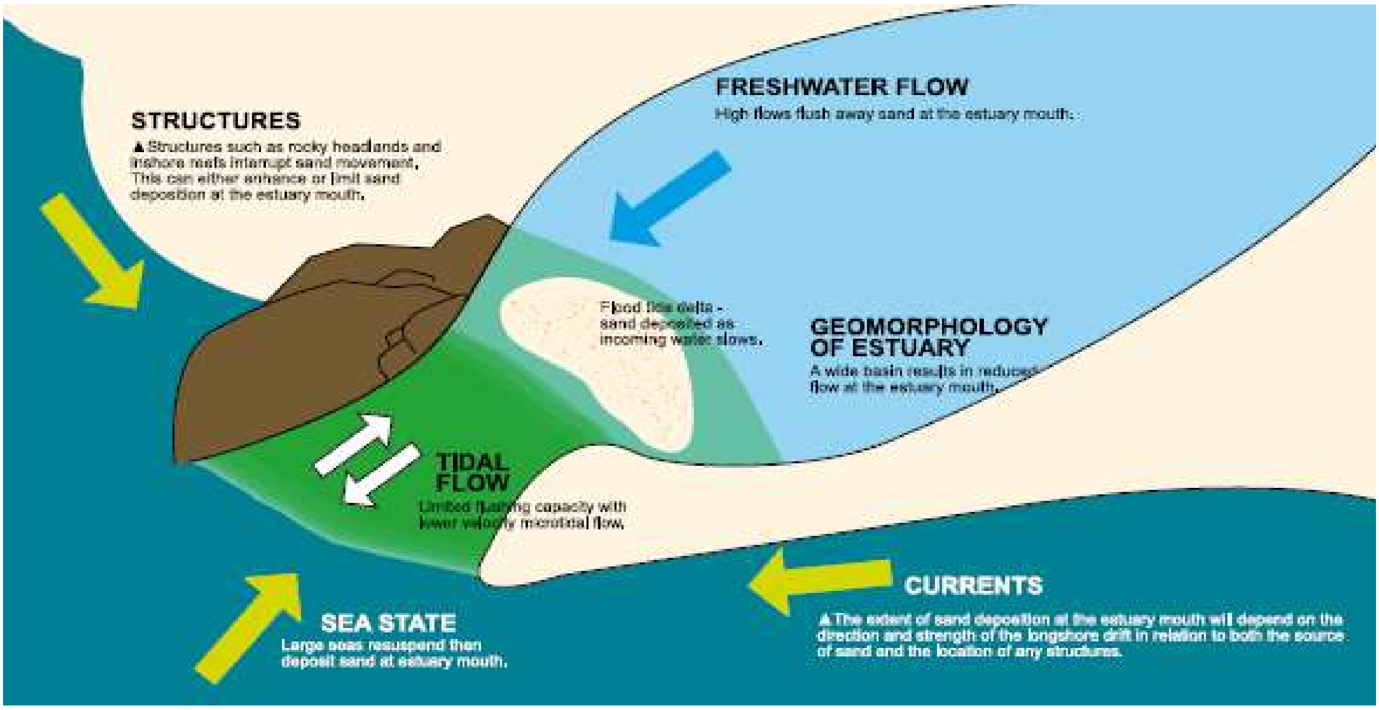


Figure 18. Factors contributing to intermittent estuary mouth status (EEMSS 20006).

Data used

Information about which estuaries are artificially opened was gathered through interviews with CMA staff (Appendix 3) and from previous studies (Barton and Sherwood 2004; EEMSS 2006; Arundel et al. 2008; Sherwood et al. 2008).

The most comprehensive data used to develop and assess this measure came from Glenelg Hopkins Catchment Management Authority's (GHCMA) estuary monitoring program and mouth records from their early adoption of EEMSS. Their data included observations of estuary mouth status made at approximately weekly intervals, water elevation in the lower estuary and records of artificial openings for the six estuaries (Glenelg, Surry, Fitzroy, Lake Yambuk, Merri (Rutledge Cutting) and Hopkins) that undergo this management intervention over a six year period (i.e. the previously anticipated IEC reporting period). In addition, there were some data for water height logged at approximately thirty minute intervals with the exception of the Merri and Hopkins. The Surry River had logged water height data for a nearly a six year period from October 2006 to July 2012, the other three estuaries had water loggers installed in 2008 and 2009.

For the implementation trial estuary mouth observations and artificial opening records were compiled and checked from GHCMA's historical and current weekly observations, and its monthly Coastal Connections estuary reports. Discussions with GHCMA staff allowed the extension of mouth status between records if there was a recorded water height for the data (assumed data) as they only regularly noted changes in status in the records. All artificial openings and most natural openings were recorded. Where there was a change in status from one observation date to another without a record of why, this was recorded as an unknown cause opening. This is because it could have been an illegal opening, or a natural opening that was not recorded. Checking the mouth status records against water height levels, especially logged water height helped confirm the existence of unknown cause openings. Before doing this the logged water height data quality was checked and all irregular data or that recorded with faulty equipment removed (Thiess data quality codes >50).

Another source of data used to assess this measure came from EstuaryWatch community monitoring records from Corangamite Catchment Management Authority (CCMA). The review of this program by Iervasi et al. (2012) and Rennie et al. (2012) resulted in data extracted and validated for eight estuaries from early 2007 to September 2010. These eight estuaries were Gellibrand, Barham, Kennett, St George, Erskine, Painkalac, Anglesea, and Thompson. Mouth observations varied from weekly to monthly. Addition information for the Gellibrand was taken from a recent review of EstuaryWatch and logged data (Harfield 2014). Data for estuaries with at least one artificial opening is summarised in Figure 19.

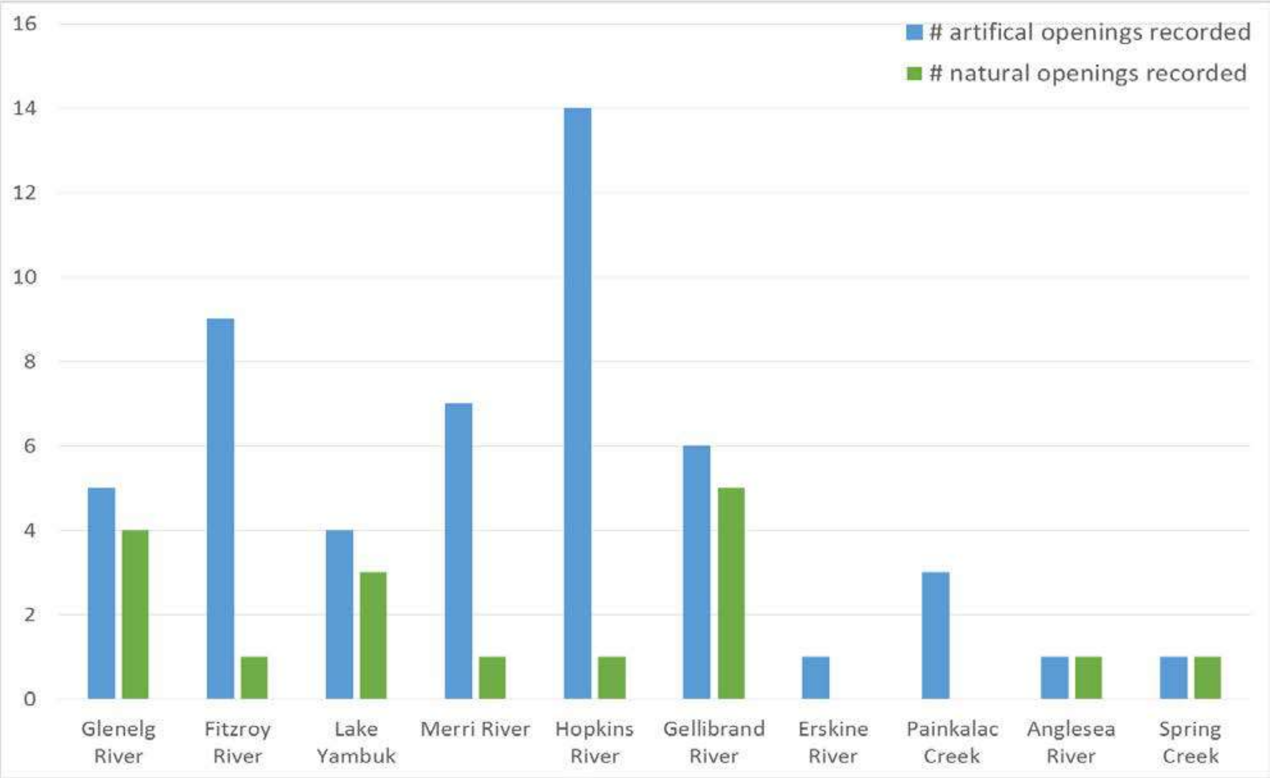


Figure 19. Numbers of artificial and natural opening of estuaries with regularly recorded data where at least one artificial opening took place. Periods of observation varied from 18 months and 6 observations to 6 years and 661 observations as reflected in score confidence (Appendix 8).

Scoring method

The scoring proposed is a simple three point system that is consistent with ISC (Table 58). It has been refined from that originally proposed in Arundel et al (2009). Should an artificial opening take place primarily for the benefit of the estuarine ecosystem following an EEMSS-based assessment it may be disregarded. As not all causes of openings (artificial or natural) were identified, the comparison to AHD water height was not undertaken as part of the implementation trial.

Table 58. Scoring for marine exchange of intermittently open estuaries over the eight year IEC reporting period.

% openings artificial	IEC Score
0%	5
0<50%	3
>50%	1

Score confidence

The data used to derive the IEC score were assessed and assigned a category of low, medium or high confidence based on data quality (Table 59). Estuary mouth observations were only recorded as open or closed and often did not assess the degree of marine connection. Estuary mouths can be fully open allowing full marine connection or the berm may perch the estuary water level above sea level and marine connectivity only occur at high tides or storm events (Perched Mouth). The distinction in connectivity is important in assessing the estuaries condition. The event of a natural opening was also irregularly recorded especially for estuary mouths remote from human settlement.

Table 59. Score confidence criteria for marine exchange in intermittently open estuaries.

Confidence	Criteria
High	Artificial openings & water height before opening recorded, water depth logged. Regular site visits record the three estuary mouth states & have been related to logged water height. OR System never artificially opened.
Medium	Artificial openings & water height before opening recorded. Regular site visits record estuary open or closed mouth state.
Low	Artificial openings recorded
Unknown	Unable to establish if data exist

Figure 20. The intermittently-open western mouth of the Merri River estuary (Rutledge Cutting).

Scores

Scores could be derived for 37 estuaries, including the 24 intermittently open estuaries that we could establish were not being artificially opened (Figure 21). These estuaries were predominately in the east of the state and were often in National Parks (Table 61). There were insufficient data on the natural vs artificial mouth states for 16 intermittently open estuaries (Figure 21). Fourteen estuaries that were artificially opened could be scored (Table 60 & Table 61) from the GHCMA and CCMA regions.

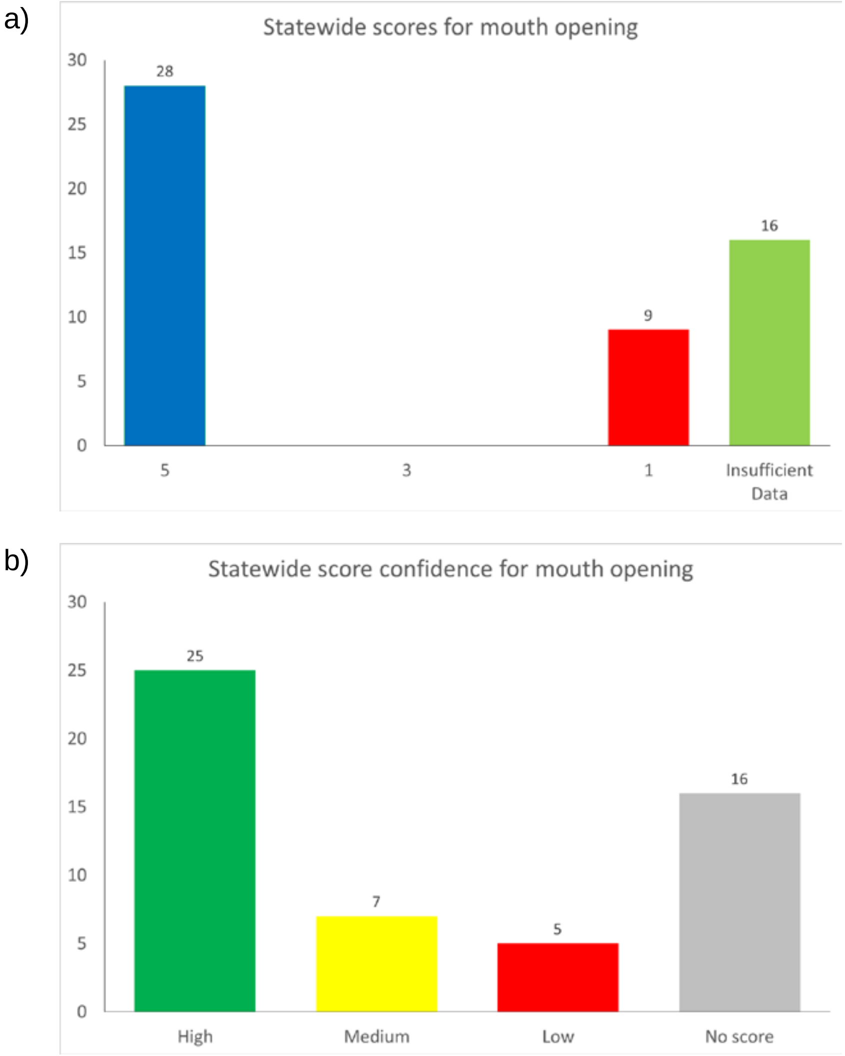


Figure 21. Statewide estuary a) scores and b) score confidence for marine exchange in intermittently open estuaries.

Table 60. Numbers of estuaries by score and score confidence for marine exchange in intermittently open estuaries.

Score Confidence	IEC Score				
	5	N/A	3	N/A	1
High	23				2
Moderate	2				5
Low	3				2

Table 61. Mouth opening scores and score confidence for estuaries summarised by CMA region.

CMA	Scores	Score confidence

region	(# estuaries/CMA)						(where scored)		
	5	N/A	3	N/A	1	NS	H	M	L
GH	1				5		2	4	
C	6				4	5	2	3	5
MW/PPWP	2					2	2		
WG	6					4	6		
EG	13					5	13		

In the GHCMA region the IEC score for the Surry River is 5 (0% artificial openings) as over the period from October 2006 to July 2012 (Figure 22) no artificial openings were undertaken although they have occurred at earlier dates (Figure 22). This score has a medium score confidence as perched mouth state was not distinguished to help validate the water height records nor were all mouth openings identified (Figure 22). Artificial openings were not undertaken during this period due to the unacceptably high ecological risk of fish kills because of very low dissolved oxygen in the surface waters (EEMSS 2006; GHCMA 2007).

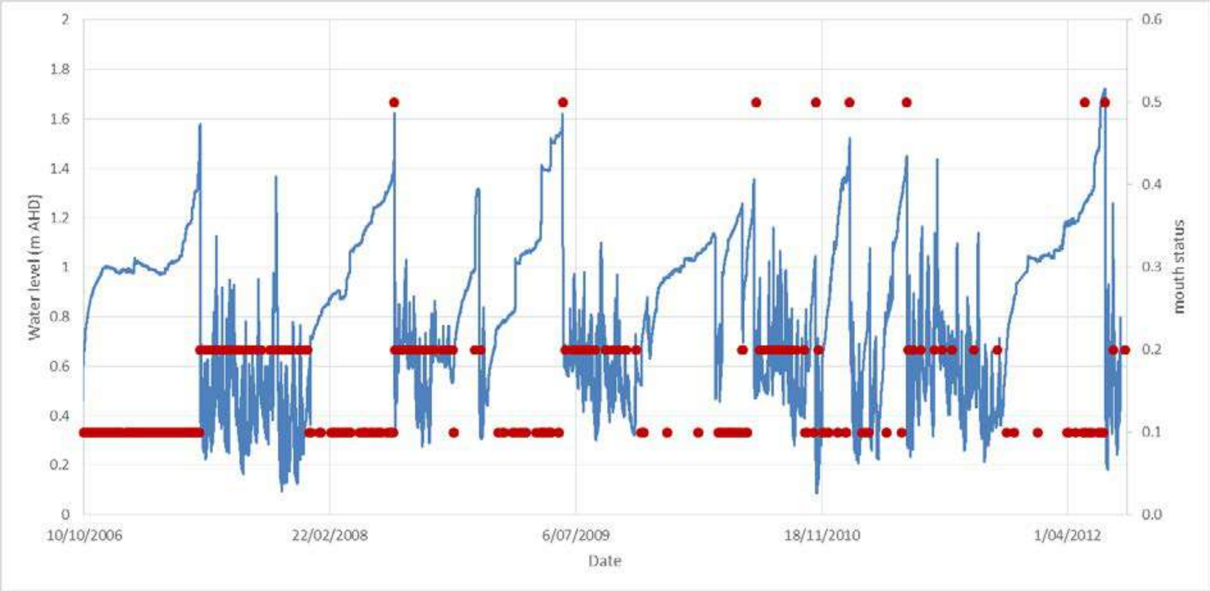


Figure 22. Logged water height data in the lower Surry River over six years (2/10/06 to 16/7/12) from telemetry data from GHCMA estuary monitoring program. The right hand axis shows mouth observations with 0.1 being closed, 0.2 open and 0.5 a recorded natural opening.

Lake Yambuk, Fitzroy, Glenelg, Hopkins and Merri (Rutledge Cutting) Rivers all scored 1 for hydrological alteration due to mouth openings (Table 62). These five systems had from four (Lake Yambuk) to fourteen (Hopkins River, Figure 23) artificial mouth openings in the period from mid-2006 to mid-2012 (Figure 19, Appendix 8). One artificial opening of the Merri River at Rutledge Cutting was noted as being conducted to relieve flooding of orange bellied parrot saltmarsh feeding area. As this opening was for decreasing ecological risk it did not contribute to the IEC score, but no records of such decisions were made for the other six artificial openings. Score confidence was medium to poor, with Hopkins and Merri Rivers having poor data quality in part due to limited water height data associated with openings (Table 62). Numbers of unknown cause openings (two to seven) also decreased data confidence for these five estuaries.

Table 62. Numbers of GHCMA estuaries by score and confidence for the intermittent estuary mouth modification.

Score Confidence	IEC Score				
	5	N/A	3	N/A	1
High					
Medium	1				3
low					2

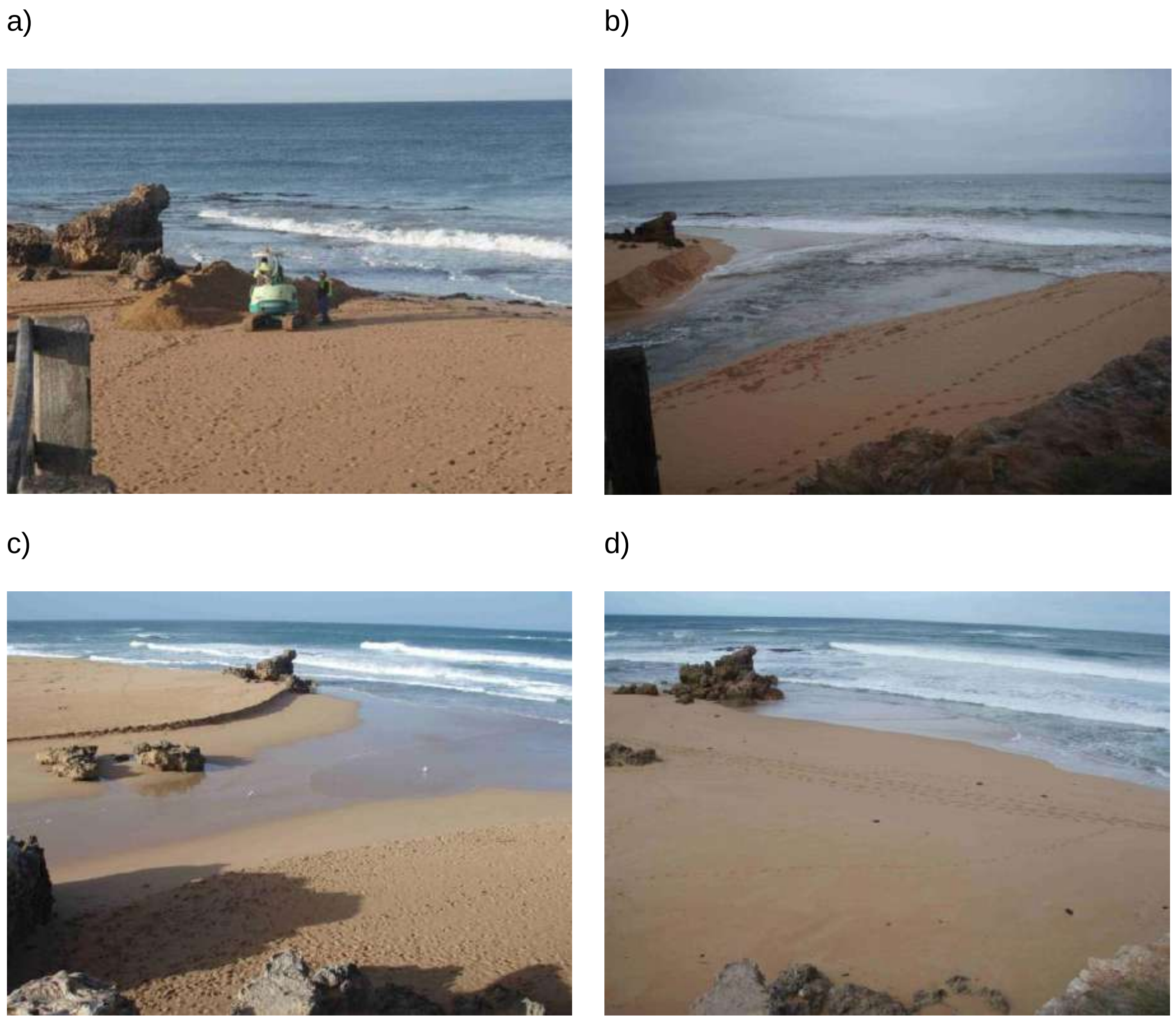


Figure 23. Hopkins River mouth a) artificial opening 1st May 2007, b) large channel to the sea 2nd May 2007, c) infilling of channel with sand 4th May 2007 and d) closure 7th May 2007. Photos by Ty Matthews, Deakin University.

Mouth modification (5a) and score confidence were generated for eight estuaries (Gellibrand, Barham, Kennett, St George, Erskine, Painkalac, Anglesea, and Thompson) in the CCMA region even though available data did not cover six years of monitoring. Gellibrand observations started in 2007 and were weekly or greater distinguishing perched mouth state from open and closed giving a good assessment of the mouth modification for that three year period (Table 63). In November 2008 a data logger was installed that complemented EstuaryWatch observations (Harfield 2014). Gellibrand's score was 1 with six artificial mouth openings compared to five natural openings. There were also six openings with unknown cause. Score confidence was medium as the data did not cover all of the six years and not all opening causes were noted. Four estuaries had a score of 5 for mouth opening over this period because they were not artificially opened but very low (Barham, Kennett and Thompson) to medium (St George) data confidence (Table 63). Five of the estuaries assessed had low overall number of observations and only monthly sampling frequency. Both Erskine and Anglesea scored 1 due to the high percentage of artificial openings, and low numbers or detail of the observations resulted in low data confidence. Painkalac had a score of 1, but had a reasonable amount of detailed observations to base this on so had a medium data confidence.

Table 63. Numbers of CCMA estuaries by score and score confidence for marine exchange in intermittently open estuaries.

Score Confidence	IEC Score				
	5	N/A	3	N/A	1
High					
Medium	1				2
low	3				2

Discussion

Records exist of artificial mouth openings for the central and east coast from at least Balcombe Creek, Powlett River, Merriman Creek, Lake Tyers, Snowy River and Mallacoota Inlet but there are limited records of mouth observations and estuary water height. As the aim of the implementation trial is to assess the practicalities of monitoring using the recommended measure and to derive scoring and data confidence methods, the trial of the mouth modification measure (5a) was limited to longer, more comprehensive records from GHCMA and CCMA.

As not all causes of openings (artificial or natural) were identified and the comparison to AHD water height was not possible as part of the implementation trial. In the future the AHD water level at artificial openings need to be compared with water levels at natural openings to derive more specific scores. These will need to be combined in a matrix that weights artificial openings at low elevations as worse for estuarine condition. Scoring guidelines for the percentage time that an entrance is open compared to a natural regime have been developed in South Africa (Taljaard et al. 2004). While such a measure would be comprehensive, it would also require an identifying the natural regime for each estuary, which was beyond the scope of this trial although with modelling of natural mouth opening frequency this could be achievable in the future.

The measure (5a) needs to be recorded for the entire reporting period, recording all mouth openings including natural openings and the estuary water height AHD at opening. Currently this is best done by installing water depth data loggers to allow assessment of all mouth openings and states. Installing telemetric water height stations should be a long term goal for all artificially opened Victorian intermittent estuaries. Remote sensing techniques may provide an interim measure of marine exchange and comparison with the frequency and duration of marine exchange for estuaries that are not artificially opened (Lill et al. 2013).

Water depth loggers can provide the estuary water height prior to opening, as well as valuable information on the duration of openings and tidal exchange when open (McLean and Hinwood 2011). An example of such data (Figure 24) shows logged water height over three separate ten week periods showing the three clearly identifiable different mouth states of closed, perched and tidal (Pope 2006), the temporal distribution of which is affected by artificial openings. The mouth state of perched has a large berm with a small channel and attenuated tidal influence.

Extensive mouth state observations are made as part of GHCMA estuary monitoring program, however logged water height data are invaluable in capturing the duration of openings. Mention was made in mouth observations that the mouth had been intermittently open between observation periods but no specific dates were recorded.

Lake Yambuk had seven records of mouth opening over the period from 12/10/06 to 9/7/12, four of which were authorised artificial openings (Figure 26). However as can be seen more clearly in Figure 26b with the logged water height, there were six openings (change in observations from closed to open) over this period for which the cause was not recorded. These may have been natural or could have been unauthorised artificial openings, without recorded mouth observations the IEC score was 1 rather than potentially improving to 3.

Management agency and community observations of mouth state, through groups like EstuaryWatch, can provide valuable data to allow the interpretation of logged water depth (Iervasi et al. 2012; Rennie et al. 2012). Currently, in Victoria, there is confusion in reliably identifying the mouth state as perched, where the estuary still has marine water connectivity at high tides or large sea states. Work still needs to be done to simplify and standardise the field based collection of mouth state data (open, perched or closed) to minimise inter-operator variability (Iervasi et al. 2012).

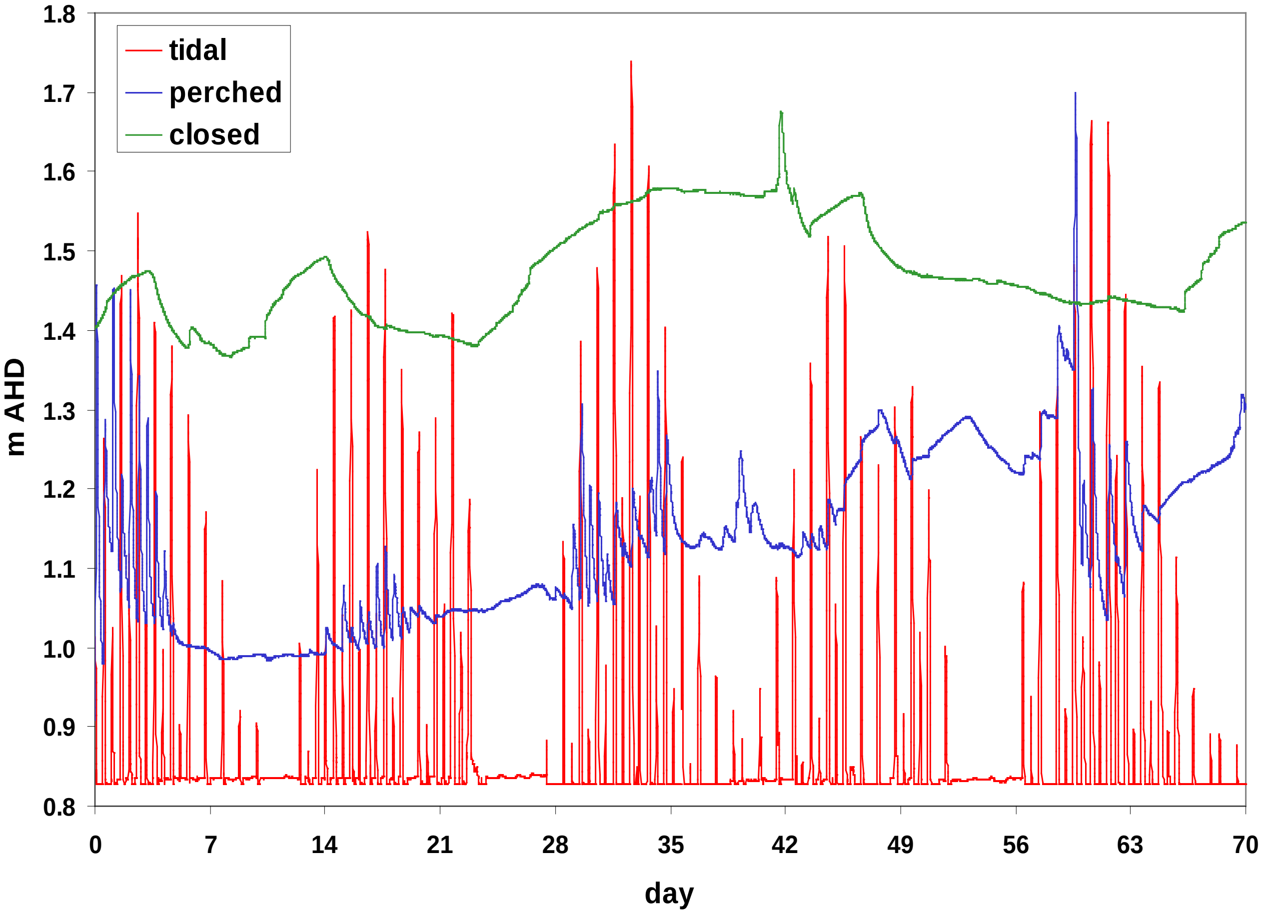


Figure 24. Logged water heights over three separate ten week periods illustrating three different mouth states in an intermittently-open estuary (Pope 2006).

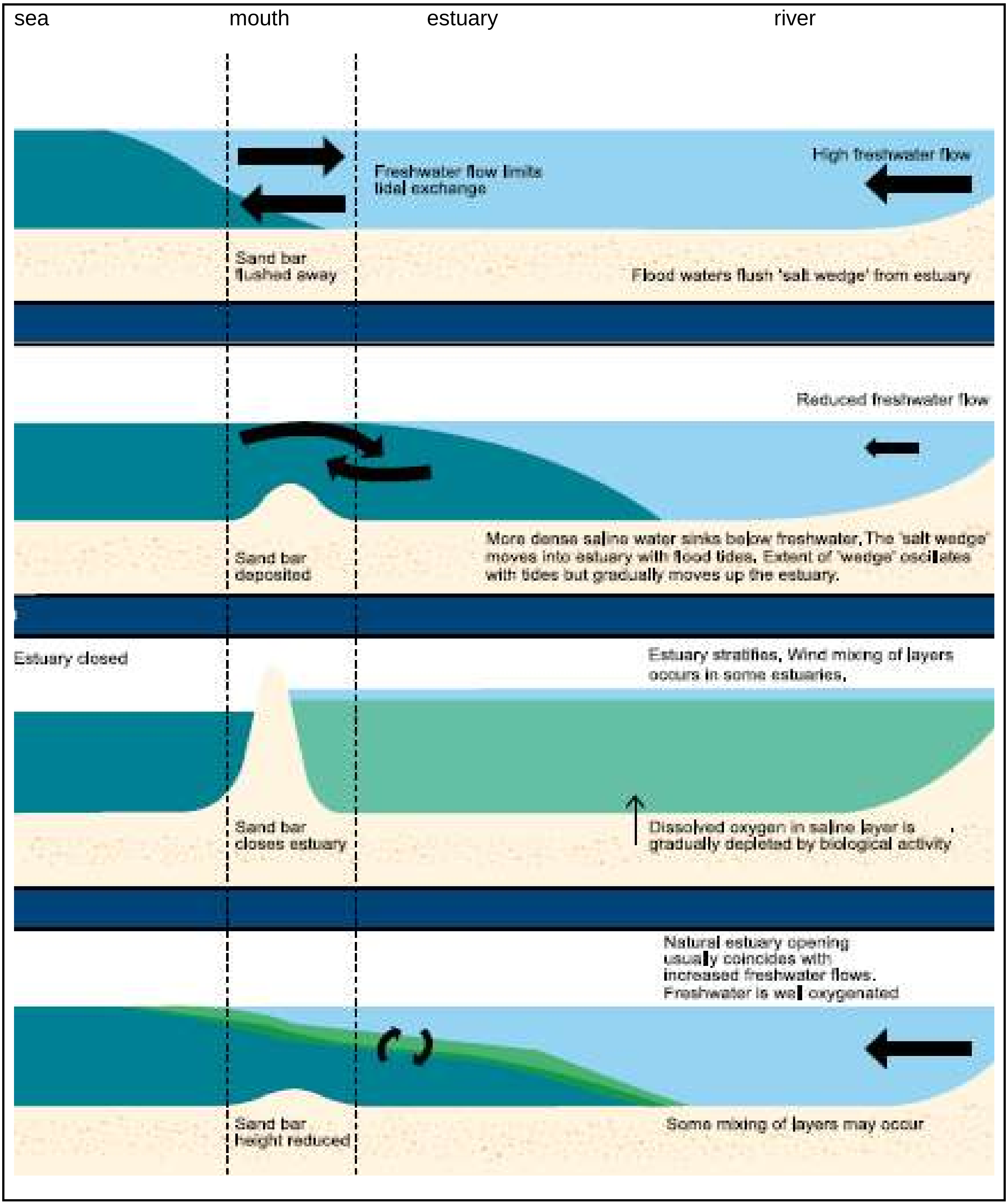
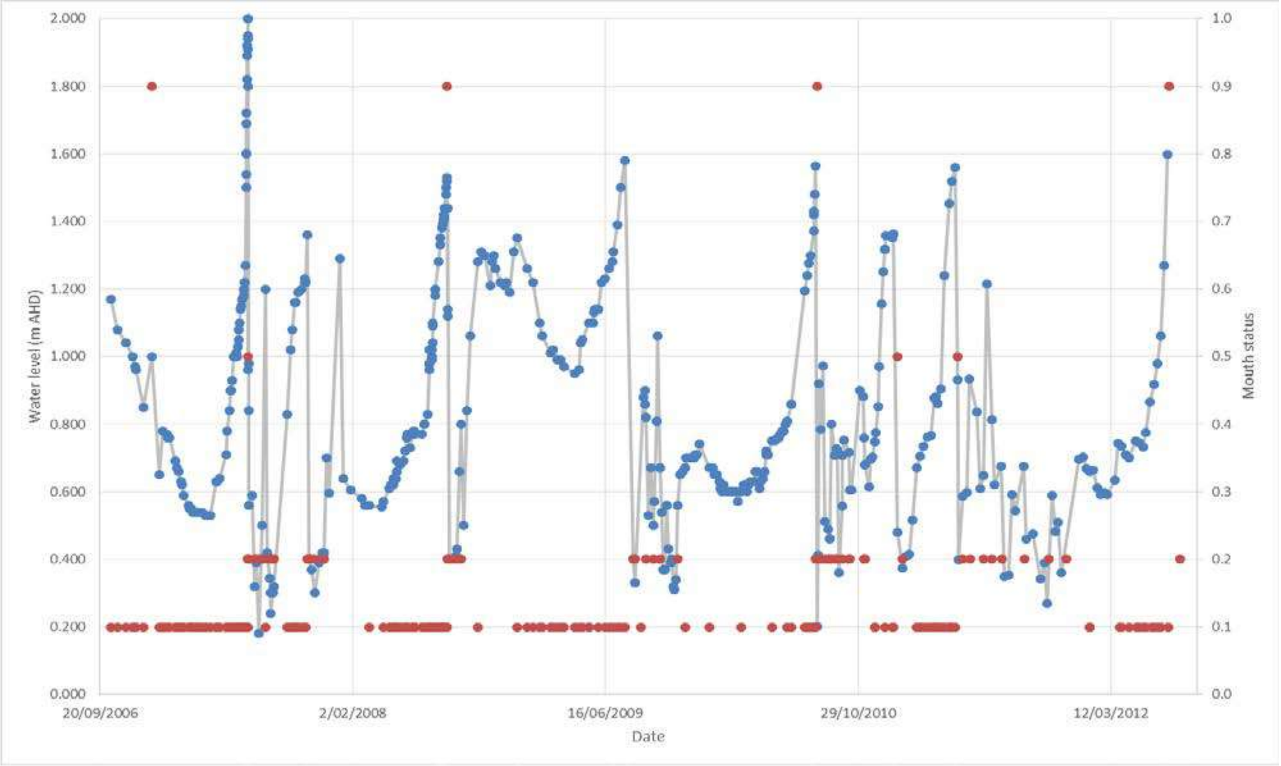


Figure 25. Changes in estuary berm and mouth status (EEMSS 2006).

a)



b)

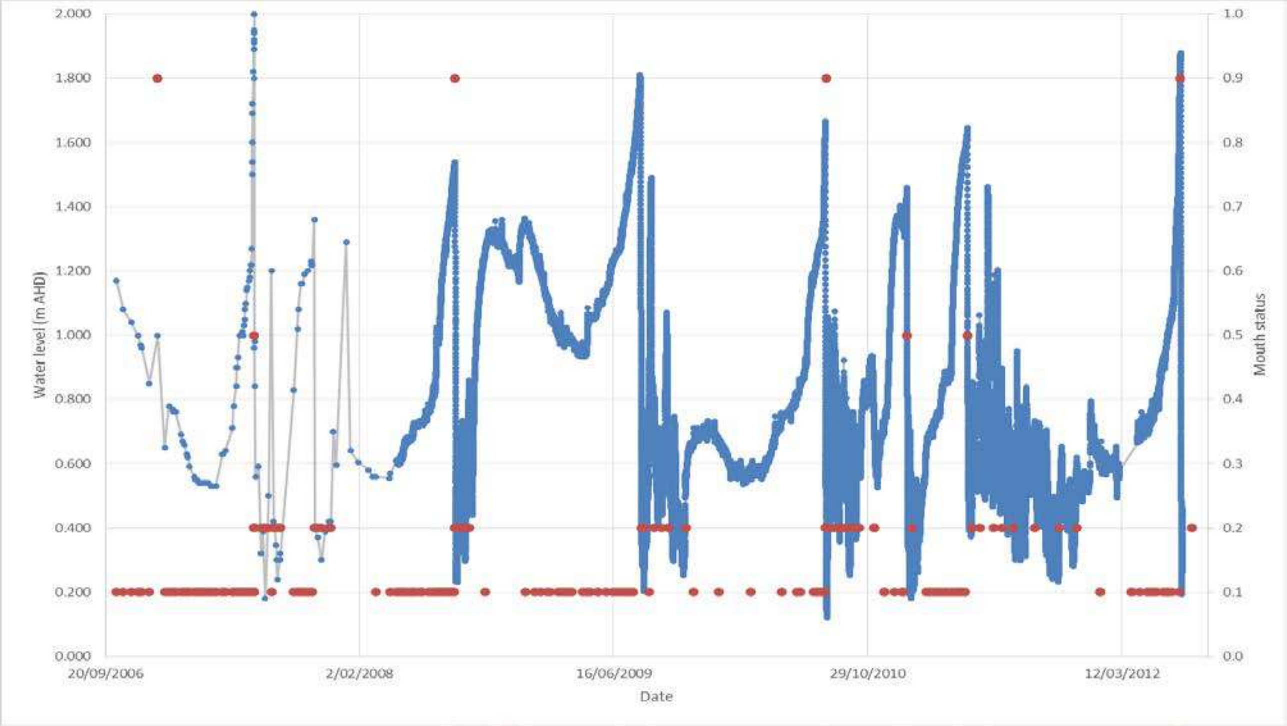


Figure 26. Water height and mouth status in Lake Yambuk from 12/10/06 to 9/7/12 from GHCMA estuary monitoring program a) Spot water height recorded when mouth status recorded b) combination of spot recording and logged water height level with mouth status for this same period. The right hand axis on both graphs shows mouth observations with 0.1 being closed, 0.2 open, 0.5 a recorded natural opening and 0.9 an authorised artificial opening.

Future developments:

- Install depth loggers in artificially opened estuaries: Hopkins, Merri, Barham, Kennett, St George, Erskine, Painkalac, Anglesea, Thompson Balcombe, Powlett, Merriman, Lake Tyers, Snowy and Mallacoota Inlet.
- Improved recording of both artificial and natural mouth opening durations is needed for a larger number of intermittent estuaries to be able to improve scoring.
- Simplify and standardise the field based collection of mouth state data (open, perched or closed) to minimise inter-operator variability.
- Incorporate estuary water height (measured as Australian Height Datum, AHD) prior to both artificial and natural opening into this measure. Currently, this is best done by installing water depth data loggers to allow assessment of all mouth openings and states.
- Compare and assess the AHD water level at artificial vs natural openings to derive more specific scores. These should be combined in a matrix that weights artificial openings at low elevations as worse for estuarine condition.
- Identify natural opening regime for each artificially opened estuary. Assess whether this could be done with modelling of natural mouth opening frequency to determine the percentage time the entrance is artificially opened compared to natural.
- Assess the applicability of remote sensing techniques for determining the frequency and duration of marine exchange for estuaries that are not artificially opened.

Figure 27. Training walls and dredge at Mordialloc Creek estuary.

5.1B STRUCTURES AND BEHAVIOURS (5B)

Permanently open estuaries

Entrances to permanently-open estuaries are frequently modified. Typically this involves increasing the cross section by dredging and use of training walls to allow boat passage (Roper et al. 2011; Duck and da Silva 2012a; Rodrigues et al. 2012; Guinder et al. 2013). This also increases the marine influence in estuaries (Duck and da Silva 2012b; Rodrigues et al. 2012). In some cases, naturally intermittent estuaries are now permanently open due to such changes (Arundel et al. 2008). Marine influence can be increased through artificially constructed entrances (e.g. cut drains) or through dredging of the entrance of a larger water body that the estuary is connected to (the ‘parent’ system).

Marine exchange measure for permanently open estuaries (5b) = history of dredging, number of training walls, presence of minor structures, artificial increase in marine exchange of ‘parent system’

Baseline = natural/pristine condition (pre-European)

The baseline for marine connectivity is the natural condition. It is a degree of marine connectivity not altered by humans but this measure does not explicitly include changes to entrance morphology related to fluvial processes (e.g. increased sedimentation or a decrease in flows large enough to affect the depth or width of entrances).

Data used

This measure requires the record of dredging and/or training walls at the mouth of the estuary. This project collected and collated data (also used in AVIRA) that scored altered marine exchange for permanently open estuaries from information gathered in the CMA/MW interviews (Appendix 3), Port Authority documents (eg Gippsland Ports 2013a; Gippsland Ports 2013b), satellite imagery, Vicmap hydrologic structures and elevation morphology layers, and field trip mouth observations (Appendices 4 & 5). This measure is predominately based on the presence of training walls and dredging rather than the % of estuary volume dredged, for which little information was available. Of the four systems with ‘child’ estuaries, Port Phillip Bay, Westernport Bay, Corner Inlet/Nooramunga and the Gippsland Lakes, only the Gippsland Lakes have had a major increase in marine exchange although Port Phillip Bay and Corner Inlet have had alterations to their entrances.

Scoring method

At present the scoring proposed is a simple three point system, refined from that originally proposed in Arundel et al (2009). Intermediate scores related to frequency and degree of increased exchange are desirable, depending on the numbers of estuaries affected and the scales of dredging activity or relative alteration through structures. Such an assessment was beyond the scope of this project.

Table 64. Scoring for alteration of mouth exchange in permanently open estuaries.

Criteria	IEC Score
Essentially natural marine exchange: Entrance not dredged and no training walls or other structures AND entrance not artificially constructed AND no major modification to marine exchange of ‘parent’ estuary where applicable	5
Some modification: No dredging of entrance BUT minor structures at entrance OR artificially constructed entrance OR major increase in marine exchange of ‘parent’ system	3
Entrance dredged OR training walls present	1

Scoring of the pressure of dredging in Portugal estuaries is based on both the area and volume dredged, as well as spoil area and volume if the spoil is deposited in the estuary (Neto et al. 2013). The dredged area is scored from the annually dredged subtidal area in relation to total area of estuary, from no change (0%), to very low 1%, low 10%, medium 30%, high 50% and very high > 50% dredging pressure (Neto et al. 2013). Dredging pressure is also scored by the amount of material (tonnes) dredged annually from estuaries (1 m^3 of sand dredged is equivalent to 2 tonnes) (Neto et al. 2013).

Score confidence

The data used to derive the IEC score was assessed and assigned a category of low, medium or high score confidence based on data quality (Table 65). The score confidence changes with the level of knowledge about the presence or occurrence of mouth modification and its effectiveness.

Table 65. Score confidence criteria for alteration of mouth exchange score in permanently open estuaries.

Confidence	Criteria
High	Presence of structures/dredging documented & effective in maintaining marine connectivity. Absence of minor structures & lack of dredging documented.
Medium	Score reduction based on major increase in marine exchange at 'parent' estuary mouth. Absence of minor structures based on map layer only.
Low	Structures known to be ineffective. Possible undocumented dredging.
Unknown	Unable to establish if data exist

Scores

All permanently open estuaries could be scored with at least a medium level of confidence. Just under half these estuaries scored 5, with no modification of the entrance (Figure 28a). Data were relatively accessible, reflected in the proportion of scores with high confidence (Figure 28b). There was no major bias in confidence with scores aside from all scores of 1 having a high confidence (Figure 28, Table 66). This reflects the criteria for this measure being a presence/absence of dredging or structures rather than a quantification of the degree of increased marine exchange. No structures in permanently open estuaries were identified as ineffective (criterion for a score of 1); the only ineffective structures identified in this study were associated with intermittently-open entrances. Scores for all assessed estuaries are given in Appendix 8.

The western part of the state has mostly intermittently open estuaries, the Barwon River estuary being the only naturally-open system west of Port Phillip Bay. The WGCMA region had a high proportion of estuaries with a score of 5, primarily reflecting a lack of modification to entrances of child estuaries of Corner Inlet. The MW/PPWPCMA region had lower scores, due to modified entrances in Port Phillip Bay and the frequency of drainage channels in child estuaries of Westernport Bay. Permanently open estuaries in the EGCMA region are mainly child estuaries of the Gippsland Lakes, these estuaries scored a maximum of 3 due to the now-permanent connection at Lakes Entrance (Table 67).

Table 66. Numbers of estuaries by score and data confidence for altered marine exchange in permanently open estuaries.

Score Confidence	IEC Score				
	5	N/A	3	N/A	1
High	17		7		12
Moderate	6		7		
Low					

Table 67. Altered marine exchange in permanently open estuaries scores and score confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	N/A	3	N/A	1	NS	H	M	L
GH			1		2		3		
C	2						2		
MW/PPWP	5		8		5		16	2	
WG	15		1		2		11	7	
EG	1		4		3		4	4	

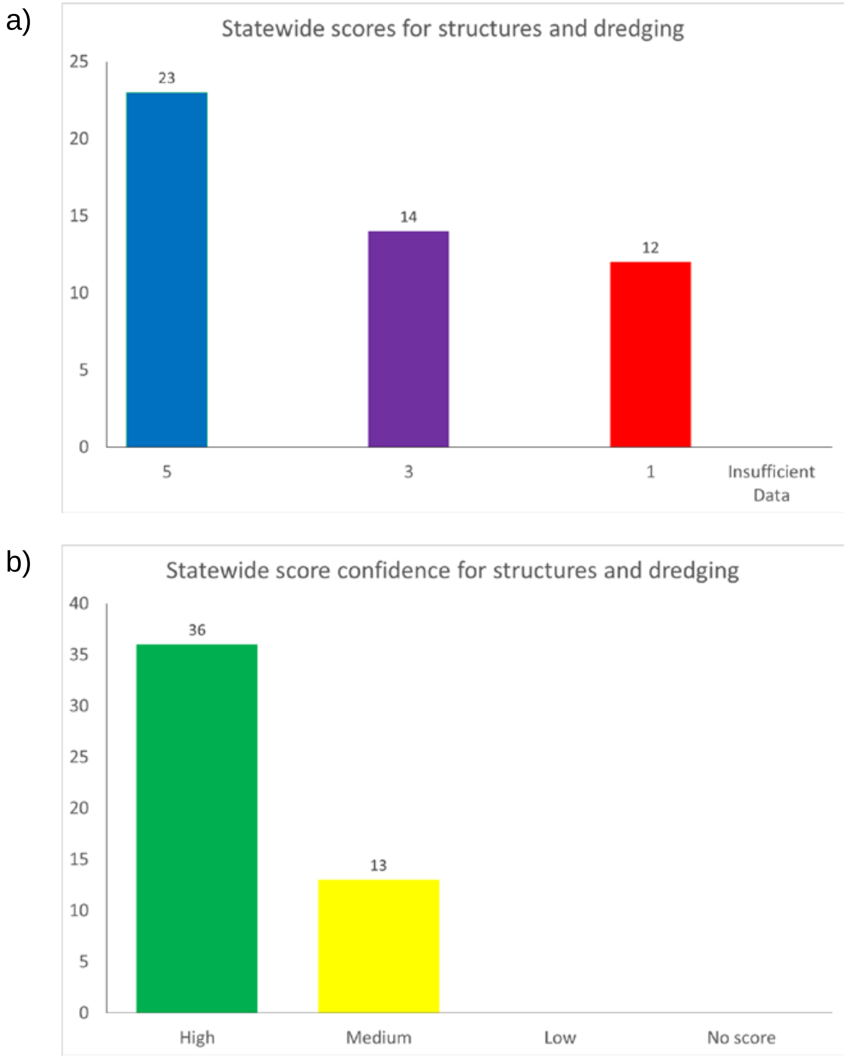


Figure 28. Statewide estuary a) scores and b) data confidence for altered marine exchange in permanently open estuaries.

Discussion

This measure was successful in terms of ease of application and availability of required data. The trade-off for this was a lack of resolution, with only a three point scoring system possible. AVIRA scored all estuaries running into Gippsland Lakes as 3 due to Gippsland Lakes (the parent estuary) having a dredged mouth with training walls. This was not applied to Port Phillip Bay estuaries as its entrance has not been dredged to the same extent. In Westernport Bay the estuaries from Cardinia to Lang Lang were all artificially created between the late 1800s and 1950s as drains from the KooWeeRup swamp. As artificially-created systems these have been scored 3.

The measure is currently a presence/absence of dredging or structures (e.g. Figure 30) rather than a quantification of the degree of increased marine exchange. Options for increasing resolution of this measure include quantification of the amount of increased marine influence due to human alteration and incorporation of temporal components. These would come at the cost of a more complex measure. The effect of dredging on marine exchange may vary for individual estuaries and an approach needs to be developed to quantify this. Ultimately the ecological effects of increased marine exchange will depend on the amount, frequency and duration of change as well as the sensitivity of existing biota to that change.

Future development:

- Develop scores related to the frequency and degree of increased exchange through the scale of dredging activity or alteration through built structures.
- Quantify of the degree of increased marine exchange with dredging. Implement information agreements with the responsible port authority or dredging agent so that quantitative data (frequency and volume, or number of days of operation and capacity of the dredge, or how much has been spent on dredging) are collected and able to be analysed.
- Increase resolution by including temporal components.
- Specific research into the ecological effects of increased marine exchange, how important are the amount, frequency and duration of change as well as the sensitivity of existing biota to that change.

Combined 5a & 5b scores

Of estuaries that had sufficient data for scoring (84%) most had relatively natural marine exchange (Figure 29a). All permanently open estuaries had sufficient data for scoring with a generally high level of confidence (Figure 29b), the 16 intermittent estuaries that could not be scored are all known to be artificially opened. There were no major biases in score confidence with score (Table 68) and there was a general pattern for lower scores in the west of the state and higher scores in the east (Table 69).

Table 68. Numbers of estuaries by score and data confidence for the combined marine exchange measure. *- Merri estuary is an average score of its two mouths.

Score Confidence	IEC Score				
	5	N/A	3	2*	1
High	40		6	1	13
Moderate	8		7		5
Low	3				2

Table 69. Combined marine exchange scores and score confidence for estuaries summarised by CMA region. *- Merri estuary is an average score of its two mouths.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	N/A	3	2*	1	NS	H	M	L
GH	1			1	6		4	4	
C	8				4	5	4	3	5
MW/PPWP	7		8		5	2	18	2	
WG	21		1		2	4	17	7	
EG	14		4		3	5	17	4	

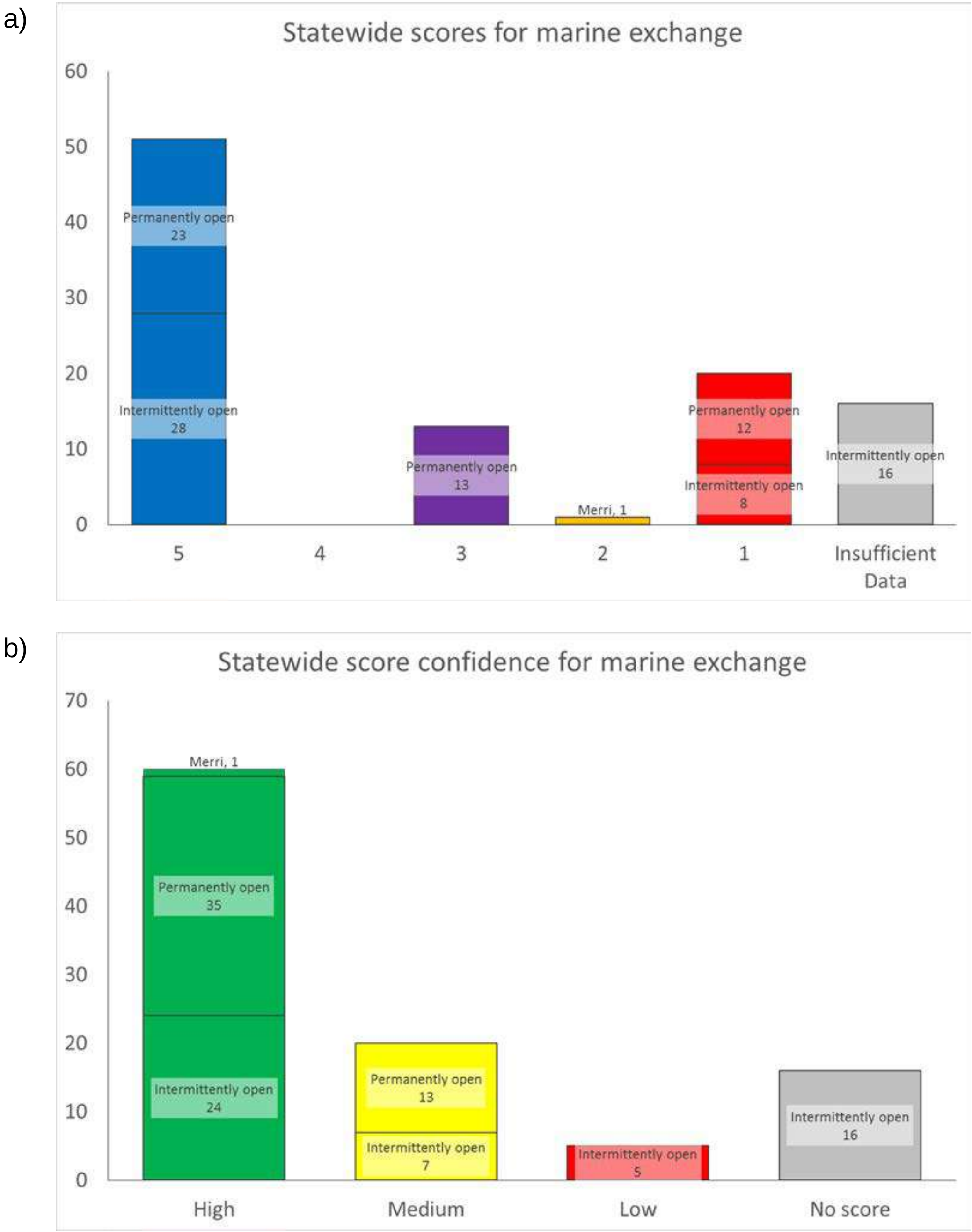


Figure 29. Statewide estuary a) scores and b) data confidence for the combined marine exchange measure. Intermittently open estuaries were assessed using the mouth opening measure (5a) and permanently open estuaries were scored using the dredging and structures measure (5b). Numbers of each type of estuary are shown within each bar. The Merri estuary has two mouths, one of each kind.

Figure 30. The Moyne River estuary mouth is considerably altered with seawalls, marinas, training walls and dredging. Photo by Peter Robertson, Warrnambool City Council.

5.2 FRESHWATER FLOW (6)

Freshwater flow modification (6a) ISC hydrological modification score: recommended

Freshwater flow modification (no ISC upstream reach) (6b): recommended

Freshwater flow modification (no ISC upstream reach) (6c): not recommended

The freshwater flow measure aims to quantify the degree of freshwater driven hydrological change within an estuary. Fresh water inflows are recognised as an important driver of estuarine condition (Arundel et al. 2008; Lloyd et al. 2012; Adams 2013) and flow requirements of estuaries have been the subject of a national (Pierson et al. 2002) and international (Adams 2013) review and assessment. Changes in rainfall and streamflow due to climate change are predicted to have major impacts on freshwater flow into estuaries (Gillanders and Kingsford 2002).

High freshwater flows to estuaries influence the extent of the salt wedge and water column mixing (7) (Lloyd et al. 2012). They can be important for water quality (8 & 9) and can be a trigger for spawning or migration of many estuarine organisms (e.g. Newton 1996; Koster et al. 2013). They help maintain an open mouth (5a), may inundate riparian (14) or floodplain habitat independently of tidal levels, and contribute to higher water levels at high tide (Lloyd et al. 2012). Very large flows can reach the bankfull level or go over the bank and create flooding events. High flows influence channel and floodplain shape and form through the mobilisation and transport of sediment (Lloyd et al. 2012). Low flows control the upstream movement of the salt wedge (7) and can be important in maintaining a low salinity environment in the upper estuary (Lloyd et al. 2012). Low flow freshes can temporarily drive the salt wedge closer to the estuary entrance (7) and increase water levels to wet vegetation communities (14) on the estuary banks or floodplain during the summer/autumn period (Lloyd et al. 2012). They can provide important cues to fish for spawning or upstream migration (Crook et al. 2010), and maintain an open estuary mouth (5a) (Lloyd et al. 2012). Zero flow can result in the upstream movement of the salt wedge (7), mouth closure (5a) and increased salinity in the estuary (7) (Lloyd et al. 2012). It is thought that the smaller the estuary the more sensitive it will be to freshwater flow modification (6)

(Whitfield et al. 2012; Adams 2013). The environmental flow volumes for estuaries are usually larger than those for their freshwater rivers (Adams 2013).

A Victorian method for determining flow requirements for estuaries, the Estuary Environmental Flows Assessment Methodology (EEFAM) has been developed (Lloyd et al. 2012). EEFAM is derived from FLOWS (NRE 2002), the Victorian state-wide method for environmental water requirement determinations in rivers (Lloyd et al. 2012). This method was modified to reflect the environmental and management issues specific to estuaries, particularly the role of salinity (7), water residence time, stratification (7), estuary entrance opening (5) and tides (Lloyd et al. 2009). EEFAM builds a recommended flow regime, from the known dependency of flora, fauna, biogeochemical and geomorphological features on flow (Lloyd et al. 2012). Two hydraulic models, a simple one-dimensional Flood Model and a more complex two-dimensional vertical slice Tide Model, are required (Lloyd et al. 2012). These require measurements of riverine discharge, estuary entrance behaviour, salinity and dissolved oxygen stratification, water level gauging and physical survey (Lloyd et al. 2012). Processes from Pierson et al. (2002) are used to identify the physical parameters which influence the environmental objectives (Lloyd et al. 2012).

Examples of EEFAM ecological objectives for the lowest scoring periods and flow components from the ISC hydrology sub-index are shown in Table 70. While ISC (DEPI 2013) compares existing flows to modelled natural flows for various flow components (e.g. summer 10th percentile low flow), EEFAM specifies actual flows and frequencies for objectives within a summer or winter period. Incorporation of these objectives or similar in the IEC would require some revision of the assessment method. For example, although summer low flows in the Werribee estuary deviate further from modelled natural than any other component in the ISC assessment, the EEFAM assessment shows that current flows are sufficient to meet most objectives based on the current ecological values of the system (Lloyd et al. 2008b).

Table 70. Comparison of most stressed flow component from ISC hydrological modification sub-index and EEFAM objectives for that component.

Estuary	Most significant flow stress period and component: ISC	Associated EEFAM ecological objectives
Werribee River estuary	Summer low flow (0/10)	Habitat: estuarine resident fish Habitat: estuarine dependent, marine-derived fish Habitat: maintain salt marsh diversity Habitat: oligohaline aquatic vegetation in upper estuary Habitat: seagrass in lower estuary
Gellibrand River estuary	Summer low flow (1.3/10)	Habitat: estuarine resident fish Habitat: estuarine dependent, marine-derived fish Spawning: estuarine dependent (freshwater dependent) fish Flooding: salt-tolerant floodplain vegetation

EEFAM requirements should be incorporated into a future IEC measure of freshwater flow modification where available. However, it is currently limited to a few estuaries so for the majority of estuaries in Victoria other measures of hydrological change need to be used. Where there is no EEFAM the preferred measure (6a) is the ISC hydrology sub-index score immediately upstream of the estuary (Arundel et al. 2009). Where there is no ISC reach immediately upstream of the estuary, the degree of hydrological change needs to be determined by assessing the volume of farm dams (6b), noting that systems with major dams have typically been included in the ISC. The use of the extraction licences (6c) sub-measure proved to be unfeasible as a further source of information in lieu of ISC hydrology assessments.

5.2A FRESHWATER FLOW MODIFICATION (ISC UPSTREAM REACH) (6A)

The freshwater flow modification measure is derived from the ISC hydrology sub-index scores.

Freshwater flow modification (6a) = ISC hydrological modification score

The ISC hydrology scores (DEPI 2013) are predominately only available for large to medium estuaries which in some cases have several scores associated with multiple tributaries and associated sections. The ISC score compares current condition to unmodified or natural flow using at least 15 years of monthly stream flow, following the Victorian FLOWS methodology (NRE 2002). The sub-index combines the flow stress attributes of ecologically important freshwater flow components that have been shown to be highly correlated with a wide range of freshwater flow characteristics. It is based on assessment of five aspects of the hydrological regime:

- Variability - in monthly stream flows
- High Flow – highest & 2nd highest monthly flows in a year (flood magnitude)
- Low Flow – lowest & 2nd lowest monthly flows in a year (low flow magnitude)
- Zero Flow – proportion of time dry (duration of cease to flow)
- Seasonality – shift in high and low flow month

The first three indices measure the change in magnitude of these hydrological events between natural and current conditions. The Zero Flow index compares differences in the period of time that there is no flow between natural and current conditions. The hydrology sub-index gives Seasonality twice the weight of the other four indices to ensure that highly impacted regulated rivers, with marked seasonal flow reversal associated with irrigation releases, are appropriately ranked. The most significant flow stress period (winter or summer) and the most significant stressor are identified along with the sub-index score (i.e. Summer Zero Flow) as a seasonally weighted score. The final score out of 10 is ‘standardised’, for example a score of 7 indicates 70% of Victorian catchments are more hydrologically stressed than the catchment under consideration.

Baseline = modelling of past conditions

The baseline for the IEC hydrological modification scores is modelled natural. Derived from the ISC index (DEPI 2013) it compares long term hydrological records or modelled flow with modelled natural conditions for individual stream reaches immediately above or in the upper estuary.

Data used

The most recent ISC 2010 (DEPI 2013) assessment was used to derive freshwater hydrological modification scores in the IEC trial. This is not directly comparable to previous ISC assessments (2004 and 1999) due to methodological changes between assessments. The river reaches in ISC 2010 (DEPI 2013) were based on the REACH_2007 GIS layer (isc_rivers_08092011_final_reach_basin) which distinguishes the estuaries from their freshwater reaches. For the IEC trial the score for the lowest ISC freshwater reach in the catchment at or immediately above the head/s of the estuary was used. For historical reasons some ISC scores were within the upper estuary and were used where available.

Scoring method

To achieve an IEC hydrological modification measure score out of 5, the raw ISC standardised seasonally weighted score from 0 to 10 was categorised (Table 71Table 71).

Table 71. Conversion of ISC hydrology sub-index scores to IEC scores.

ISC hydrology sub-index score	IEC Score
>8 - 10, no flow stress	5
>6 - 8, some flow stress	4
>4 - 6, moderate flow stress	3
>2 - 4, flow stress	2
0 - 2, high flow stress	1

Where a section had multiple tributaries with different ISC scores the IEC score was derived from the average of the raw ISC scores (weighted by catchment area of each tributary) and treated as above (Table 71). Estuary sections below the ISC-scored reach have the same IEC score unless another ISC-scored tributary enters the system. When this was the case and the ISC score was different for each tributary, the IEC score below their junction was derived from the weighted average of the raw ISC scores. Tributaries or sections without ISC scores did not contribute to the IEC score but resulted in a lower data confidence score.

Score confidence

The ISC Hydrology sub-index is based on monthly stream flow data. It takes into consideration the impacts of all rural and urban demands (at the current level of development), private diverters, and farm dams. These data area derived from gauged records, streamflow models or rainfall runoff models developed for previous studies. Where no gauged data or model data were available for a particular site, they were transferred from another comparable site for which information was available.

Thirty-nine IEC estuaries have active flow gauges in their catchments. The ISC score is based on all available flow records requiring a minimum of 15 years of monthly data, with between 21 to 58 years of flow data used for deriving the IEC score. The flow record end date varies with estuary, Lake Tyers records ended in 1993, so the data used to derive the IEC score are over 20 years old, in comparison, Kennett and Wye had modelled flow data from 2010. Most scores are derived from records that end between 2000 and 2007. There were some limitations with using ISC 2010 (DEPI 2013) as larger systems (with double hydrology lines) or those with a large lower lagoon (i.e. Snowy) sometimes had a gap in the REACH_2007 layer between the ISC reach and the estuary.

The data used to derive the ISC score and hence the IEC score were assessed and assigned a category of low, medium or high confidence based on data quality (Table 72). This was based on whether the freshwater modification was derived from gauged flow or modelled. From the ISC 2010 (DEPI 2013) output available it was not possible to assess whether an estuary assessment was based on either modelled flow or rainfall, nor if the assessment had been transferred from elsewhere. Score confidence (Table 72), and hence score confidence, also considered if the catchment of the estuary was fully covered in the assessment and included all subestuaries.

Table 72. Score confidence criteria for freshwater flow modification (ISC upstream reach).

Confidence	Criteria
High	Gauged, >75% catchment coverage, all subestuaries included
Medium	Gauged or modelled. Incomplete catchment coverage (25-75%). If gauged subestuaries missing
Low	No gauge, modelled only, incomplete catchment coverage, subestuaries missing. If gauged, catchment coverage <25%.
Unknown	Unable to establish if data exist

Scores

In total 59 IEC estuaries had ISC 2010 hydrology scores (DEPI 2013), with the 42 estuaries without ISC scores being predominately small systems (Figure 31a, Table 74). Scores for individual estuary sections and for estuaries as a whole are given in Appendix 8. Fourteen estuaries only had ISC scores for a portion of their catchment, for example, the Yarra River ISC score was an extrapolation from the Maribrynong River, which was already included in the score for the Yarra estuary. Of the 59 estuaries with ISC scores, 14 had multiple tributaries scored. Most of these estuaries (Fitzroy, Yambuk, Aire, Anderson, LaTrobe, Avon, Mitchell/Nicholson, Snowy, Tamboon, and Mallacoota) had different hydrological scores for each tributary. Four estuaries (Glenelg, Painkalac, Yarra and Lake Tyers) had the same hydrology scores for all their tributaries. Condition scores for estuaries were relatively evenly distributed and 27 percent of scored estuaries had high score confidence (Figure 31).There was a general trend for higher data confidence in more modified estuaries (Table 73 & Table 74) reflecting the greater likelihood of gauges and flow modelling in more hydrologically altered systems.

For estuaries with available ISC scores (DEPI 2013), hydrological stress through seasonal alteration was mostly identified as decreased summer low flow. There were ten exceptions: Koroit Creek and Latrobe (Thomson River) where decreased winter lows were the primary stress; Anglesea River had summer high flow stress; Aire River (Ford and Aire Rivers), Tom Creek, Newlands Arm, Lake Tyers (Stony and Boggy Creeks) and Mallacoota Inlet (Genoa River) are all identified as having summer seasonality stress; Skeleton Creek has summer variability stress; and Mitchell/Thompson (Nicholson River) and Thurra River summer zero flow stress.

Table 73. Numbers of estuaries by score and score confidence for the freshwater flow modification measure (ISC upstream reach).

Score Confidence	IEC Score				
	5	4	3	2	1
High	1	2	1	6	6
Moderate	1	3	6	4	4
Low	5	8	4	4	4

Table 74. Freshwater flow modification (ISC upstream reach) scores and score confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH			4	2	2		4	3	1
C	2	4	1	4	4	2	4	4	7
MW/PPWP		2		4	5	11	3	3	5
WG	1		5	4	2	16	3	3	6
EG	4	7	1		1	13	2	5	6

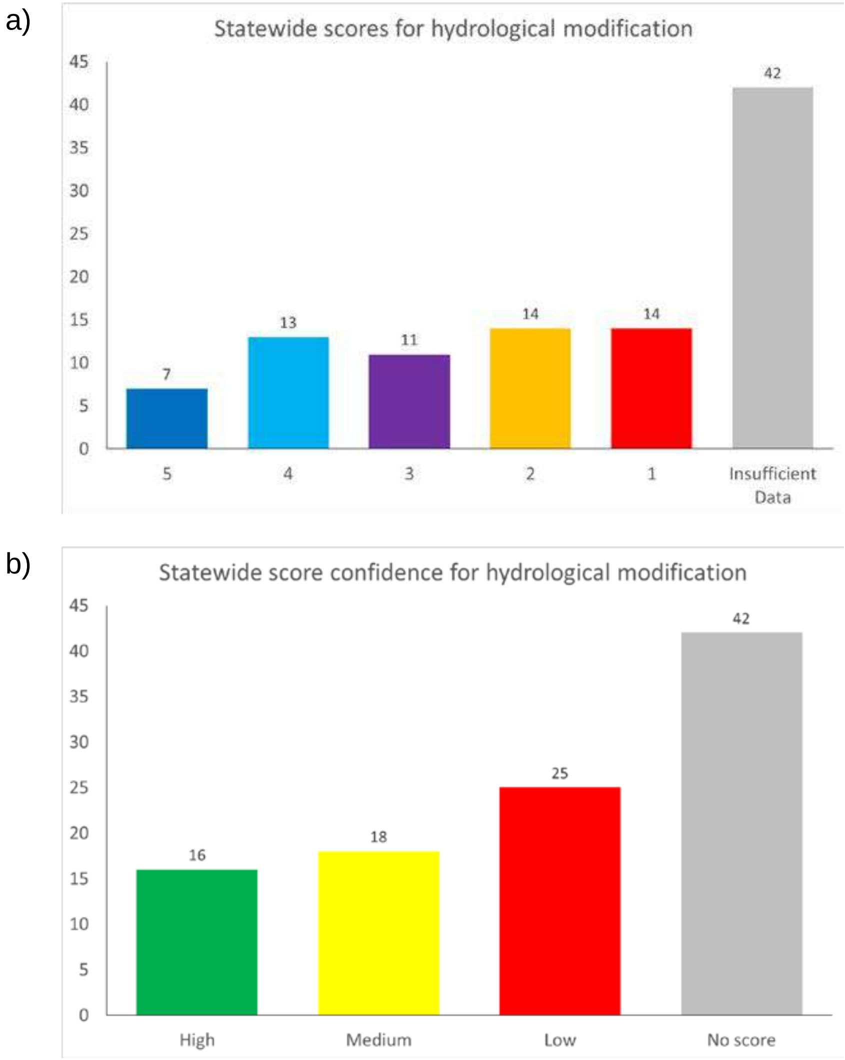


Figure 31. Statewide estuary a) scores and b) data confidence for the freshwater flow modification measure (ISC upstream reach).

Discussion

While the ISC hydrology scores were developed for freshwater systems, the flow components assessed are also important for estuaries, although it is not known if the relative importance of each flow component is consistent between rivers and estuaries. In contrast to rivers, estuaries have a complex set of interactions of freshwater inflow and marine exchange, which control water levels and water quality. Direct translation of ISC scores to estuaries need be used with caution as no specific assessment of their relationship to estuarine condition has been made.

EEFAM includes non-freshwater aspects of the estuary flow regime such as tidal fluctuation, storm surge, dynamic entrance conditions and dynamic salinity profiles (Lloyd et al. 2012). It develops freshwater flow objectives, specifying multiple flow thresholds for specific locations in the estuary (Lloyd et al. 2012). The timing, duration and size of the flow objectives are set to ensure minimal risk to the estuary's ecological and geomorphological assets (Lloyd et al. 2012). The estuary ecological assets include vegetation in and associated with the estuary as defined by Victoria's Ecological Vegetation Classes (EVC), and representative fish species from estuarine resident, estuarine dependent, freshwater derived and marine derived groups.

Geomorphological assets include channel and mouth maintenance and salt wedge position (Lloyd et al. 2012).

To date only the Gellibrand (Lloyd et al. 2008a), Werribee (Lloyd et al. 2008b) and LaTrobe (Brizga et al. 2011) estuaries have undergone a full EEFAM assessment (Lloyd et al. 2012). In the future with more, usually flow stressed, estuaries undergoing EEFAM assessments the adequacy of ISC hydrology index to estuarine flow requirements may be better assessed. Where EEFAM has been applied to an estuary, the compliance of the multiple freshwater objectives set in the EEFAM should be assessed in preference to using ISC scores. This uses the management target rather than reference approach and is the trend for all waterway assessment in Victoria (DEPI 2013). The translation of EEFAM compliance to IEC hydrology modification will have to be defined for each estuary depending on how many and what type of flow objectives were set.

The new IEC score and EEFAM both identify the large freshwater hydrological modification and stress in the Gellibrand and Werribee estuaries. Gellibrand has an IEC score of 2 and Werribee a score of 1, with both estuaries having major summer low flow stress. All ISC assessed aspects of the Werribee's flow regime had been impacted with major decreases in summer high flow and winter low flow magnitude, with some shift in the seasonality index. The EEFAM process identified fourteen important flow components with detailed flow specifications in the Werribee estuary and eleven in the Gellibrand (Lloyd et al. 2008a). The consequences of current freshwater hydrology, in conjunction with tidal fluctuation, storm surge, dynamic entrance conditions and dynamic salinity profiles compared to natural were only explicitly commented on in the Werribee EEFAM report (Lloyd et al. 2008b).

Future development:

- For each estuary that has EEFAM compare compliance with IEC hydrology modification to help improve this measure.
- Assess the relationship of ISC hydrology scores to estuarine condition.

5.2B FRESHWATER FLOW MODIFICATION (NO ISC UPSTREAM REACH) (6B)

This measure is required where no EEFAM or ISC hydrology score is available (Arundel et al. 2009). This is the case for predominately small estuary systems (mean catchment area of 68km^2 compared to 1500km^2 for systems with ISC hydrology scores). This hydrological modification score was originally to be based on the number of dams in catchment of the estuary standardised by catchment area. However the size and volume of the dams also needs to be taken into consideration, following the work of Lowe et al. (2005) and publication of the results of a State Government-commissioned mapping project in the 'Farm Dam Boundaries (FARM_DAMS/)' layer in 2013 (metadata ANZLIC ID: ANZVI0803005037).

Freshwater flow modification (no ISC upstream reach) (6b) = megalitres of storage per km^2 for the entire catchment

Baseline = natural/pristine condition (pre-European)

Historically there would have been no dams, and the degree of modification would have been no greater than small indigenous eel traps on the freshwater systems that run into Victoria's estuaries.

Data used

The FARM_DAMS layer included boundaries of water bodies in southern Victoria identified from aerial imagery (2007-2011), LiDAR topography and satellite imagery (2005). This layer covered all estuary catchments except the northern part of the Snowy catchment, which was not required for this sub-measure. In calculations, water bodies identified as aquaculture, industrial and town storage, waste water and settling ponds were excluded. Of the approximately 191,000 remaining water bodies 170,600 were mapped using aerial imagery.

From areas in the GIS layer dam volumes were calculated using the formula derived for Victorian dams by Lowe et al. (2005): $V = 0.000145S^{1.314}$, where V is volume in megalitres and S is surface area in m^2.

Boundaries for most catchments had been derived as part of an earlier project (Barton et al. 2008). Boundaries for Gippsland Lakes child estuaries, as well as those of Warringine, Watsons, Saltwater, Bourne, Wreck and Miranda Creeks and Wau Wauka outlet were derived from surface catchments derived from a coarser 9 second DEM as part of the Bureau of Meteorology's Geofabric data (v1.0 metadata ANZLIC ID: ANZCW0503900102) and trimmed or to adjacent catchments as required using the Vicmap 1:25,000 Hydro layer as a guide. Areas of catchments were calculated using the VICGRID94 projection.

Scoring method

The scoring method has been refined from that originally proposed in Arundel et al (2009). Due to variability in the relationship between farm dam density and hydrological effects, the scoring proposed is a simple three point system that is consistent with ISC. Thresholds for these scores were derived from a comparison of farm dam densities across catchments for which hydrological modification scores existed in the ISC. The maximum threshold for a farm dam score of 5 was set at the maximum density of the ISC scored systems. Reflecting the fact that systems with low ISC scores were likely to be influenced proportionally more by major diversions than farm dams, the minimum threshold for a farm dam score of 1 was set at the 75th percentile of densities for ISC-scored systems that had a hydrological modification score of 2 (Figure 32, Table 75).

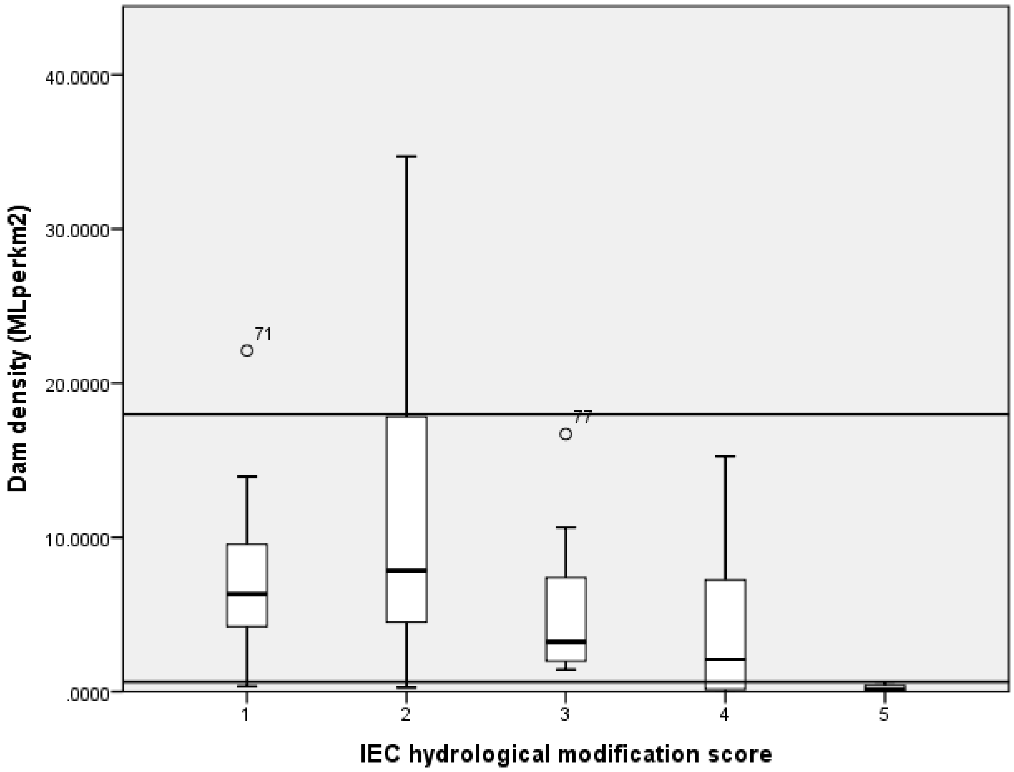


Figure 32. Distribution of dam density for estuaries with hydrological modification scores derived from the ISC. Thresholds for scoring systems without ISC measure are shown as horizontal bars.

Table 75. Scoring of freshwater flow modification (no ISC upstream reach).

Catchment farm dam density (volume per km^2)	IEC Score
Less than 0.63 ML/km^2	5
0.63 ML/km^2< dam density < 17.98 ML/km^2	3
Greater than 17.98 ML/km^2	1

Score confidence

The relationship between dam density in the catchments of the smaller systems without ISC scores and hydrologic effects in estuaries depends on many factors including the spatial arrangement, number and sizes of dams, evaporation, time and amount of water use, rainfall, soil depth, hydraulic conductivity and water table depth (Lowe et al. 2005). Given the variability in these factors across the state and the relative simplicity of this measure, score confidence has been uniformly rated medium for farm dam density (Table 76).

Table 76. Score confidence criteria for freshwater flow modification (no ISC upstream reach) derived from the dam density (b).

Confidence	Criteria
Medium	Variability of relative impact of measure on estuarine condition

Scores

All 42 estuaries that did not have ISC 2010 hydrology scores were scored on the basis of catchment farm dam density (Figure 33, Table 77). Details of scores for individual estuaries are found in Appendix 8. All estuaries with scores of 5 were in the east of the State, with catchments that were primarily national park and with no dams. The exception, Neils Creek, had a catchment farm dam density of 0.12 ML/km^2 and a total of two dams in its small (3.4 km^2), primarily agricultural catchment. Estuaries with scores of 1 had dam densities up to 37.0 ML/km^2 and mostly flowed to Westernport, with the exceptions of Mordialloc Creek (Port Phillip Bay) and Wreck Creek, near Andersons Inlet. All score confidences were medium based on the variability of relative impact measure on estuarine condition (Table 76).

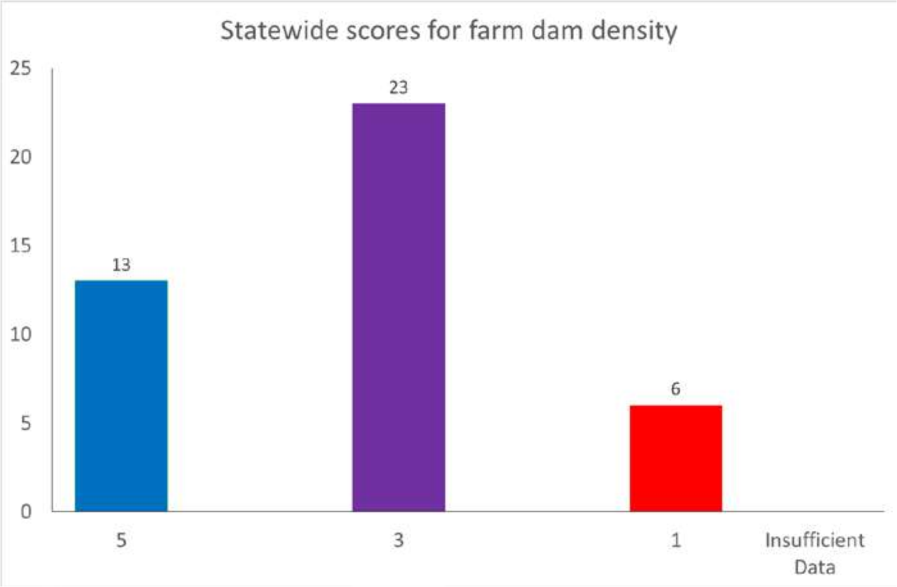


Figure 33. Statewide scores for estuary freshwater flow modification (no ISC upstream reach) (does not include systems for which a hydrological modification score exists).

Table 77. Freshwater flow modification (no ISC upstream reach) scores for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)				
	5	N/A	3	N/A	1
GH					
C			2		
MW/PPWP			6		5
WG	6		9		1
EG	7		6		

Discussion

The distribution of farm dam density for the catchments where it was required as a sub-measure was typical of catchments generally. The range of densities was typical of those throughout the state and so likely to result in similar impacts on flow on a catchment area basis (Figure 35).

The relationship between farm dam density and overall reductions in flow is a relatively broad one. Some additional factors that reduce freshwater flows are correlated with dam density whereas others (such as soil type and catchment configuration) are not. This measure does not take into account stream or groundwater extraction. As such it is a partial assessment of freshwater flow modification to estuaries that is much coarser than the ISC hydrological modification assessment. However it was one assessment of freshwater modification to these smaller estuaries that was feasible using available data and resources.

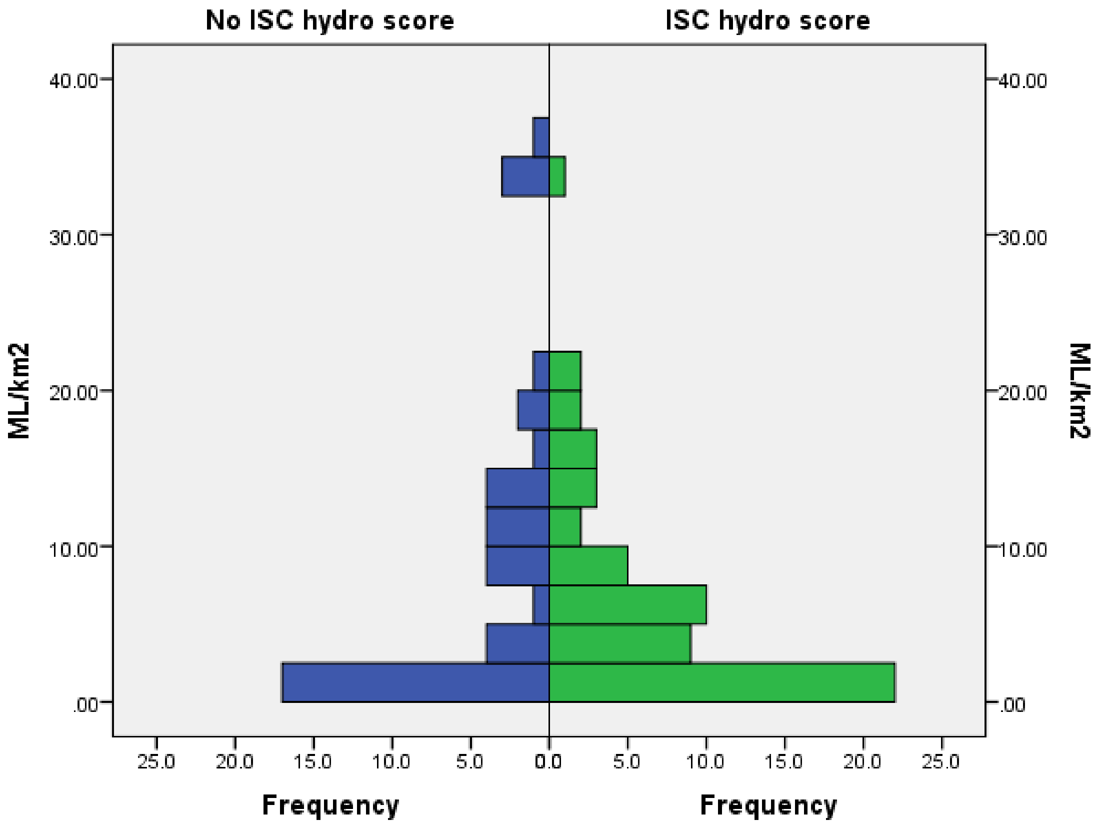


Figure 34. Distribution of farm dam densities for estuaries with and without ISC hydrology scores.

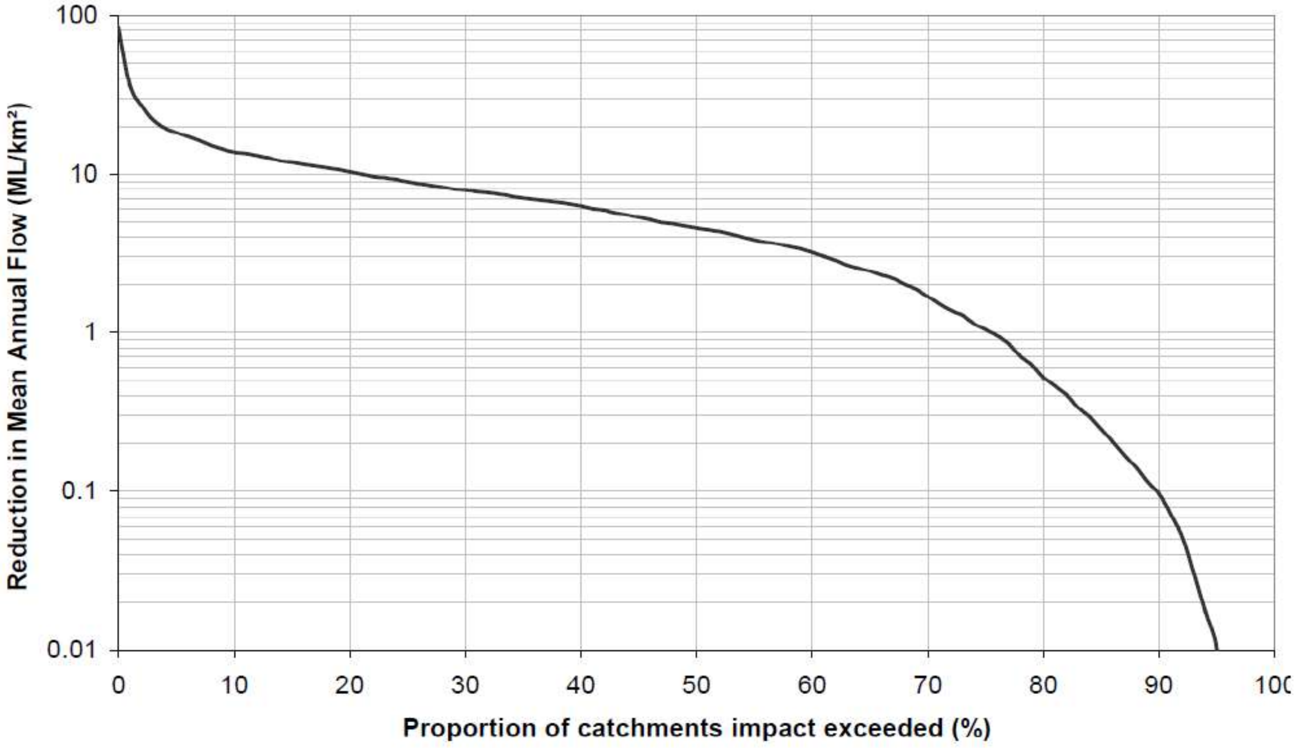


Figure 35. Distribution of modelled reductions in mean annual flow due to farm dams across 1600 catchments statewide (Lowe et al. 2005).

Future development:

- Assess the relationship between overall reductions in flow and total dam density/volume with soil type and catchment configuration.
- Take into account stream or groundwater extraction.
- Improve sensitivity of score confidence.

5.2C NUMBER OF EXTRACTION LICENCES (NO UPSTREAM ISC REACH) (6C)

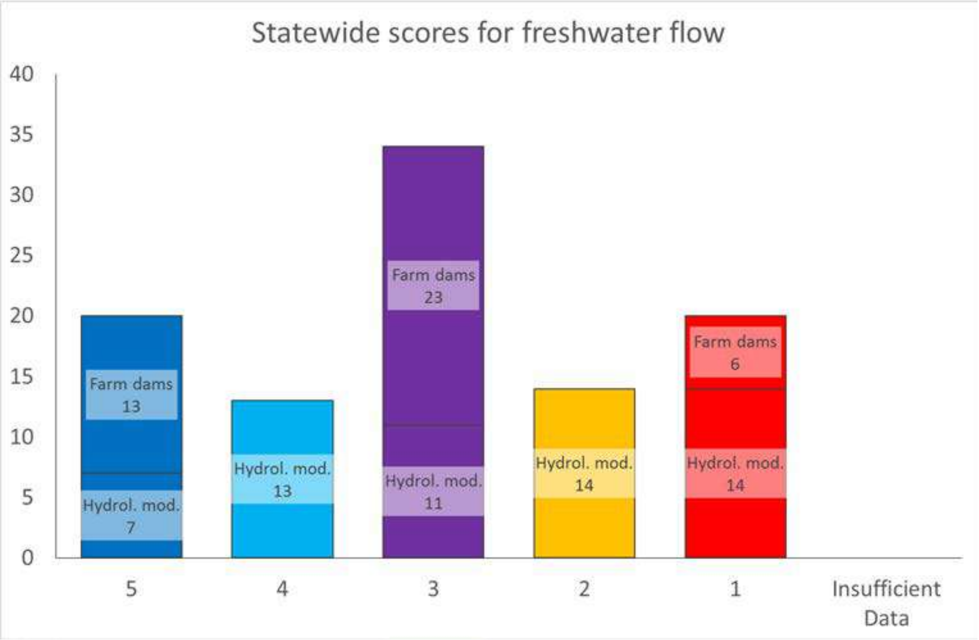
This measure requires the number and volumes of fresh water extraction licences in the catchment to determine the extraction volume relative to the mean annual flow (MAF) immediately above the estuary. This measure is need when there is no ISC reach upstream. This is predominately for small systems with licenced offtakes for stock and domestic use.

Discussion

It was initially intended to select a few catchments for the trial of this measure and obtain the number and volume of licences from the water boards that manage extraction from those catchments. However this proved time intensive and outside the resources of the trial. Also MAF was not available for these small systems. Water extraction in the catchments of the smaller systems without ISC scores is poorly known. Ground water extraction is poorly documented yet is known to play an important role in the hydrology of freshwater and estuarine systems. Further work needs to be done to incorporate ground water extraction into this measure.

Combined scores

a)



b)

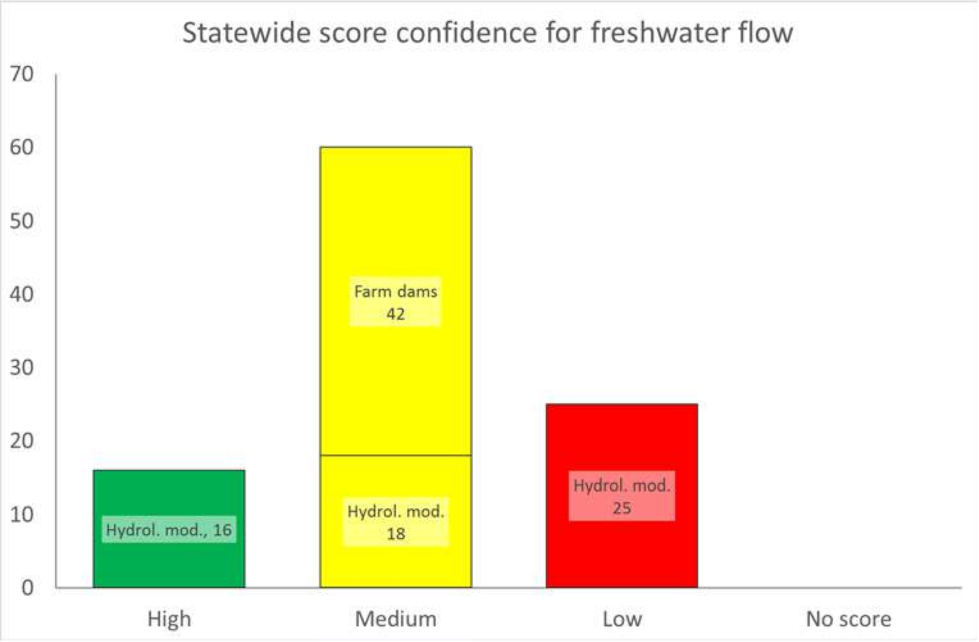


Figure 36. Statewide estuary a) scores and b) data confidence for the combined freshwater flow measure. Estuarines with tributaries assessed by ISC hydrologic modification were scored based on that measure (6a). Remaining estuaries were scored using farm dam density (6b). Numbers of estuaries measured with each method estuary are shown within the bars.

Due to the use of the farm dam sub-measure and ISC hydrological modification all estuaries could be scored. Scores were relatively uniformly distributed, taking into account that farm dams scores used a three point scale (1, 3, 5) only (Figure 36a). There was a tendency for estuaries with a high degree of score confidence to have lower scores (Table 78). This is likely due to an association between levels of extraction and the presence of enough gauges to allow the freshwater flow measure to be fully assessed. Estuaries with high scores were associated with relatively unmodified catchments, often in national parks. Estuaries with low scores were concentrated in the central part of the state (Table 74). Further detail on scoring and score confidence is presented by sub-measure in sections 5.2A and 5.2B above.

Table 78. Numbers of estuaries by score and data confidence for the combined freshwater flow measure.

Score Confidence	IEC Score				
	5	4	3	2	1
High	1	2	1	6	6
Moderate	14	3	29	4	10
Low	5	8	4	4	4

Table 79. Combined freshwater flow scores and score confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH			4	2	2		4	3	1
C	2	4	3	4	4		4	6	7
MW/PPWP		2	6	4	10		3	14	5
WG	7		14	4	3		3	19	6
EG	11	7	7		1		2	18	6

Figure 37. Sampling a salinity depth profile in the Cabbage Tree Creek subestuary of the Snowy River estuary.

5.3 SALINITY REGIME (7)

Salinity regime (6): not recommended as a measure, needs substantial further development. To be collected as contextual information in the interim

Changes in the distribution of salinity through an estuary are a key response to marine and freshwater inputs (Arundel et al. 2009). The salinity regime in any part of the estuary is a major factor that determines the suitability of that location for biota (Antunes et al. 2012; Walsh et al. 2013). It is also a key mediator of chemical processes (Taljaard et al. 2009b; Teixeira et al. 2013) and so an important contextual, as well as condition, measure (Arundel et al. 2009). Distribution of salinity profiles throughout an estuary are dependent on riverine inflow and other variables such as wind velocity and tidal currents which together determine the effectiveness of turbulent mixing (Lloyd et al. 2009; Uncles and Stephens 2011; De Pascalis et al. 2012; Lee and Birch 2012). Understanding salinity structure is an important component of the evaluation of estuary water requirements (Lloyd et al. 2009). This measure interacts with other IEC measures such as marine exchange (5), freshwater flow (6), turbidity (8), dissolved oxygen (9) and Flora (13 to 16) and Fauna. There are many possible distribution patterns of salinity that vary in response to estuary size and shape, prevailing weather, and marine and tidal inputs (Taljaard et al. 2004; McLean and Hinwood 2011). Despite this variety of patterns, a common trend associated with reduced freshwater flows and increased marine connectivity is for upstream movements of the overall salinity distribution (Pierson et al. 2002; Gillanders et al. 2011; Lester et al. 2011; McLean and Hinwood 2011; Hong and Shen 2012; Rodrigues et al. 2012; Teixeira et al. 2013).

The salinity regime measure (7) should assess whether the salinity regime had moved upstream in the estuary and whether the degree of vertical stratification had changed over the reporting period (Arundel et al. 2009). The suggested measure requires depth profiles of salinity at fixed sites along the length of the estuary measured on spring and neap and high and low tides (for open estuaries) during high flow and low flow periods (Table 2). Data should be collected each water year (from July to the end of June the following year) and assessed across the entire reporting period (six to eight years) to integrate longer term variability. Assessment of this measure was identified primarily as needing to collate existing data, refine the method and field sheets and derive new data. Considerable resource issues could be incurred trying to assess this measure.

Salinity regime (6) = % change in axial salinity gradient from baseline (length of estuary) & vertical salinity stratification

There was considerable discussion in both scoring workshops on how to score and whether the data needed for this measure were too intensive for a broad condition monitoring program like the IEC. Scoring change in the salinity regime considered using other measures (marine exchange (5) & freshwater flow (6)) as surrogates but it was decided that it is such an important feature of an estuary that it should be scored independently based on salinity data.

It is thought that it will be possible to treat salinity regime in a similar way to the ISC hydrology method, with periods of salinity in zones of estuaries being analogous to periods of various flow components. For example, hypersalinity could be treated as equivalent to zero flow and fresh flushes being equivalent to floods. Using this approach a modelled baseline would be required that could incorporate ecological salinity requirements similar to those used in EEFAM. For both baselines and scoring it is likely that there would be differences associated with the type of estuary. Estuaries with artificially increased base flows may require a refinement of scoring criteria.

Particularly useful for future development of this measure will be the results from now ceased long-term monitoring conducted by GHCMA in seven sites the Surry River estuary for six years from June 2006. This monitoring provided time series data along the estuary similar to the recommended measure. Insufficient time series data existed for other estuaries although further assessment of individual estuary studies may provide short term data series. EEFAM components and studies also need to be assessed to inform the future development of this measure. Sampling was conducted in the field trips that could inform the refinement of this measure. Due to its importance in estuarine systems and its strong relationship with other measures it is recommended that salinity be measured in association with other measures to provide information for interpreting results until such time as the measure is ready for use in future IEC sampling.

Future development:

- Utilise the extensive salinity data from the Surry River collected by GHCMA, and from salinity studies in Mitchell River estuary. The salinity regime measure could be similar to the ISC hydrology measure and incorporate some of the different processes identified in EEFAM.
- Assess the value of knowing that salinity regime change happened and the cost benefit of knowing the change in the condition of the estuary.

6 RESULTS OF IMPLEMENTATION OF WATER QUALITY MEASURES

This theme considers characteristics of water quality as indicators of ecological condition (Figure 38, Table 81). The recommended Water Quality theme consists of two measures, water clarity and dissolved oxygen (Table 38) assessed against EPA (2010) riverine estuary water quality guideline values (Arundel et al. 2009). This contrasts with the AVIRA metric for degraded water quality which includes six parameters: dissolved oxygen, turbidity, pH, chlorophyll *a*, total phosphorus and total nitrogen. Chlorophyll *a* is included in IEC as a measure of phytoplankton biomass (16) in the Aquatic Flora theme.

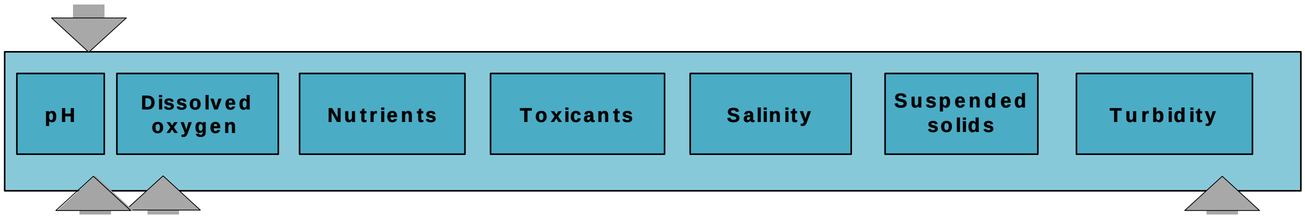


Figure 38. Water quality components of conceptual model. (Full model shown in Figure 1).

Table 80. Recommended measures within Water Quality theme from Arundel et al. (2009).

PHYSICAL FORM	HYDROLOGY	WATER QUALITY	SEDIMENT	FLORA	FAUNA
		8. Water clarity (turbidity) 9. Dissolved oxygen			

Assessment of estuary water quality follows the principles of ANZECC and ISC, and are based on estuary sections (Figure 5, Arundel et al. 2009). Ideally there are multiple sites within a section from which the data area collectively used. Five sets of data (Table 81) were used for the implementation trial of the two estuarine water quality measures. Unfortunately there were limited data available at the required frequency and level of replication (i.e. monthly over multiple sites within estuaries over multiple years) to assess the method recommended by Arundel et al. (2009). There was not scope to include sampling at this intensity within the trial implementation although some sampling was done to increase spatial coverage. The method developed here is consistent, yet flexible enough to maximise the use of data from a range of different sampling programs in the absence of a coordinated, statewide monitoring program.

The most comprehensive data set was from Glenelg Hopkins CMA's estuary monitoring program (Table 81). The mid-channel water column was profiled near monthly from boat or bridge in multiple sites in six estuaries (Glenelg, Fitzroy, Surry, Yambuk Lake, Hopkins and Merri) by the contractor Thiess (Table 81). Melbourne Water sampled the surface waters of six estuaries monthly, with two sites in the Yarra (Maribrynong and Yarra) and one site in each of the other estuaries (Kananook, Mordialloc, Kororoit, Merricks, Yallock Outfall). Corangamite CMA, through its community-based EstuaryWatch program (Table 81), had regular, near monthly sampling in four estuaries; data from three (Painkalac, Erskine and Gellibrand) were used (Iervasi et al. 2012; Rennie et al. 2012). EstuaryWatch had multiple sites per estuary but not all sites were sampled each time and sampling tended to be shore based, potentially limiting the sampling of estuarine bottom waters. Turbidity was measured using tubes resulting in a categorical rather than a continuous scale measurement allowing only approximate medians to be calculated (Iervasi et al. 2012). Data were also available from a Deakin University research project from eight Great Ocean Road estuaries (Aire, Barham, Kennett, St George, Erskine and Anglesea Rivers and Painkalac Creek) in the CCMA area. This data set included multiple sites in the lower estuary collected in summer over multiple years (Table 81). The fifth data set was collected during fieldwork as part of the implementation trial (Appendix 5). Data from this sampling were spatially extensive in the estuaries sampled, but only sampled each estuary once or twice in summer over the three year sampling period (Table 43 & Table 81).

Table 81. Details of the data sets used to assess turbidity and dissolved oxygen for the implementation trial.

Dataset	Contact	# estuaries	Mid-channel profiles	Multiple sites/estuary	Sample frequency
GHCMA	Jarred Obst	6	yes	yes, fixed	monthly
MW	Sophie Bourgues	6	top only	no (2 in Yarra), fixed	monthly
CCMA*	Rose Herben	3	some + edge top	yes but not regularly, fixed	Near monthly
Deakin	Jan Barton, Adam Pope	8	yes, + edge top	yes, random & fixed	Single, multiple summers
IEC implementation trial	Jan Barton, Adam Pope	50	yes	yes, random	Single summer

* visual tube method used for turbidity: reported as within one of a set of ranges

From these five data sources turbidity and dissolved oxygen measurements were available for 55 estuaries (Table 81, Appendix 9). For the implementation trial each site sampled was allocated to the appropriate estuary section (Riverine or Lagoon, Figure 5). For each data set, site location and data collection method were checked to ensure the samples would be representative of the estuary section. Data were also examined for entry or database extraction errors, and the top and bottom water samples from each profile defined. Bottom samples were only appropriate for use when taken in the middle of the channel. GHCMA's monitoring recorded bottom samples to a maximum of 1.5 m below the halocline, which reached the bottom of all sites except in the Glenelg riverine section. Records for bottom samples from the channel edge or from a fishing platform were not used, and this applied to data collected by EstuaryWatch and some data from the Deakin research project. For turbidity, bottom water results were checked to make sure elevated readings due to bottom disturbance were not included, if this was the case, a sample just above the bottom was used where available.

Scores were derived using EPA water quality guideline trigger values (EPA 2010). This was done over water years, from July to the end of June the following year, to ensure the hotter, drier summer months with greater risk of dissolved oxygen exceedances were assessed together. Water years 2006/07 to 2011/12 were used, covering six years to mimic the timeframe of IEC program (now eight years). Annual medians were only calculated where a minimum of ten samples had been collected at approximately monthly frequency as per the guidelines (EPA 2010). Where inadequate data existed to calculate medians, available data were assessed against EPA (2010) single sample guideline values, this included all data from the Deakin research project and IEC implementation trial data. The Melbourne Water data could only be assessed for surface waters. For all scores see Appendix 9.

If there was more than one source of data for scoring an estuary in any particular water year, preference was given to the source that had data suitable for calculating medians. If available data were not suitable for calculating medians, all data from an estuary section were pooled and the percentage exceedance of single sample guidelines for each water year was used.

For each estuary, section data were summarised as median, % single samples exceeded, minimum value, maximum value and number of samples for each water year. The data were assessed for exceedance in each water year (EPA 2010). In order to ensure low risk to the ecosystem, EPA (2010) recommended neither single sample nor median trigger values should not be exceeded. None of the available data could be assessed using control charting as recommended by EPA (2010) as not all the parameters needed for the model were available.

6.1 WATER CLARITY (TURBIDITY) (8)

Water clarity (8) - turbidity: recommended

Turbidity or cloudiness of estuarine waters is a measure of light scattered and absorbed by particles and molecules. It is a measure of suspended matter (e.g. sediment, debris and phytoplankton), and dissolved organic matter such as humic substances. Turbidity affects light penetration and hence primary production and the distribution of aquatic plants, particularly submerged macrophytes (13a) (McMahon et al. 2013; Neto et al. 2013). The amount of suspended matter is influenced by the condition of inflowing river and marine waters (Arundel et al. 2009). Catchment activities which increase the input of fine sediments, organic matter and/or nutrient loads will contribute to raised estuarine turbidity levels either directly or indirectly via stimulated phytoplankton production (16) (McMahon et al. 2013). Activities within the estuary such as dredging (5b) or boat wake induced bank erosion (11) can also increase turbidity levels (McMahon et al. 2013). Factors such as tidal flow, sediment type, depth and estuary orientation contribute to resuspension of particulates by wind-mixing and flow (Snow and Taljaard 2007). Turbidity can be further influenced by the trapping and flocculation of sediment at the halocline and hence levels may vary with the extent of estuary stratification or position of the salt wedge (7).

Water clarity, as measured by turbidity (NTU), was recommended to be collected monthly over six years (i.e. an entire IEC reporting period) and assessed by water year (Arundel et al. 2009), avoiding high flow events as recommended by Scheltinga and Moss (2007) but not necessarily done in the collection of data used here. Three sites were to be randomly chosen, within each riverine and lagoonal section in the estuary (Table 42) at the start of a monitoring program. Tidal flow, depth and channel width are also recorded when sampling to assist with data interpretation.

Water clarity (8) = % turbidity exceeding EPA (2010) estuary water quality median & single sample guidelines

Baseline = current state-wide data (best available)

EPA's (2010) guidelines were developed from targeted sampling in the lower part of estuaries along the western and central Victorian coast. The guideline values were developed from the best-available estuaries, those with the lower intensity land use. As these guidelines form the basis of the IEC water clarity measure scoring, the baseline uses best available data. There are no historical or pre-European settlement data to set a baseline however there are several estuaries in the east of the state with little or no catchment modification and a correspondingly small amount of data that could be used for future development of the guidelines.

Data used

The data used for trialling the implementation of the water clarity measure are outlined in the Water Quality theme introduction and summarised in Table 81. The major impediment to trialling this measure was the limited amount of data collected appropriately across Victoria's estuaries (Appendix 3).

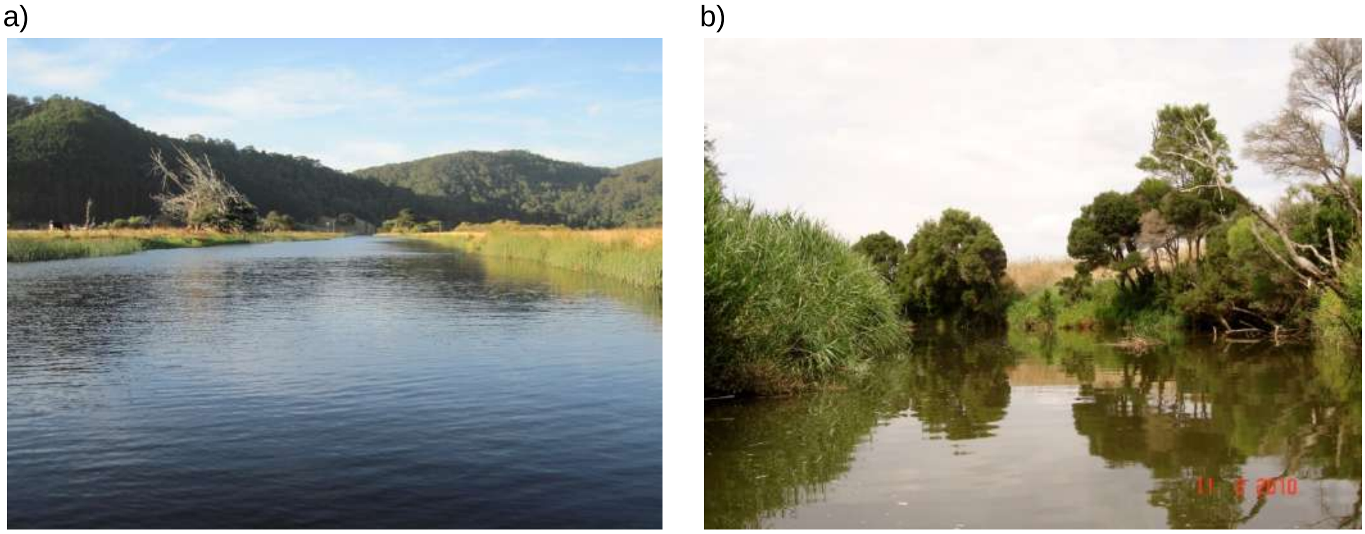


Figure 39. Examples of sites with a) low Aire River and b) high Tarwin River (Anderson Inlet) turbidity in Feb 2010.

Scoring method

The scoring method has been refined from that originally proposed in Arundel et al (2009). Scoring for water clarity (8) was based the EPA (2010) water quality guideline values (Table 82). Scoring used both the median threshold and % exceedance of single sample measurements over a water year (Table 83). Estuary Watch turbidity tube data were only assessed as single samples, with the top waters considered to exceed EPA (2010) guidelines if in or above 15-20 range (EPA 18) and the bottom waters in or above 20-30 range.

Table 82. EPA (2010) estuary water quality guideline trigger values for turbidity (NTU) in surface and bottom waters.

Parameter		Surface	Bottom
Turbidity (NTU)	Annual Median*	5	7
	Single sample	18	26

*calculated from a minimum of 10 samples collected at a monthly frequency

Table 83. Scoring for water clarity (turbidity) against EPA (2010) guidelines for exceedance of annual median thresholds and % of single sample. Annual medians require at least 10 samples in a water year.

Exceedance of EPA guidelines (EPA 2010): annual median threshold & % single sample	IEC Score
Neither exceeded	5
Annual median not exceeded AND single sampled exceeded OR No annual median BUT single sample not exceeded	4
Annual median < 110 % of guideline OR single sample exceedances < 25%	3
Annual median 5.5 <40 NTU (surface) or 7.7<8.8 NTU (bottom) OR single sample exceedances 25<50%	2
Annual median >40 NTU (surface) or >8.8 NTU (bottom) OR > 50% of single samples above guideline	1

Score thresholds between the five categories for annual medians were set by analysis of all available data (Figure 40). The threshold between score 1 and 2 was set at the 90th percentile of the available data (Table 83). The threshold between scores 2 and 3 were based on a value of 110% of the guidelines. The threshold between scores 3 and 4 was set at the guidelines for medians. For a score of 5 guidelines for both medians and single samples had to be met (Table 83, Figure 40).

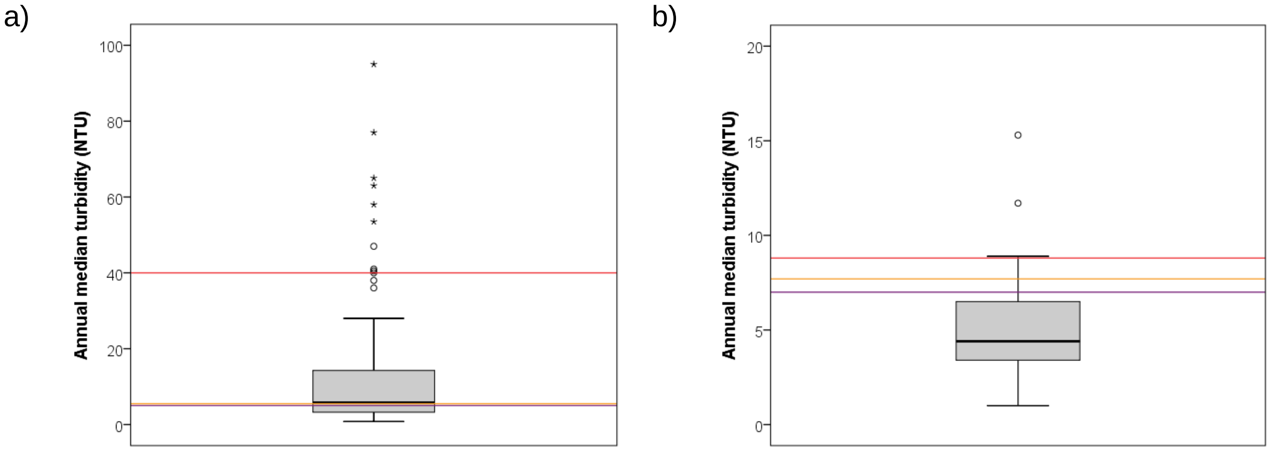


Figure 40. Annual median turbidity for a) surface and b) bottom waters for all sections and years available. Lines indicate thresholds for scoring (purple = EPA trigger values). Note the different scales for each plot.

Scores were calculated at the estuary section level, then were averaged up to an estuary score. To score a section, the data from each site in a section were incorporated. The median and % single sample exceedances were then calculated separately for the top and bottom waters for each water year. All section scores for top and bottom for each water year are averaged to give an estuary score. The choice of averaging section scores vs annual section scores was decided on the basis that large sections were likely to be sampled more and so were not spatially under-represented. To keep transparency in the scores this needs to be done so individual problem sections can be identified.

Scoring intervals for NSW estuary condition assessment were also based on % exceedance above each estuary class trigger level (Roper et al. 2011). Thresholds for NSW scoring categories were similar to those used in the IEC trial implementation for sections with only single-sample assessments, specifically: very poor (1) ≥90 %, poor (2) 75% < 90%, fair (3) 50% < 75%, good (4) 10% < 50% and very good (5) <10% (Roper et al. 2011).

Score confidence

The data used to derive the IEC water clarity (8) score were assessed and assigned a category of low, medium or high confidence based on data quality (Table 84). Score confidence considered how many years of data were available, the percentage of estuarine sections sampled, whether both surface and bottom waters were sampled and the degree of temporal and spatial replication within years and sections. Aggregating scores to give a single section score (averaged over years) or a single estuary score (across all sections and years) presents score confidence challenges when not based on monthly monitoring over six years with three sites in each section. Score confidence falls when the sampling is not monthly, as medians cannot be calculated with less than 10 samples per year (EPA 2010), also when there are less than three sites per section and when not every section is sampled or sampled in the recommended way. This method of defining score confidence allows scores to be calculated from limited data but clearly acknowledges the level of confidence that should be placed on that score.

Table 84. Score confidence criteria for the water clarity measure.

Confidence	Years sampled (out of 6) ** to be revised for an 8 year period in future*	Sections sampled (in any year)	% Top and bottom sampled (of year & section combinations)	Annual median for sections?	3 or more sites in any section?
High	4-6	>50%	>75%	All	Yes
Medium	4-6	>50%	>75%	All	No
Medium	4-6	>50%	>75%	Some	
Low	4-6	>50%	>75%	None	
Medium	4-6	>50%	<=75%	All or some	
Low	4-6	>50%	<=75%	None	
Medium	4-6	<=50%	>75%	All or some	
Low	4-6	<=50%	>75%	None	
Low	4-6	<=50%	<=75%		
Medium	2-3	>50%	>75%	All or some	
Low	2-3	>50%	>75%	None	
Low	2-3	>50%	<=75%		
Low	2-3	<=50%			
Low	1				

Scores

Forty-six estuaries had insufficient turbidity data for the calculation of water clarity scores (Figure 41a) with the majority of these estuaries along the Gippsland coast (Table 86). Scores could be calculated for 55 estuaries with 55% having a water clarity score of 4 and 27% a score of 3 (Figure 41a). Only one estuary, Fitzroy River, had a score of 5 and also had high score confidence. Campbell Creek, Cardinia Creek and Bass River all had a score of 1. However, of the estuaries scored, 73% had low score confidence (Figure 41b). All four estuaries with high score confidence (Table 85) were from the GHCMA region (Table 86).

Table 85. Numbers of estuaries by score and score confidence for the water clarity measure.

Score Confidence	IEC Score				
	5	4	3	2	1
High	1	3			
Moderate		4	6	1	
Low		23	9	5	3

Table 86. Water clarity scores and score confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH	1	5				2	4	2	
C		7	6		1	3		3	11
MW/PPWP		3	6	3	2	8		6	8
WG		7		3		18			10
EG		8	3			15			11

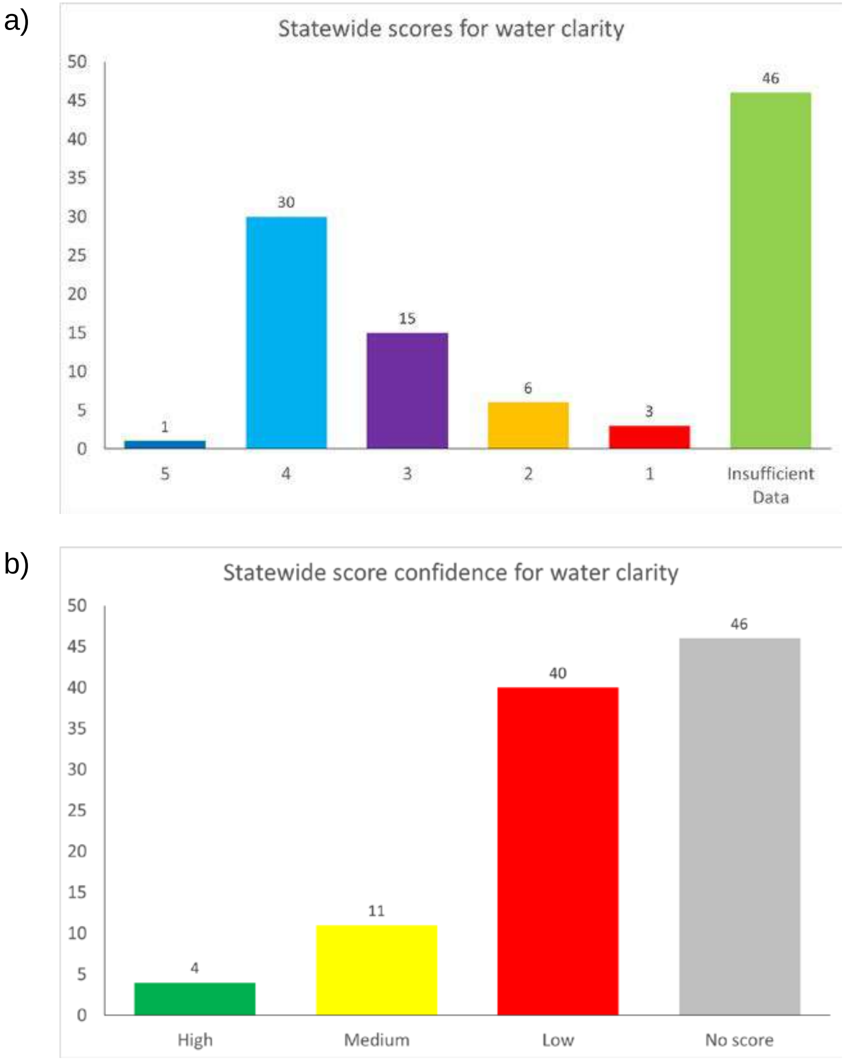


Figure 41. Statewide estuary a) scores and b) score confidence for the water clarity measure.

Discussion

The major impediment to trialling this measure was the limited amount of data collected appropriately across Victoria's estuaries as detailed in the water quality theme introduction. Method refinement concentrated on clear guidelines for the design and placement of sampling sites, and scoring based on EPA (2010) guidelines. Data for turbidity in Victorian estuaries are sparse (Appendix 3), with the majority collected only in the lower estuary or lagoon, or not appropriately in bottom waters. Due to the difficulty in establishing the sampling methods and site position in existing data sets, data were limited to the last six years to ensure that facts could be checked with the relevant authorities. This also ensured the different data sets to be considered in the trial were collected over the same time period and mimicked an IEC assessment.

It is recommended that top and bottom water turbidity in three sites in every estuary section are used to assess the water clarity measure. For the implementation trial, Secchi disc readings were also taken at the same time as turbidity was measured with a meter as an alternative way of assessing water clarity. Both the implementation trial and the NSW estuary condition assessment (Roper et al. 2011) had difficulties with the reliability of Secchi disc as a measure of water clarity in highly stratified or tannin waters or in very shallow estuaries. Measuring IEC water clarity as turbidity (NTU) is the preferred method over Secchi disc readings.

EPA (2010) top and bottom water median and single sample guidelines (Table 82) for riverine estuaries were used to evaluate exceedances. The low number of estuaries scoring 5 is likely to be related to the requirement for no single sample to exceed the single-sample trigger value. As the likelihood of an exceedance increases, not only with higher turbidity, but also with greater numbers of samples, a more suitable approach to this threshold in the future would be to allow a small proportion of single sample exceedances (e.g. <5%) that reflects the number of samples used to develop a score.

NSW turbidity trigger values exist for surface waters only and were derived using the 80th percentile of long term data from reference estuaries. NSW estuaries were divided into three functional types were based on dilution and flushing capacity. Five trigger values were used for surface waters of: Lagoon, Lake and River (lower, mid and upper) estuaries (Roper et al. 2011). ‘Lagoon’ included typically small and intermittently open lagoons and creeks and would include most Victorian estuaries; ‘Lake’ included bays, drowned river valleys and lakes either permanently or intermittently open, a few Victorian estuaries (e.g. Lake Tyers) would fall into this class; ‘River’ included mature barrier river estuaries all of which were permanently open, a few larger ‘child’ estuaries in Victoria could fall into this category.

Minimum sample size for assessment against the NSW guidelines is not detailed specifically, but in estuaries without other sources of data six sampling times were used per year within regionally-based target sampling windows of several months duration. In a similar approach to that used here, percent exceedance of a low-risk trigger value was used to develop condition scores in NSW (<50% exceedance of trigger is good or very good). Comparison of EPA’s (2010) riverine estuary surface water guidelines and NSW trigger levels shows that the Victorian single sample value of 18 is higher than all NSW triggers, reflecting its intended use. The Victorian median trigger of 5 NTU is broadly consistent in the way it is used and in value to most NSW types (Table 87). The higher NSW trigger values for mid and upper ‘River’ estuaries suggest that the Victorian triggers may be too conservative for some upstream sections but this is not borne out, at least with available data, in differences in individual section scores within Victorian estuaries (Appendix 9).

Table 87. Comparison of trigger values used in Victoria and NSW.

State	Estuary type	Surface/Bottom?	Guideline type	Trigger Value (NTU)
Victoria	Riverine (excludes bays)	Surface	Annual median (of 10+ samples)	5
			Single sample	18
		Bottom	Annual median (of 10+ samples)	7
			Single sample	26
NSW	Lagoon (intermittent)	Surface	Single sample (but scoring based on % exceedance of up to 3 years data)	3.3
	Lake (perm. open or intermittent)			5.7
	Lower River (perm. open)			5.0
	Mid River (perm. open)			8.0
	Upper River (perm. open)			13.7

EPA’s associated control charting method was not used in this implementation trial as it requires an additional six specific parameters collected monthly when turbidity is measured (EPA 2010). These parameters are bottom water pH, top and bottom water conductivity and stratification status (Table 42). In addition the average daily flow over the previous week is needed, which is an issue in smaller estuaries without flow gauges. Analysis of new and existing monitoring data by control charting in the future would contribute to the further development of scoring distributions.

EPA's guidelines were developed from monthly data from a single fixed site, usually a bridge, and mostly in the lower part of reference estuaries. Future development of the IEC water clarity measure needs to specifically assess how well the EPA (2010) guidelines apply to the entire estuary, to both river and lagoonal sections with multiple sites as well as across the state. There is also an opportunity to use pristine but unstudied estuaries in the east of the state to further develop a baseline associated with natural (vs best available) turbidity regimes.

IEC water clarity scoring categories were developed from analysis of all available data across all estuaries for median and/or % single sample exceedance of EPA (2010) guidelines (Table 83) based on the recommendations from both scoring workshops. Score thresholds were developed from the data. Data that enabled a high score confidence (Figure 41b, Table 84) were only available from four estuaries in south-west Victoria that were as part of the GHCMA Estuaries Monitoring Program (Table 86) which has now ceased. To allow further refinement of the water clarity measure with higher data confidence, monthly water monitoring programs in estuaries, particularly in Gippsland, need to be developed and established.

This future research need is highlighted by the difference of Victorian guidelines to NSW turbidity trigger levels as discussed above. Future IEC development also needs to consider the effect of the size of the estuary section, which vary widely in size, length and area, across Victoria. Three sites may not be sufficient for large sections such as riverine Glenelg. In future this could be considered as the number of sites per area or length. For riverine estuaries, sampling can often be unevenly distributed longitudinally along the river. Roper et al. (2011) found potential bias in the medians in each of the three functional zones of riverine estuaries for turbidity.

Natural turbidity levels are influenced by the type and size of particles and hence will be affected by a range of estuarine characteristics such as tidal flow, soil type, geology, slope, orientation, prevailing wind direction, depth and width. The future development of the water clarity measure, when more data are available, needs to take these factors into account (initially using current functional type) and examine setting baseline conditions for particular estuaries types and sections. As part of this future refinement of this measure, the ecological consequence of high turbidity, to fish and seagrass in Victorian estuaries needs to be specifically considered.

Future development:

- Establish monthly water monitoring programs in estuaries, particularly in Gippsland to allow further refinement of the water clarity measure with higher data confidence.
- Assess how well the EPA (2010) guidelines apply to the entire estuary, to both river and lagoonal sections with multiple sites.
- Include the six additional parameters (bottom water pH, top and bottom water conductivity and stratification status and average daily flow over the previous week) EPA (2010) recommended to allow assessment to include EPA's control charting method. This would contribute to the further development of scoring distributions.
- Examine a more suitable approach to thresholds to allow a small proportion of single sample exceedances (e.g. <5%) that reflects the number of samples used to develop a score.
- Investigate pristine but unstudied estuaries in the east of the state to further develop the baseline associated with natural (vs best available) turbidity regimes as highlighted by the difference of Victorian guidelines to NSW trigger levels.

- Assess the effect of estuary section size, length and area, for potential bias and optimum number of sample sites.
- Research to understand the ecological consequences of high turbidity for fish and seagrass in Victorian estuaries.

6.2 DISSOLVED OXYGEN (9)

Dissolved oxygen (9): recommended

Dissolved oxygen is essential for (aerobic) aquatic biota. Oxygen levels within the estuary are a balance of oxygen input from photosynthesis, aeration (e.g. wind mixing) and inflow (of oxygenated marine and riverine waters), and reduction from respiration and nitrification (i.e. conversion of ammonium to nitrate and nitrite by bacteria in the sediment and water column) (Scheltinga et al. 2004; Arundel et al. 2009; Giordani et al. 2009). Dissolved oxygen concentrations naturally vary over a twenty-four hour period due to tidal exchange and because there is net production of oxygen by plants and algae during the daytime when photosynthesis occurs. By comparison, plants and algae respire at night time, and this process consumes oxygen. Because of this highly productive/eutrophic systems are expected to have large diurnal dissolved oxygen ranges (Scheltinga et al. 2004).

Dissolved oxygen levels, particularly in the bottom waters of stratified estuaries, are often depleted through decomposition of organic matter by microbial activity (Arundel et al. 2009; EPA 2010). This is a natural process, with hypoxia and anoxia being recorded in several ‘pristine’ estuaries – both intermittently and permanently open (Barton 2006; Sherwood et al. 2008). Anthropogenic activities resulting in increased input of nutrients and organic matter to estuaries are likely to accelerate the process and influence the extent and duration of oxygen depletion. The limited tidal input and long water residence time in wave-dominated, intermittent estuaries makes them more prone to hypoxic events. Even short-lived anoxic and hypoxic events can cause major "kills" of aquatic organisms, low oxygen can have an immune suppression effect on fish and increase the toxicity of many toxicants (Scheltinga et al. 2004). Apart from the direct impact of low oxygen levels on biota, anoxic bottom waters can trigger the release of sediment-bound nutrients and indirectly affect condition by subsequent events such as algal blooms (13b(ii)) (Pope 2006; EPA 2010).

Elevated nutrient loads are associated with increased primary production of phytoplankton (16) and macroalgae (13b). Algal blooms (Maher 2001) and excessive growth of macroalgae e.g. *Cladophora,* have been recorded from several Victorian estuaries (Barton 2006). The increased biomass can result in very high daytime dissolved oxygen levels (>110%, EPA 2010) and night-time oxygen sags. These are strongly correlated with chlorophyll *a* (measure 16) concentrations (O’Boyle et al. 2012). The resultant decomposition of the large plant biomass can cause widespread hypoxia (< 2 mg/L) or anoxia (0 mg.L-1, EPA 2010). Mass mortality of fish (fish kills) have been associated with these events particularly when combined with artificially opening the entrance (measure 5a) (EEMSS 2006; Becker et al. 2009).

Nutrient concentrations (inorganic and particulate) in estuary waters are the function of a complex suite of physicochemical and biological processes (Scheltinga et al. 2004), and within an estuary the portion of nutrients in the water column (compared to sediments and organisms) can be variable. Water column nutrients were not recommended as measures as it is difficult to describe or predict associations between particular concentrations and estuarine condition (Arundel et al. 2009). In a study of NSW intermittent estuaries (ICOLLs), no correlation between nutrient concentrations and nutrient loads or catchment use was detected (Scanes et al. 2007). Similarly, studies in Victorian estuaries did not detect a biological response to estuarine nutrient concentrations (Barton 2006; Sherwood et al. 2008).

Dissolved oxygen levels can be reported as oxygen concentration (mg/L) or percentage saturation (%). Maximum oxygen concentration (mg/L) in water is affected by salinity and temperature, but percentage saturation levels reflect relative oxygen production and demand independent of both factors. Dissolved oxygen (% saturation) is the recommended way of reporting this measure although both ways are usually measured by water quality meters and should be recorded if available (Arundel et al. 2009). The dissolved oxygen measure was recommended to be based on monthly mid-channel surface measurements taken over six years and assessed by water year (Arundel et al. 2009). In each estuary section, sampling was recommended at three randomly chosen sites (Table 2). In addition to monthly measurements, vertical daytime (late afternoon) dissolved oxygen profiles were recommended to be taken at the same sites to detect anoxic bottom waters and algal blooms (Arundel et al. 2009). For this implementation trial EPA guidelines (2010) were used that specify trigger levels for surface and bottom waters (which take into account lower oxygen in the bottom waters of reference estuaries) and so both depths were assessed wherever possible. Also, it was recommended that dissolved oxygen surface measurements are logged over 24 hours (15-20 minute intervals) at the most vulnerable site of each section to assess diurnal oxygen sag (Arundel et al. 2009). This 24 hour log should be collected once in a water year (Arundel et al. 2009). Additional contextual data needs to be collected at the same time, including temperature and salinity.

Dissolved oxygen (9) = dissolved oxygen samples exceeding EPA (2010) estuary water quality median & single sample guidelines

Baseline = current state-wide data (best available)

EPA's (2010) guidelines were developed from targeted sampling in the lower part of estuaries along the western and central Victorian coast. The guideline values were developed from the best-available estuaries, those with the lower intensity land use. As these guidelines form the basis of the IEC dissolved oxygen measure scoring, the baseline uses best available data. There were no historical or pre-European settlement data to set a baseline. However, there are several estuaries in the east of the state with little or no catchment modification and a correspondingly small amount of data that could be used for future development of the guidelines.

Data used

The data used for trialling the implementation of the dissolved oxygen measure are outlined in the Water Quality theme introduction and summarised in Table 81. The major impediment to trialling this measure was the limited amount of data collected appropriately across Victoria's estuaries (Appendix 3).

Scoring method

The scoring method has been refined from that originally proposed in Arundel et al (2009). Dissolved oxygen data are two-tailed, in the sense that both very high and low values reflect poor condition. EPA (2010) guideline values for annual medians and single sample exceedances in surface and bottom waters (Table 88) were used to determine condition scores of 4 and 5, but it was more difficult to define the thresholds between the lower categories (Table 89). These score thresholds were set by analysis of all available data (Figure 43). The threshold between score 1 and 2 was set at the 10th percentile of the exceedance dataset and between score 2 and 3 was set at the guideline value minus 10% (Table 89, Figure 43).

Table 88. EPA (2010) estuary water quality guidelines dissolved oxygen (%) trigger levels for surface and bottom waters.

Parameter		Surface	Bottom
Dissolved Oxygen (%)	Annual Median*	<90	<65
	Single sample	70-110	15-110

*calculated with a minimum of 10 samples collected at approximately monthly frequency

Oxygen sag over 24 hours is not explicitly dealt with in the EPA (2010) guidelines and results were not used in developing scores but are examined in the discussion of this section.

Figure 42. Algal bloom in 2010 in Shipwreck Creek estuary, in the Sandpatch Wilderness Area Croajingolong National Park.

Table 89. Scoring criteria for dissolved oxygen for sections per water year using EPA (2010) guidelines for exceedance of annual median thresholds and % of single sample.

Criteria	IEC Score
Neither median nor single sample trigger value exceeded AND annual median <110% saturation	5
Annual median not exceeded AND <110% saturation AND single sample guideline exceeded No annual median BUT single sample not exceeded	4
Annual median 81 < 90; 110<115 % (surface) 58.5<65;110<115 % (bottom) OR IF SS only <25% exceedances	3
Annual median 62.5 < 81% (surface) 25.1 < 58.5 (bottom) OR > 115% 25-50% SS exceedance	2
Annual median < 62.5% (surface) or < 25.1% (bottom) > 50% exceedance SS	1

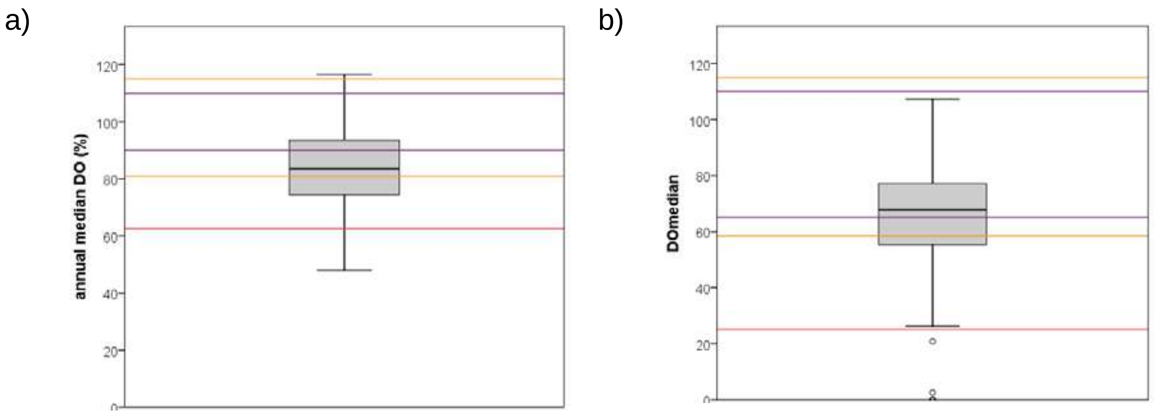


Figure 43. Annual median dissolved oxygen concentrations for a) surface and b) bottom waters for all sections and years available. Lines indicate thresholds for scoring.

Score confidence

The data used to derive the dissolved oxygen (9) score were assigned a category of low, medium or high confidence based on data quality (Table 90). Score confidence considered how many years of data were available, the percentage of estuarine sections sampled, whether both surface and bottom waters were sampled and the degree of temporal and spatial replication within years and sections. Aggregating scores to give a single section score or a single estuary score presents score confidence challenges when not based on monthly monitoring over six years with three sites in each section. Score confidence falls when the sampling is not monthly, as medians cannot be calculated with less than ten samples per year, also when there are less than three sites per section and when not every section is sampled or sampled in the recommended way. This method of defining score confidence allows scores to be calculated from limited data but clearly acknowledges the level of confidence that should be placed in that score.

Table 90. Score confidence criteria for the dissolved oxygen.

Confidence	Years sampled (out of 6) ** to be revised for an 8 year period in future*	Sections sampled (in any year)	% Top and bottom sampled (of year & section combinations)	Annual median for sections?	3 or more sites in any section?
High	4-6	>50%	>75%	All	Yes
Medium	4-6	>50%	>75%	All	No
Medium	4-6	>50%	>75%	Some	
Low	4-6	>50%	>75%	None	
Medium	4-6	>50%	<=75%	All or some	
Low	4-6	>50%	<=75%	None	
Medium	4-6	<=50%	>75%	All or some	
Low	4-6	<=50%	>75%	None	
Low	4-6	<=50%	<=75%		
Medium	2-3	>50%	>75%	All or some	
Low	2-3	>50%	>75%	None	
Low	2-3	>50%	<=75%		
Low	2-3	<=50%			
Low	1				

Scores

Scores could be calculated for 51 estuaries (Figure 44a), the majority of estuaries with insufficient data were on the Gippsland coast (Table 92). No estuaries had a score of 5, with the majority (61%) having a dissolved oxygen score of 3 (Figure 44a, Table 91). Little River, Mordialloc Creek and Bass River estuaries all had a score of 1. Overall there were no strong geographic trends in score values. The nine estuaries with a score of 4 were spread across the Victorian coast on the open coast and in sheltered embayments.

Of the estuaries that were scored, 71% had only a low score confidence (Figure 44b, Table 91). This is because only the GHCMA and CCMA monitoring programs provided relatively large amounts of relevant data. Only four estuaries had high score confidence, all were from the GHCMA region (Table 92).

The main reason for low scores was low dissolved oxygen, with relatively few estuaries outside the upper thresholds (Figure 43). Surface waters were more often below the guidelines than bottom waters. Although only six estuaries could have medians calculated for their bottom waters, three estuaries - Glenelg River, Lake Yambuk and Hopkins River riverine sections recorded dissolved oxygen % saturation of zero. All three had a bottom water median in their riverine section of zero in the water year 2006/2007. Glenelg River had additional zero medians in 2008/2009 and 2009/20010, and Hopkins River in 2011/2012. Numerous estuaries had single samples records of near zero % saturation over this period. Both the surface and bottom waters of the riverine section of Nicholson River in the Mitchell/Nicholson River estuary was near zero for sampling in 2011/2012. The bottom waters of the riverine section of Gellibrand River estuary were also near zero in 2007/2008.

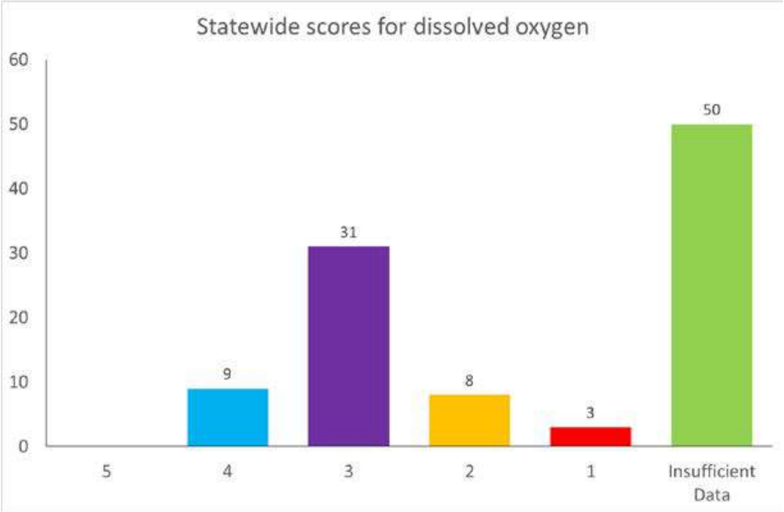
Table 91. Numbers of estuaries by score and score confidence for the dissolved oxygen measure.

Data Confidence	IEC Score				
	5	4	3	2	1
High		1	3		
Moderate			7	3	1
Low		8	21	5	2

Table 92. Dissolved oxygen scores and score confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH		1	5			2	4	2	
C		1	11	2		3		3	11
MW/PPWP		2	4	4	3	9		6	7
WG		4	3	1		20			8
EG		1	8	1		16			10

a)



b)

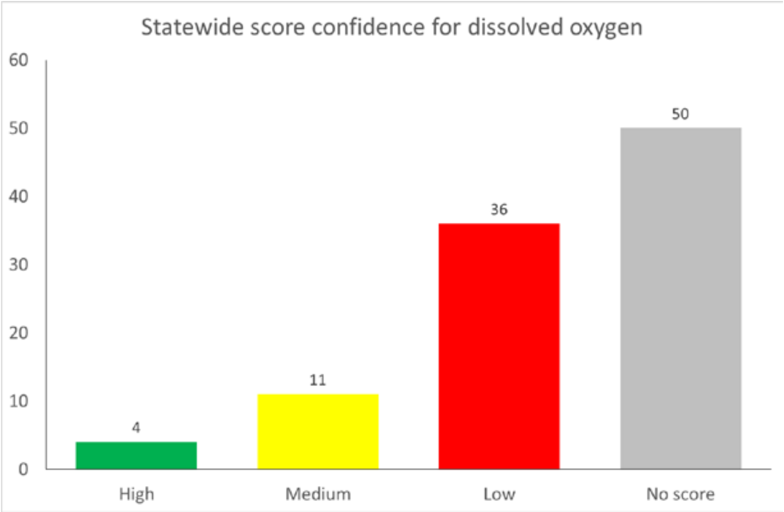


Figure 44. Statewide estuary a) scores and b) score confidence for the dissolved oxygen measure.

Discussion

The implementation trial of this measure focused on collating existing data, refining collection methodology and collecting new data, particularly 24 hour oxygen sags and data in systems statewide. Method refinement concentrated on clear criteria for the placement of sampling sites, and scoring based on EPA (2010) guidelines. Existing data for dissolved oxygen in Victorian estuaries were sparse, with the majority collected in the lower or estuary lagoon (Appendix 9). Due to the difficulty in establishing the sampling methods and site position in existing data sets, data were limited to the last six years to ensure that facts could be checked with the authorities. This also ensured the different data sets to be considered in the trial were collected over the same time period and mimicked an IEC assessment. It is recommended that dissolved oxygen in both surface and bottom waters at three sites in every estuary section are used to assess the dissolved oxygen measure.

IEC dissolved oxygen scoring categories were developed from analysis of all available data across all estuaries for median and/or % single sample exceedance of EPA (2010) guidelines (Table 83) based on the recommendations from both scoring workshops. Additional score thresholds were developed from the data.

EPA's guidelines were developed from monthly data from a single fixed site (usually a bridge) in predominately the lower estuary. Future development of the IEC dissolved oxygen measure needs to specifically assess how well the EPA (2010) guidelines apply to the entire estuary, to both river and lagoonal sections with multiple sites. Only a few Gippsland estuaries were included in the development of the EPA (2010) guidelines and the relevance of these guidelines should be assessed for all, especially the pristine eastern Gippsland estuaries. Future IEC development also needs to consider the effect of the size of the estuary section, which vary widely in size, length and area, across Victoria. Three sites may not be sufficient for large sections such as riverine Glenelg. This could be considered as number of sites per area or length. For riverine estuaries, sampling can often be unevenly distributed longitudinally along the river.

EPA's (2010) associated control charting method was not used in this implementation trial as it requires an additional four specific parameters collected monthly when dissolved oxygen is measured (Table 42). These parameters are bottom water pH, top and bottom water conductivity and stratification status (EPA 2010). Analysis of new and existing monitoring data by control charting in the future would contribute to the further development of scoring distributions.

NSW estuary condition assessment does not use dissolved oxygen as a condition measure as low dissolved oxygen is not a frequent problem in their estuaries (Roper et al. 2011). QLD EPA guidelines (Scheltinga and Moss 2007) provide condition scores (1 to 5) for two oxygen indicators. One indicator is based on the minimum sustained dissolved oxygen values during the days following an inflow event and the second on a measure of ambient dissolved oxygen i.e. the percentage of zones/sites that exceed ANZECC/ARMCANZ (2000) guidelines.

Low dissolved oxygen can occur in estuaries in good condition but estuaries in poor condition are likely to have many more low dissolved oxygen events than similar estuaries in better condition. It may be that particular sections and estuary types are more prone to naturally low dissolved oxygen. Existing data did not allow an in-depth assessment of this, but should be considered when more data become available.

Dissolved oxygen typically has substantial temporal and spatial variability but the recommended monthly sampling means that it reflects patterns of dissolved oxygen on a broad temporal scale. The IEC dissolved oxygen measure will miss some events, but may pick up results of events or associated conditions (e.g. high chlorophyll concentrations, fish kills). In future, the dissolved oxygen five condition bands should be reviewed considering changes relative to ecological effects. It may be possible to relate the condition bands to the extent of the water column deoxygenated, i.e. amount of aerobic habitat. It also may be advisable to take 1 off the IEC dissolved oxygen score if both top and bottom are deoxygenated.

Data that enabled a high score confidence (Figure 44a, Table 91) were only available from four estuaries in south-west Victoria that were as part of the GHCMA Estuaries Monitoring Program (Table 85) which has now ceased. To allow further refinement of the water clarity measure with higher data confidence, monthly water monitoring programs in estuaries, particularly in Gippsland, need to be developed and established.

Summary results from the surface dissolved oxygen logger deployments (Figure 46) are shown in Figure 45. Overnight dissolved oxygen concentrations were generally lower than those measured during the daytime sampling. Maxima were similar, but occasionally lower in the logged data, most likely due to deployments late in the day for less than 24 hours but potentially also due to spatial variability. Of the 19 sections that met single sample guidelines based on a single sampling event (and so scored 4), eleven exceeded trigger values based on logged data. This highlights the temporal variability in dissolved oxygen concentrations and the potential for misleading results from inadequate sampling. The seasonal and temporal variability of surface water diurnal oxygen changes needs to be further assessed.

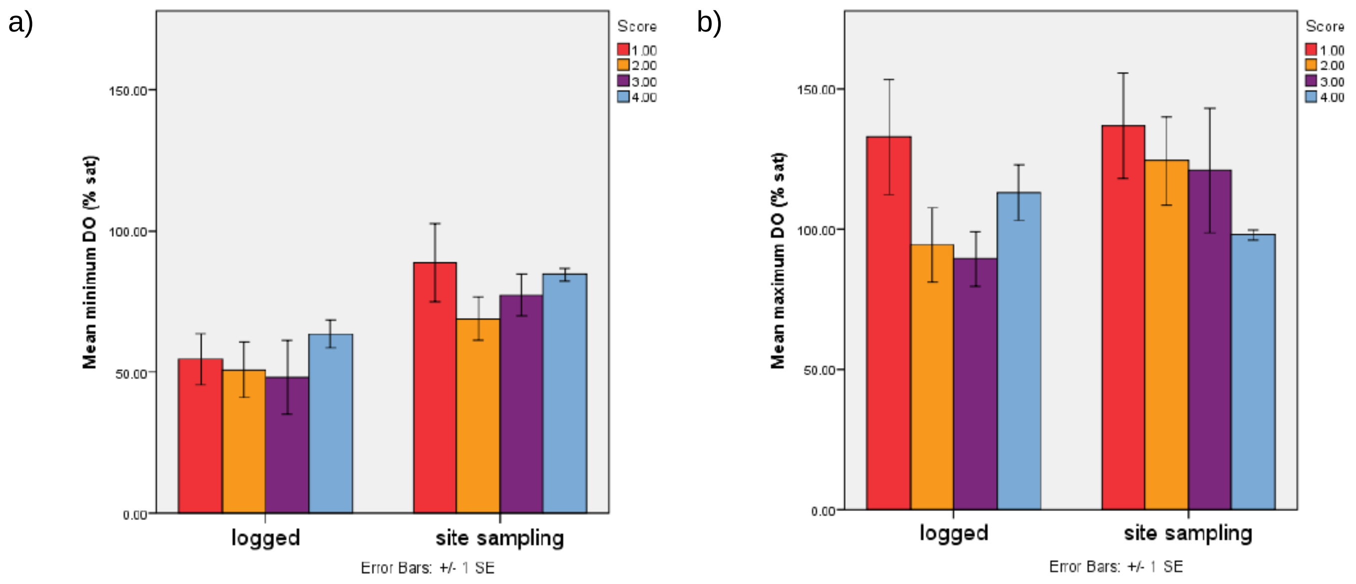


Figure 45. Comparison of a) minima and b) maxima of dissolved oxygen in sections which were both logged and sampled in the implementation trial. Means are grouped by condition scores derived from the sampling of sites within the section.

Future development:

- Establish monthly water monitoring programs in estuaries, particularly in Gippsland to allow further refinement of the water clarity measure with higher data confidence.
- Assess how well the EPA (2010) guidelines apply to the entire estuary, to both river and lagoonal sections with multiple sites.
- Assess how well the EPA (2010) guidelines apply to Gippsland estuaries.
- Assess the seasonal and temporal variability of surface water diurnal oxygen changes. Subsample existing and future dissolved oxygen data from the permanent loggers in GHCMA (Glenelg, Surry, Fitzroy and Lake Yambuk estuaries) and CCMA (Gellibrand).
- Incorporate diurnal oxygen measurement, with dissolved oxygen surface measurements logged over 24 hours (15-20 minute intervals) at the most vulnerable site of each estuary section. This 24 hour log should be collected once in a water year and incorporated into scoring this measure.
- Examine a more suitable approach to thresholds to allow a small proportion of single sample exceedances (eg <5%) that reflects the number of samples used to develop a score.
- Assess the effect of estuary section size, length and area, for potential bias and optimum number of sample sites.
- Review the five condition bands considering changes relative to ecological effects. It may be possible to relate the condition bands to the extent of the water column deoxygenated, i.e. amount of aerobic habitat. It also may be advisable to take 1 off the IEC dissolved oxygen score if both top and bottom are deoxygenated.
- Include the four additional parameters (bottom water pH, top and bottom water conductivity and stratification status) EPA (2010) recommended to allow assessment to include EPA's control charting method. This would contribute to the further development of scoring distributions.

Figure 46. Diurnal oxygen logging of surface waters in Eumeralla River, Lake Yambuk 2011.

7 RESULTS OF IMPLEMENTATION OF SEDIMENT MEASURES

Sediment plays a key role in the ecology of estuaries (Figure 47, Table 93), it comprises an important habitat as well as mediating key aspects of trophic dynamics and nutrient cycling processes (Arundel et al. 2009). Mudflats, including intertidal mudflats, have been recognised in Victoria as an Ecological Vegetation Class (EVC 990) devoid of vascular plants but can be an important substrate for photosynthetic unicellular organisms (15) (EEMSS 2006). The hydrological regime and estuarine morphologies together with lithological influences and anthropogenic effects influence the textural and chemical composition of sediments (Mil-Homens et al. 2014). Estuaries are physically shaped by the interaction of river, wave and tidal energy with sediment supply (Arundel et al. 2009). While estuaries are typically sinks for fluvial sediments, patterns of deposition and erosion within estuaries vary in complex ways through space and time in response to shaping forces. Sediments are an integral part of estuaries and support their biological elements (Mil-Homens et al. 2014). Soft sediments play a substantially larger functional role in estuaries than they do in most streams and rivers which is why it is considered as a separate theme (Arundel et al. 2009). This reflects the importance of both sediment movement and quality to estuarine condition (Arundel et al. 2009).

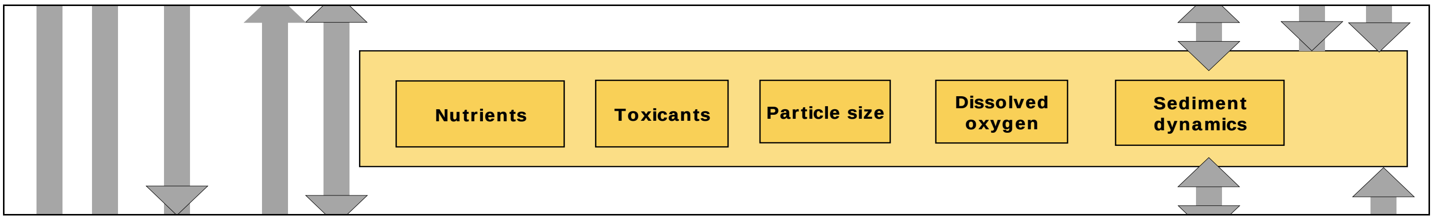


Figure 47. Sediment components of conceptual model (Full model shown in Figure 1).

Table 93. Recommended measures within Sediment theme from Arundel et al. (2009).

PHYSICAL FORM	HYDROLOGY	WATER QUALITY	SEDIMENT	FLORA	FAUNA
			10. Sediment particle size 11. Bank erosion 12. Sediment respiration rate		

The sediment of an estuary includes features of sediment quality such as nutrients, toxicants and dissolved oxygen; and aspects of physical structure such as particle size, erosion, sedimentation and sediment transport (Arundel et al. 2009). Estuaries act as sinks for sediment and associated nutrients and toxicants and therefore integrate the effects of human activity over time. The inclusion of this Sediment theme is supported by studies in Victoria (Barton 2006) and Tasmania (Edgar and Barrett 2000; Edgar et al. 2000) that suggested sediments were likely to provide useful indicators of estuarine condition (Arundel et al. 2009).

The Sediment theme links to all other themes and considers aspects of the physical properties, movement and biota of sediments (Arundel et al. 2009). Changes to the dynamics and distribution of sediments in an estuary, including the increases in fluvial sediment load (measure 2) from the ‘Physical Form’ theme, affect the ecological condition of estuaries via several interlinking causal pathways such as reductions in the light environment (8) (also reflected in water quality), alterations of depths (1), particle sizes (10), and mobility of benthic habitats. In this sense, sediments influence recommended measures across all themes. The recommended Sediment theme (Arundel et al. 2009) consists of three measures, sediment particle size (10), bank erosion (11) and sediment respiration rate (12) (Table 38).

7.1 SEDIMENT PARTICLE SIZE (10)

Sediment particle size change (10): recommended with further development of scores and score confidence

Changes in particle size in the upper parts of estuaries (away from the flood tide delta) are often linked to patterns of erosion (11) and sedimentation (1) (Arundel et al. 2009). The proportion of fine sediments in some systems is thought to increase, along with sedimentation rates, as a response to human-related changes in sediment supply and hydrodynamics (Scheltinga and Moss 2007; McMahon et al. 2013). Sediment inputs are generated by soil erosion in catchments disturbed by human activity as well as riverbank and shoreline erosion (Roper et al. 2011; McMahon et al. 2013). Increased sediment within an estuary can have many causes, such as increased coastal erosion due to loss of vegetation, episodic and large scale events (drought, floods, storms, bushfires), and point source discharges (Scheltinga et al. 2004). Changes in the distribution of fine particles within estuaries between surveys can provide an integrated record of changes in patterns of sedimentation (Arundel et al. 2009). Enhanced sedimentation rates can result in important changes to the form and function of waterways (e.g. they may cause: changed shoreline and mudflats area, channel infilling, habitat/benthic community smothering or removal, increased turbidity levels, and the burial or resuspension of nutrients, trace elements, toxicants and organic matter (Scheltinga and Moss 2007)). Contamination of sediments with metal and organic pollutants has led to a decline in ecological condition in some, typically highly urbanised, estuaries. While there are established techniques for measuring sediment contamination, its localised nature and the cost of analyses make such assessments better suited to targeted rather than state-wide programs (Arundel et al. 2009).

Variation in the type of sediment (e.g. from marine sand to mud), salinity, water depth, water movement and position in relation to other habitat types all strongly influence the biota. Subtidal sandy bottoms occur in more exposed areas, particularly in larger embayments and coarse sediment settles out along river beds, floodplains and at tributary mouths (Roper et al. 2011). Muddy basins are associated with sheltered areas of many estuaries, fine suspended sediment fills bays and central basins and reduces water clarity (8) (Roper et al. 2011). In fine sediments, bacterial decomposition of organic material depletes oxygen from all but the top few centimetres of sediment, below which the mud is black and sulphur-smelling due to anaerobic bacteria (Turner et al. 2004). A decreases in particle size is often related to increased risks to condition from organic matter, nutrients, pollutants, smothering and clogging and habitat change for infauna.

The sediment particle size measure is based on the proportion of sediment in the top 10cm of the estuary bed that is <125 µm in diameter (i.e. clays, silts and very fine sands) as a measure of sedimentation (Arundel et al. 2009). A design of eight replicates at depositional locations in the upper, middle and lower zones of the estuary was suggested for the IEC (Arundel et al. 2009). Sampling was recommended to be repeated twice a decade but would fit in better with the IEC reporting period if done once every eight years. Immediate implementation of this measure was considered hard to achieve as there were very few existing data identified as being collected in depositional locations. Identifying depositional locations that could be revisited/resampled in eight years was difficult in the field and requires a higher than moderate level of skill. A moderate level of skill and specialized equipment is required for particle size analyses but it can be done by a range of commercial laboratories. A range of Australian Standards have been published regarding measurement and representation of sediment particle sizes (e.g. AS 1141.11—1996 for dry sieving of coarser sediments).

Sediment particle size change (10) = % increase in fine sediment (<125 µm) in top 10cm of depositional locations

Baseline = current individual estuary data

Baseline is difficult to determine for this measure and has to be set at the current depositional area particle size for each individual estuary. The sediment size data from the first visit are the baseline. The first assessment of the sediment condition will be possible when the first IEC is conducted.

Data used

Little existing data are available for depositional locations in Victorian estuaries. The assessment of this measure was based on sediment cores collected as part of the implementation trial (Appendices 5 & 10). Surface (<10 cm depth) sediment cores (3.8 cm diameter, 10cm depth) were collected from depositional locations (lagoonal mud flat, fluvial delta etc) within each upper, middle and lower estuary zone. These sites have been photographed and GPS referenced to allow resampling when the first formal IEC is undertaken. Initially, in the summer of 2010, five replicate cores were taken in a 2 x 10 m site. In 2011, replication at the site was increased to eight cores. Sediment redox and visible oxic depth measurements were taken from each core before it was bagged and frozen for later laboratory analysis. Sediments were pre-treated in the laboratory with a wet oxidation technique using hydrogen peroxide to remove organics before drying to prevent caking prior to sieving (Bowman and Hutka 2002; McKenzie et al. 2002).

In total, 569 samples were collected from 43 estuaries and 55 subestuaries, with a mean of 41% <125 µm and a range of 97 to 0.1%. The lower estuary zone had slightly less fine surface sediment (mean 34%, range 90 to 0.1%) than either the middle (mean 47%, range 96 to 0.4%) or upper (mean 46%, range 97 to 0.3%) zones.

Scoring method

A preliminary scoring method of five categories is proposed with very poor condition being represented with a greater than 20% increase in sediment <125 µm (Table 94).

Table 94. Scoring for sediment particle size change.

% increase in proportion of fines	IEC Score
0% OR decrease of fines	5
<5%	4
>5%	3
>10%	2
>20%	1

Score confidence

Confidence in scores needs to be developed as part of a later comparison using samples from this study as a baseline. Suggested criteria for assessment are shown in Table 95.

Table 95. Score confidence criteria for the sediment particle size change.

Confidence	Criteria
High	Areas sampled have low potential for scouring & represent a substantial proportion of potential estuarine habitat. All possible subestuaries sampled. Statistically significant change in proportion of fines.
Medium	*To be developed*
Low	*To be developed*
Unknown	Unable to establish if data exist

Scores

No scores were generated from these data as this was the first initial sampling and was conducted to refine the method, identify depositional zones and collect baseline data.

Discussion

The measure is intended as a temporal measure at specific locations within an estuary. In some cases, such as Cardinia estuary, gravel washed down in recent floods was evident as a discrete layer and contributed to higher particle sizes in the samples. This highlights the need for expert interpretation of the data and potential sources of variation as well as the context dependency of the measure. The component of the trial assessing post-European sedimentation events using stable isotope sediment dating (Section 4.1) will assist in developing interpretation of this measure and in assessing its viability.

Sampling was recommended to be repeated twice a decade (Arundel et al. 2009) but would fit in better with the IEC reporting period if done once every eight years. More detailed scaling of this measure will be possible once the sampling is repeated. Following collection of such data it can be assessed if different ranges of scoring scales will be required for differing groups of estuaries.

For Victorian estuaries, interpretation of these data will need to take into account influences of estuary type (particularly with respect to the availability of depositional areas and the frequency of scouring). Contextual information for this measure includes major flooding, extended droughts, presence of large dams and the existence of riverine sand slugs.

This measure was one of several possible measures of sedimentation/erosion recommended as national indicators, although for Queensland estuaries it was excluded as impractical (Scheltinga and Moss 2007). In South Africa, mapping of the distribution and sedimentary composition of shoals in each estuary is combined with particle size information from six benthic sites and used as a basis for an expert opinion on the percentage similarity of total intertidal area and sand fraction compared to an undisturbed system (Taljaard et al. 2004).

Future development:

- Repeat sampling of the depositional locations from the implementation trial estuaries to determine responsiveness of measure in IEC timeframe.
- Assess, using the repeat sampling data, if different ranges of scoring scales will be required for differing groups or of estuaries, particularly with respect to the availability and type of depositional areas and the frequency of scouring.
- Improve score confidence criteria using the repeat sampling data.
- Finalise stable isotope component and assess integration with % change in fines.

7.2 BANK EROSION (ISC METHOD) (11)

Bank erosion (11): recommended with some further development

In addition to increased fluvial sediment supply, sediments can enter the water column of estuaries from local drainage lines and by erosion of the bank and bed of the estuary itself (Arundel et al. 2009; Roper et al. 2011; McMahon et al. 2013). In general, while catchment sources are usually dominant, in specific locations the supply of sediment from the estuary bed or banks may also be significant (Scheltinga and Moss 2007). In systems where non-fluvial sources are significant, bank erosion (which can be linked to increased disturbance of the bankside zone or to reduced fluvial sediment supply) can lead to reduced ecological condition by pathways such as changing the particle size (10), altering availability and depth of benthic (including intertidal) habitat, reducing water quality (8) and smothering biota. Increased sea levels and frequencies of storm surges that are predicted with climate change are likely to increase overall sediment flux (erosion and deposition) in low-relief coastal regions, including estuaries (Arundel et al. 2009).

Bank erosion in estuaries was recommended to be assessed as per the ISC 2004 method for bank stability (DES 2005) in which three sites within each estuarine section were assessed (Arundel et al. 2009). It was thought if successful, collection of data could be done by relatively unskilled personnel

Bank erosion (11) = ISC 2004 bank erosion method

Baseline = Expert opinion

With the absence of existing data the baseline needs to be based on expert opinion for each estuary.

Data used

The ISC 2004 method (DSE 2005) was trialled for estuaries through field sampling (Appendix 5). The banks of each site are compared to a standard set of photos and a suite of six metrics scored for both the left and right banks. Site photos of the banks were taken for reference (e.g. Figure 48) and to build an estuary specific bank erosion photo library.

Scoring method

Data for this measure were scored on a five point scale as per ISC scoring (Table 96). Armoured banks were given a score of 4 to reflect that they were not a natural bank but probably were contributing little sediment to the estuary if they were functioning as designed. Issues of altered lateral connectivity (4) and fringing vegetation (14) would be picked up in other scores. Each site generally had both the left and the right bank scored. The score for an estuary section was based on the average score for all three sites and replicates combined (average of a maximum of six scores) as done in the ISC (Victorian Department of Sustainability and Environment 2006). If not every bank was scored, this was captured in data confidence.

Estuary scores were calculated as shoreline-proportional averages of the section scores (unrounded mean score of replicates in a section). Unrounded section scores were multiplied by the proportion of the total estuary perimeter represented in that section and added together. Where not all sections in an estuary were scored, a standardised estuary score was calculated by dividing the summed scores from sections where scores were available by the proportion of the total estuary represented by those sections. Summed proportional section scores were then rounded to the nearest integer.

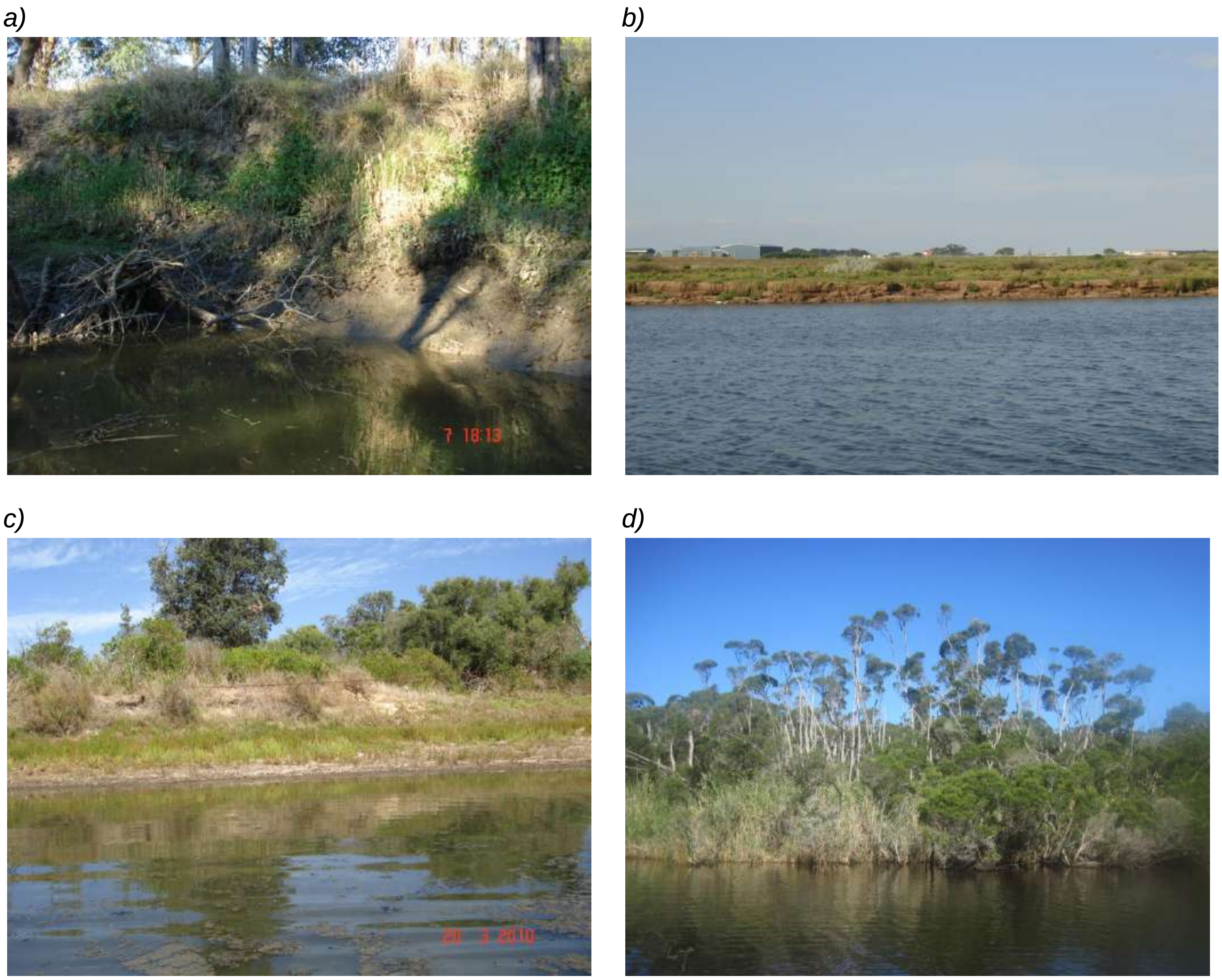


Figure 48. Examples of banks across the scoring range for the erosion measure from a) score 1 Bass River, b) score 2 Werribee River, c) score 3 Merricks Creek to d) score 4 Tyers Inlet.

Table 96. Scoring for bank erosion (DSE 2005).

Banks: stability; toe; slope >45º & undercut; cover of vegetation; >33% exposed woody roots; livestock damage	IEC Score
Good stable & intact; no toe; not >45º; continuous cover; <33% roots; no damage	5
Limited/isolated erosion; no toe; not >45º & undercut, near continuous cover; <33% roots, no damage	4
Moderate erosion; instabilities toe, gentle OR >45º slope, discontinuous cover, >33% roots, no damage	3
Extensive erosion; mostly unstable toe OR >45º slope with toe, minimum cover, >33% roots, obvious damage	2
Extreme erosion, very recent bank movement; unstable toe; cover >45º slope; no vegetation, >33% roots, obvious damage	1

Score confidence

The ISC 2004 bank erosion method (DSE 2005) was developed for freshwater rivers and, because of that, the score was uniformly given a low data confidence where it was assessed in an estuarine lagoon section (Table 97). It is often hard to see edges and bank in the flatter morphology of lagoons. The data confidence for sections in the more riverine part of estuaries was determined from the number of sites and number of samples scored, based on three size categories of the zone perimeter (<5 , 5 to 17 & >17km, Table 97). The estuary score confidence is a proportional average of the zone score confidences. Seawalls were all scored 4 indicating they were not natural and their efficacy in preventing bank erosion was unknown.

Table 97. Score confidence criteria for bank erosion for estuaries of different size.

Confidence	Criteria: Perimeter <5km
High	> 2 sites or 3 to 6 samples
Medium	1 site or < 3 samples; or Lagoon section
Low	
Unknown	Unable to establish if data exist
Confidence	Criteria: Perimeter 5 to 17 km
High	3 sites & 5 to 6 samples
Medium	2 sites or 4 to 3 samples
Low	1 site or < 3 samples; or Lagoon section
Unknown	Unable to establish if data exist
Confidence	Criteria: Perimeter >17 km
High	
Medium	3 sites & 5 to 6 samples
Low	< 3 sites or < 4 samples; or Lagoon section
Unknown	Unable to establish if data exist

Scores

Across Victoria, 48 estuaries could be scored for bank erosion, with 53 estuaries having insufficient data to be scored (Figure 49a, Table 98). At the estuary level there were no very low or very high scores with the majority of estuaries scoring either a 3 or a 4 (Figure 49a). This is likely in part be due to the averaging across samples, sites and sections in scoring an estuary and should be revisited in future assessments. The eight estuaries that scored 2 for bank erosion were Barham, Kennett, Wye, Werribee, Powlett and Yeerung Rivers, Painkalac Creek and Lake Yambuk. Four of these estuaries were in the Corangamite CMA region with the other four spread along the Victorian coast (Table 99). The majority of the estuaries that had inadequate data to be scored were along the central (12 estuaries) or Gippsland coast (33 estuaries, Table 99). Data for the estuaries scored are given in Appendix 10.

The majority of scored estuaries had a score confidence of high or medium (Figure 49b, Table 99). The seven estuaries that had low data confidence were the Merri, Yarra, Bunyip and Snowy Rivers, Lake Bunga and Anderson and Mallacoota Inlets. With the exception of the Lake Bunga this low score confidence reflected the large size of these estuaries.

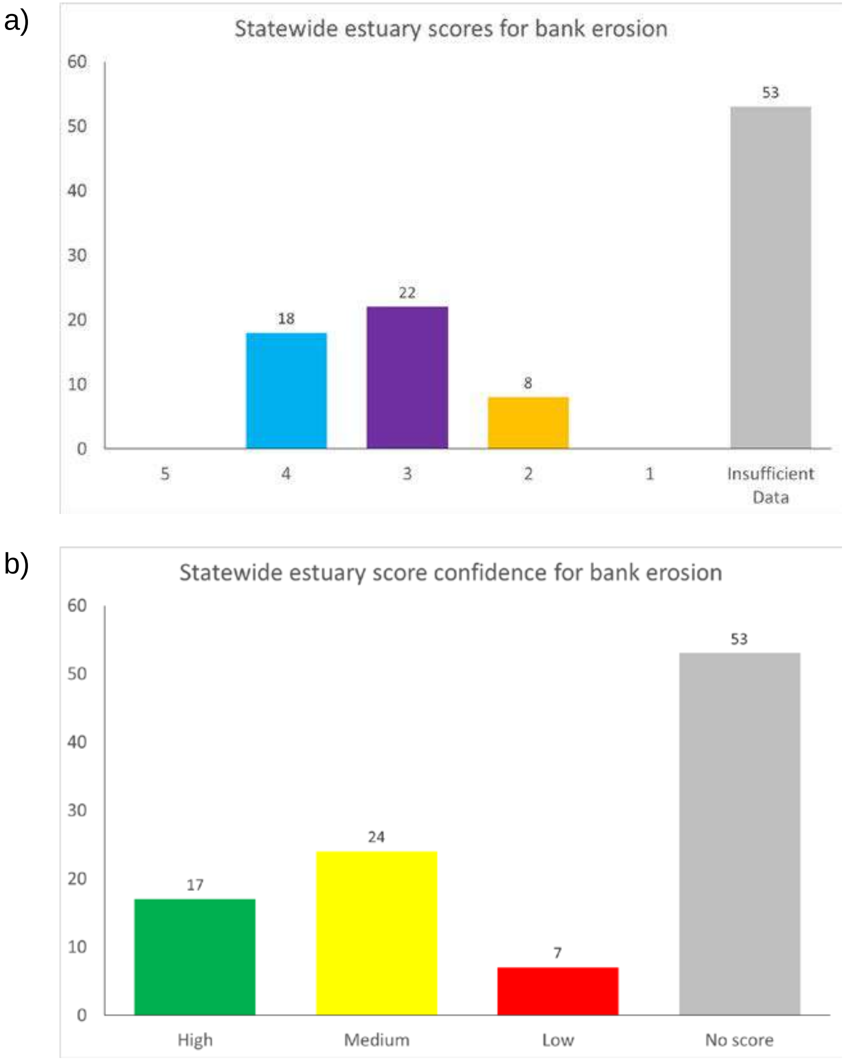


Figure 49. Statewide estuary a) scores and b) score confidence for the bank erosion measure.

Table 98. Numbers of estuaries by score and score confidence for the bank erosion measure.

Score Confidence	IEC Score				
	5	4	3	2	1
High		8	5	4	
Moderate		9	11	4	
Low		1	6		

Table 99. Bank erosion scores and data confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH		3	1	1		3		4	1
C		3	5	4		5	4	8	
MW/PPWP		3	6	1		12	6	2	2
WG		4	5	1		18	5	4	1
EG		5	5	1		15	2	6	3

Discussion

This measure still needs substantial adaptation from the ISC 2004 scoring method (DSE 2005) for estuaries, particularly in large lagoons and low lying fringing sand and mudflats which was reflected in the low score confidences. Issues with the scoring method related mostly to general morphological differences between estuaries and rivers in combination with the typically reduced velocity and bi-directionality of flows in estuaries. There were considerable difficulties scoring all sections when the majority of the bank was not exposed due to high water levels (tidal or mouth state) or for low relief sandy shores (beaches and berms).

Since the start of the implementation trial there has been major redevelopment of the ISC bank erosion method (DSE 2005). It is now based on slope and height of the bank, as well as broad geomorphic character. The ISC LiDAR erosion assessment method (Johansen et al. 2011) could give whole of ecosystem coverage rather than small sections of bank. Difficulties may be encountered if the IEC LiDAR is being flown in conjunction with the ISC LiDAR due to water levels. The IEC LiDAR needs to be collected at low tide in open systems, this will be particularly problematic for intermittently open estuaries. Also LiDAR (with low pulse rates and low point densities) does not penetrate through *Phragmites* beds. Alternatively mapping or aerial photo validation could be done with a small remote controlled drone with a camera. Photos taken for this measure (e.g. Figure 50) should be geolocated and published online in a photolibrary.

The erosion ranking developed by this trial should ideally be reviewed by an estuarine geomorphologist and rated for potential sediment contribution. The importance of bank erosion as a measure of estuarine condition will vary between estuaries in response to geomorphology (e.g. narrow, riverine estuaries vs broad lagoons) and proportional contribution to suspended sediment concentrations and loads (*i.e.* links to Water Quality and Physical form themes). Ultimately, scoring for this measure should be interpreted in context of the type of estuary and the influence of other sediment sources in the estuary. Bank erosion in some systems may be a response to a reduced fluvial sediment supply disrupting the sediment balance of intertidal areas. In these systems there may be an offsetting benefit elsewhere in the estuary.

Future development:

- Review of the rankings developed and rate for potential sediment contribution by an estuarine geomorphologist. The importance of bank erosion as a measure of estuarine condition will vary between estuaries in response to reduced fluvial sediment supply, geomorphology and proportional contribution to suspended sediment concentrations and loads. Does the measure need to be scaled for this?
- Further adapt the ISC 2004 scoring method (DSE 2005) for estuaries, particularly for large lagoons and low lying fringing sand and mudflats and assess its applicability to non-channelised sections. Refine methodology to cope with high water levels (tidal or mouth state) or for low relief sandy shores (beaches and berms).
- Evaluate the changes in the ISC method for bank erosion (DSE 2005), would they would improve this measure?
- Evaluate the ISC LiDAR erosion assessment method. Would it give whole estuary coverage, what would be needed to field validate the automatic classification in estuaries, what are the errors associated with high water and dense fringing vegetation? Is it appropriate to make develop a measure integrating the stream and coastal LiDAR with the existing *in situ* bank erosion assessments?
- Assess mapping or aerial photo validation with a camera on a remote controlled drone.

Geolocate implementation trial photos and publish online in a photo library.

Figure 50. Bank erosion and slumping along the Bass River estuary.

7.3 SEDIMENT RESPIRATION RATE (12)

Sediment respiration rate (12): not recommended

Respiration (and photosynthesis) in estuarine sediments are a key part of nutrient cycling as well as playing an important role in the availability of oxygen in the water column (9) and mediating dynamics of sediment-associated pollutants (Arundel et al. 2009). Sediment respiration rate is the rate at which oxygen is consumed by organisms in the sediment. Net respiration is the result of oxygen consumption balanced by oxygen production from photosynthesis. This measure integrates sediment, organic matter and nutrient input into an estuary over time and shows less temporal variability than individual measures of suspended sediment or nutrients. Respiration rate is a measure of activity of benthic microalgae. High sediment respiration rates are often due to increased decomposition in response to unnaturally increased organic matter loads and eutrophication of estuaries. A common response of benthic communities to elevated inputs of organic matter and nutrients is for these external sources to become the dominant carbon source (i.e. heterotrophic) rather than communities generating organic matter through photosynthesis (i.e. autotrophic).

Discussion

The NSW Office of Environment and Heritage (OEH) considers a high sediment respiration rate (< -105 $\mu MO_2/m^2$/day, heterotrophic) where it is unexpected (e.g. shallow margins with good light) as poor and a low sediment respiration rate (≥ 0 $\mu MO_2/m^2$/day, autotrophic to zero) as good. Estuaries in good condition have benthic communities as the dominant carbon source through photosynthesis. Poor condition estuaries have a high sediment respiration rate due to increased decomposition in response to unnaturally increased organic matter loads and eutrophication of estuaries. The collaboration with NSW OEH examined if the results from similar systems in NSW apply to Victorian estuaries.

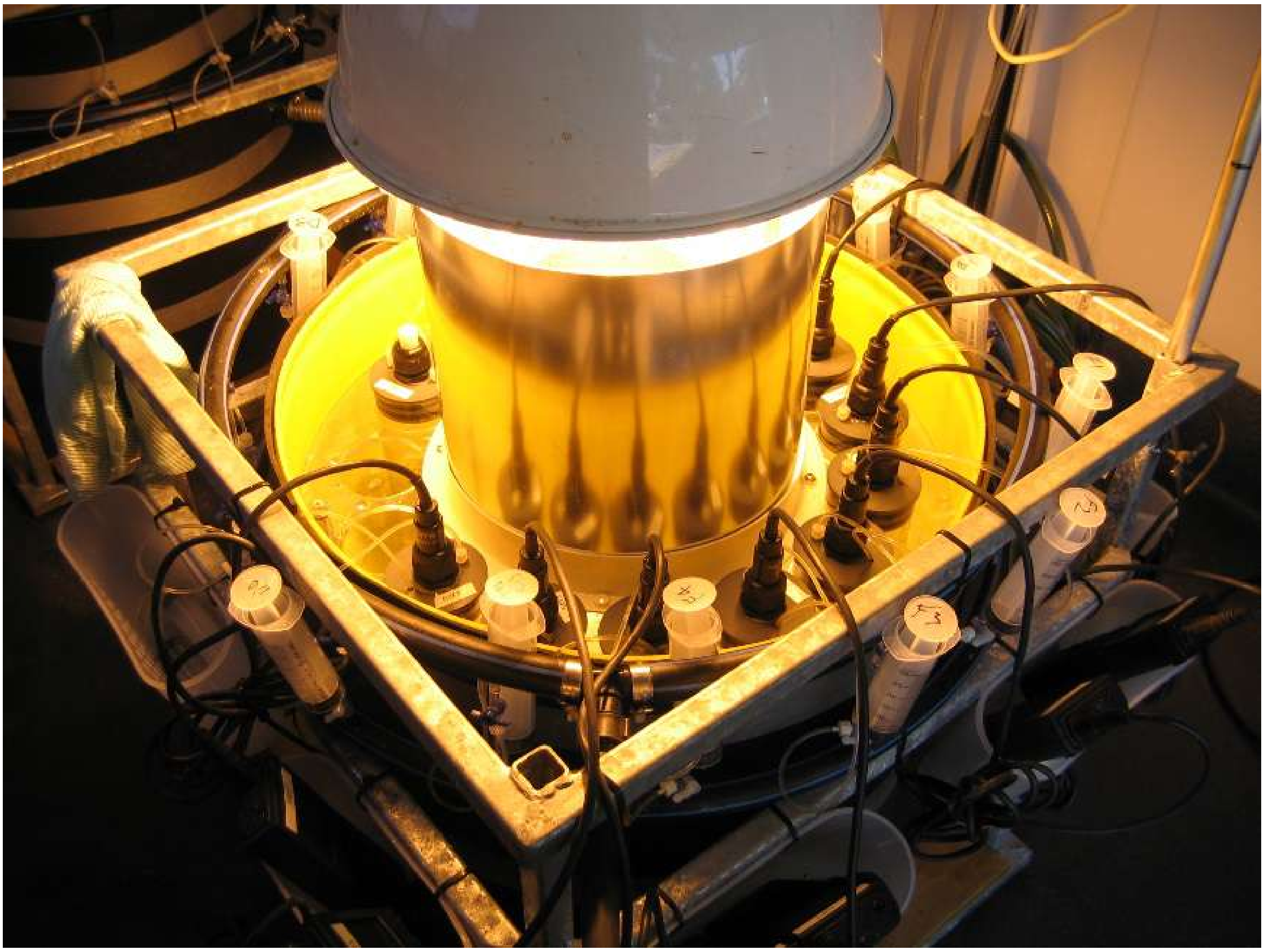


Figure 51. Sediment cores being incubated under light conditions.

A collaborative (NSW OEH colleagues with the IEC trial team members) sampling trip in four Great Ocean Road estuaries was conducted in the first week of February 2011. The design was four estuaries - St George, Kennett, Painkalac and Spring, over a gradient from low threat and high threat. Other IEC measures, including microphytobenthos and phytoplankton, were collected at the same time. Water quality, dissolved oxygen and turbidity and microphytobenthos (Figure 66) were sampled for a three months prior to the incubated core sampling as contextual information. Five pairs of cores were taken at each of three sites in the lower estuary from shallow areas (i.e. that are not light limited). The sediment respiration measure uses cores incubated in a field laboratory based on the NSW OEH technique (Potts et al. 2009) (Figure 51). They were then lab incubated in light and dark conditions.

The sampling found that the four estuaries were benthic chlorophyll-a dominated and for the ecological process measures, benthic community respiration (BCR) decreased (Figure 52a), and net ecosystem metabolism (NEM) (Figure 52b) increased, across the land use gradient. BCR and microphytobenthos production were highly correlated across the estuaries suggesting they were highly coupled. The sediments were net autotrophic and generally negligible to low sources of dissolved inorganic nitrogen and dissolved inorganic phosphorus to the water column.

This measure was too resource intensive to undertake and currently the interpretation of the results for scoring is not straightforward. It is not recommended that this measure be implemented as part of the initial IEC. NSW OEH also does not routinely use sediment respiration rate to assess estuary condition, although it is used in specific intensive studies. It is a useful tool for understanding the complex biogeochemistry and the sediments' role as a source or sink of nutrients in estuaries when results outside of expectations for other measures are found. As such it is a secondary intensive tool for assessing estuary condition.

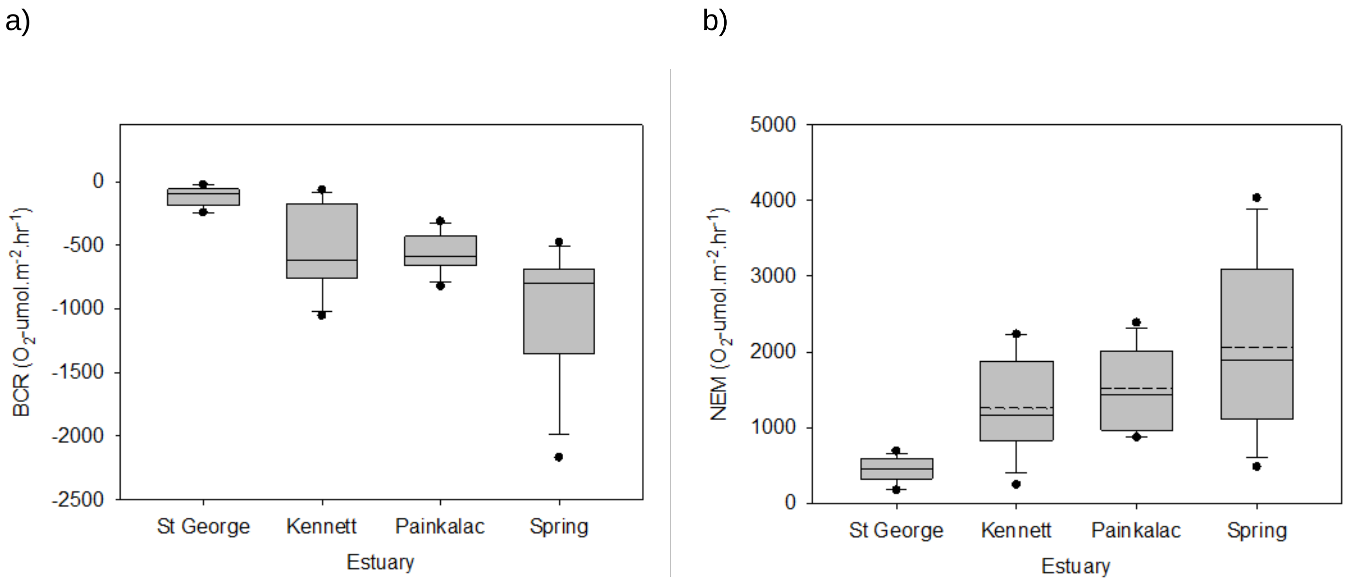


Figure 52. Incubated core results across a land use intensity gradient of low (St George) to high (Spring) for a) benthic community respiration (BCR) and b) net ecosystem metabolism (NEM).

8 RESULTS OF IMPLEMENTATION OF FLORA MEASURES

Flora is an important component of the natural environment in and around estuaries, especially intermittently-open estuaries (Whitfield et al. 2012). Algal and macrophytic floral components contribute to overall estuarine function and measures of both were recommended for the IEC (Figure 53, Table 100).

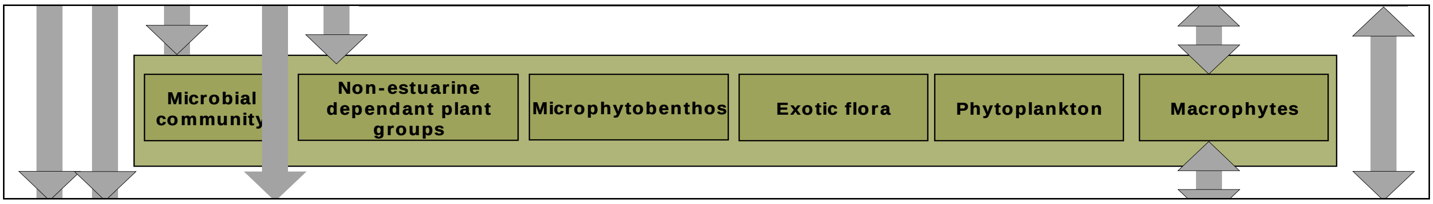


Figure 53. Flora components of conceptual model (Full model shown in Figure 1).

Table 100. Recommended measures within Flora theme from Arundel et al. (2009).

PHYSICAL FORM	HYDROLOGY	WATER QUALITY	SEDIMENT	FLORA	FAUNA
				13. Aquatic macroflora a) Macrophytes b1) Macroalgae b2) Macroalgae # of blooms 14. Fringing macrophyte 15. Microphytobenthos (Phaeophytin &/or Chl *a*) 16. Phytoplankton (Chlorophyll *a*)	

Macrophytic native vegetation in Victoria is grouped into Ecological Vegetation Classes (EVCs). Although species within a particular EVC may vary, the general structure and habitat the EVC occupies are similar (Arundel et al. 2009). A list of 16 estuarine EVCs, both aquatic and riparian, their floristic components and threats, were identified in EEMSS (2006). This also included bare sediment tidal Mud-flats (EVC 990) which is devoid of vascular plants but can be an important substrate for photosynthetic unicellular organisms or microphytobenthos (15). The critical estuarine water heights in intermittently-open estuaries have been identified for six EVCs: Coastal saltmarsh (EVC 9) and Swamp scrub (EVC 53) at the lowest elevation; Estuarine wetland (EVC 10) and reedbeds (EVC 592) at mid-level elevations; and Littoral (EVC) and Warm temperate rainforest (EVC 32), both restricted to East Gippsland, with critical elevations 30 cm below the surface of the EVC (EEMSS 2006). Specific heights have also been recognised in individual applications of Estuary Environmental Flows Assessment Methodology (EEFAMS) (Lloyd et al. 2008a; Lloyd et al. 2008b; Brizga et al. 2011).

Assessment of the condition of the vegetation in and surrounding wetlands forms part of many recent indices and assessments (Sinclair and Sutter 2008a; Roper et al. 2011; Victorian Saltmarsh Study 2011; Papas and Moloney 2012; Van Niekerk et al. 2013). NSW's state of the catchments (Roper et al. 2011) provides an initial baseline of the condition of estuaries in NSW and the pressures influencing their condition. The two vegetation indicators used in NSW were phytoplankton (micro-algae) biomass measured as chlorophyll *a*, and seagrass, mangrove and saltmarsh extent (current extent vs what was mapped 30 years ago). South Africa assesses phytoplankton and microphytobenthos as well as the change in area of estuarine habitats including vegetated habitats: intertidal salt marsh; supra-tidal salt marsh; submerged macrophytes; reeds and sedges; mangroves; and swamp forest (Van Niekerk et al. 2013). Abiotic habitats' change in area are also assessed: sand/mud; banks; channel; and rocks (Van Niekerk et al. 2013).

Detailed mapping of fringing vegetation has been undertaken at 1:50,000 scale for seven estuaries in the Glenelg Hopkins CMA (Sinclair and Sutter 2008b), eight estuaries in the Corangamite CMA (Osler et al. 2010) and state-wide for saltmarsh and mangroves (Victorian Saltmarsh Study 2011).

The Index of Wetland Condition (IWC) has been developed to assess the condition of high value wetlands, excluding wetlands with a marine water source, in Victoria. The IWC has 13 variables in six sub-indices: wetland catchment, physical form, hydrology, water properties, soils, and biota (flora) in the spring and autumn of an assessment year (Papas and Moloney 2012). The biota sub-index has four vegetation measures: critical life forms; presence of weeds; indicators of altered processes; and vegetation structure and health (Papas and Moloney 2012). These measures together cover the diversity, health and weediness of the native wetland vegetation in the wetland. The catchment sub-index has land use intensity in the 250m surrounding the wetland, and the width of the native vegetation surrounding the wetland and whether it is a continuous zone or fragmented. Reference condition is the estimated condition of the wetland at the time of European settlement, based on scientific knowledge and expert opinion.

Two (2009/ 2010 and 2010/2011) statewide IWC assessments have been undertaken in Victoria, covering 827 high value wetlands, which is approximately 6% of the naturally occurring, non-alpine wetlands in Victoria (Papas and Moloney 2012). The 2009/10 IWC included an assessment of Lakes Hordern, Craven and Costin in the Aire River estuary not realising that all these lakes are part of the estuary and have marine water influence. The overall IWC assessment was excellent for Lake Hordern and good for Lakes Craven and Costin (Papas and Moloney 2012). All sub-indices were excellent for Lake Hordern except for biota which was good. Physical form, water properties and biota were excellent for Lakes Craven and Costin, with wetland catchment and hydrology moderate. The two lakes differed in the assessment of the soils sub-index with Lake Costin excellent and Lake Craven poor. The soils sub-index measures the amount and severity of wetland soil disturbance from human, feral animals or stock activities (Papas and Moloney 2012).

This theme (Figure 3, Table 38) considers the condition of the flora that occurs in and around estuaries. It includes macrophytes such as saltmarsh, mangroves, reedbeds, seagrass and macroalgal beds, and microphytes such as phytoplankton in the water column or microphytobenthos associated with sediment (Arundel et al. 2009). The flora theme includes the subtidal, intertidal and riparian areas and is broader than the ISC ‘Streamside zone’ (Arundel et al. 2009). The recommended Flora theme (Arundel et al. 2009) consists of four measures, aquatic flora (macrophyte change and macroalgal cover) (13), fringing macrophytes (14), microphytobenthos (15) and phytoplankton (16) (Table 100).

8.1 AQUATIC FLORA (13)

8.1A AQUATIC MACROPHYTE EXTENT (13A)

Aquatic macrophyte extent (13a): recommended with further development of sampling design, methodology and scoring.

Seagrasses are flowering (vascular) plants that occur in most of Victoria’s estuaries. They are recognised in two EVCs, sea-grass meadows (EVC 845) and saline aquatic meadows (EVC 842). Seagrass meadows include the genera *Zostera* and *Heterozostera*, which also occur in the marine environment. Saline aquatic meadows include the genera *Ruppia* and *Lepilaena,* both of which also occur in non-estuarine wetlands. Compared to marine seagrasses (e.g. *Posidonia australis*), areas covered by both EVCs can vary substantially through seasons and years. Of the estuarine groups, *Ruppia* and *Lepilaena* are most characteristic of pioneer species in that they can colonise areas quickly but are relatively short lived compared to *Zostera* and *Heterozostera*. Freshwater macrophyte species (e.g. those recorded by Ball and Blake 2009b) can also be found in the upper parts of some estuaries however these are not the focus of this measure.

Submerged or aquatic macrophytes such as seagrass beds form complex ecosystems and act to stabilise sediment and alter water flow (Arundel et al. 2009). They are highly productive and ecologically important habitats that provide habitat for a range of invertebrate and fish species, including foraging and refuge habitat for recreational and commercial fish species (Turner et al. 2004; Whitfield et al. 2012). Submerged macrophytes provide hard surfaces in areas of soft sediment that are colonised by epiflora and epifauna (Turner et al. 2004; Whitfield et al. 2012). Variation in seagrass extent and cover in intermittently-open estuaries can occur due to natural changes in water levels associated with flow regimes and entrance condition, but stable conditions during the closed mouth phase of intermittently-open estuaries will promote the growth of submerged macrophytes (Riddin and Adams 2010). If the mouth is closed for long enough, they can grow and expand to occupy the entire water column where the habitat is suitable, i.e. shallow and calm water with stable salinity (Whitfield et al. 2012).

Submerged macrophytes are affected by a range of natural and anthropogenic influences, particularly those that alter the light availability, water movement, salinity regime, sediment deposition and biogeochemistry (see review in Adams and Riddin (2007)). Understanding mechanistic relationships between seagrass and their environmental stressors informs why change has occurred (Kilminster et al. 2014). A loss of submerged macrophytes may have significant impacts on faunal composition and abundance and on the subsequent functioning of intermittently-open estuaries (Riddin and Adams 2010).

Both freshwater flow (6) and entrance openings (5) act to alter the amount of potential habitat available for seagrass beds. Monitoring of these may provide information to differentiate natural changes from those associated with human activities.

This measure was proposed to be based on the percentage change in the extent of seagrasses from historical to present. Immediate implementation of this measure was thought to be hard to achieve due to the high level of skill needed (Arundel et al. 2009).

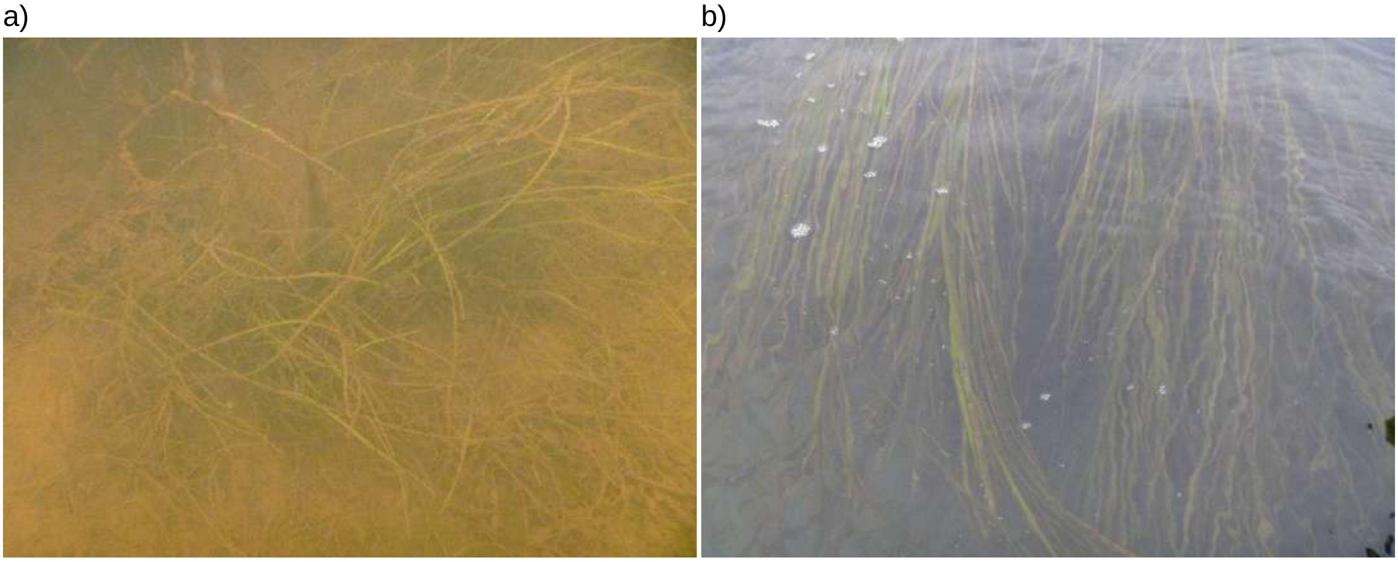


Figure 54. Aquatic macrophytes: *Zostera* in a) Painkalac and b) Powlett estuaries in March 2011.

Aquatic macrophyte extent (13a) = % change in aquatic macrophyte extent from historical

Baseline = historical data/expert opinion

In estuaries that have been surveyed at times where seagrass extent is known to be high in comparison to decadal changes these mapped extents should be used. If long term changes are not known an assessment of potential maximum extent based on any existing seagrass mapping and knowledge of influencing factors must be made.

Data used

Water clarity (8) in the majority of Victorian estuaries is often unsuitable for traditional mapping methodologies using remote sensing, despite its obvious advantages for broad scale surveys (e.g. Australian Estuary Database in Digby et al. 1999; discussed in Blake et al. 2000). Various methods have been used in recent years to overcome this (e.g. Blake and Ball 2006; Pope 2006). These include use of diver observations, underwater photography/video (where possible) (e.g. Woodland et al. 2015) and sidescan sonar. Of these methods sidescan sonar can cover a large area most efficiently but requires a degree of ground truthing with one of the other methods. Use of remote underwater cameras is sometimes possible in intermediate water clarities where the presence of seagrasses cannot be identified from above the surface. Diver observations can be used in extremely low visibility and allow for samples to be taken for identification purposes.

For the IEC a relatively simple and efficient method of monitoring aquatic vegetation is required to allow sampling across a large number of systems. Especially where remote sensing methods are not viable, this means that a form of spot or transect method will be required at the cost of broad coverage. Design of sampling programs using these methods (i.e. locating appropriate sampling sites) benefits greatly from previous extensive mapping, especially at times when seagrass is widely distributed. Previous studies are also important as they allow assessments of change that are critical in developing this metric. In smaller estuaries, this metric should be based on the whole system (most commonly including the lagoonal section near the entrance and a portion of the adjacent riverine section upstream). In larger systems an assessment based on sections may be more appropriate (as per Mallacoota below) to identify any within-estuary spatial differences in seagrass condition.

Seagrasses have been mapped in approximately 25 Victorian estuaries (Blake and Ball 2006; Pope 2006; Ball and Blake 2009a; Woodland et al. 2015) (Appendix 11). Four estuaries where seagrasses have been mapped in the past and data was available were used for methodological trials of this measure (Painkalac Creek, Anglesea River, Wingan Inlet and Mallacoota Inlet).

Anglesea River and Painkalac Creek estuaries are small, intermittently open estuaries on the east facing coast of the Corangamite region. Seagrasses were both mapped and sampled by transects in the 1999-2002 period (Pope 2006). Wingan Inlet and Mallacoota Inlet are both located in East Gippsland. Wingan Inlet has a permanently-open entrance whereas Mallacoota Inlet closes periodically. Seagrasses in both were mapped by Blake et al. (2000) in 1999, including the sampling of spot locations on site.

In the Anglesea and Painkalac estuaries, ten and thirteen transects were sampled on the 17th and 18th of March 2011 respectively. Information on density (patchy, dense) and type of beds (*Zostera*, mixed, *Ruppia*) was recorded, repeating the methodology in Pope (2006). This method was also similar to one of those used by Ball and Blake (2009b). Results are shown in Figure 55.

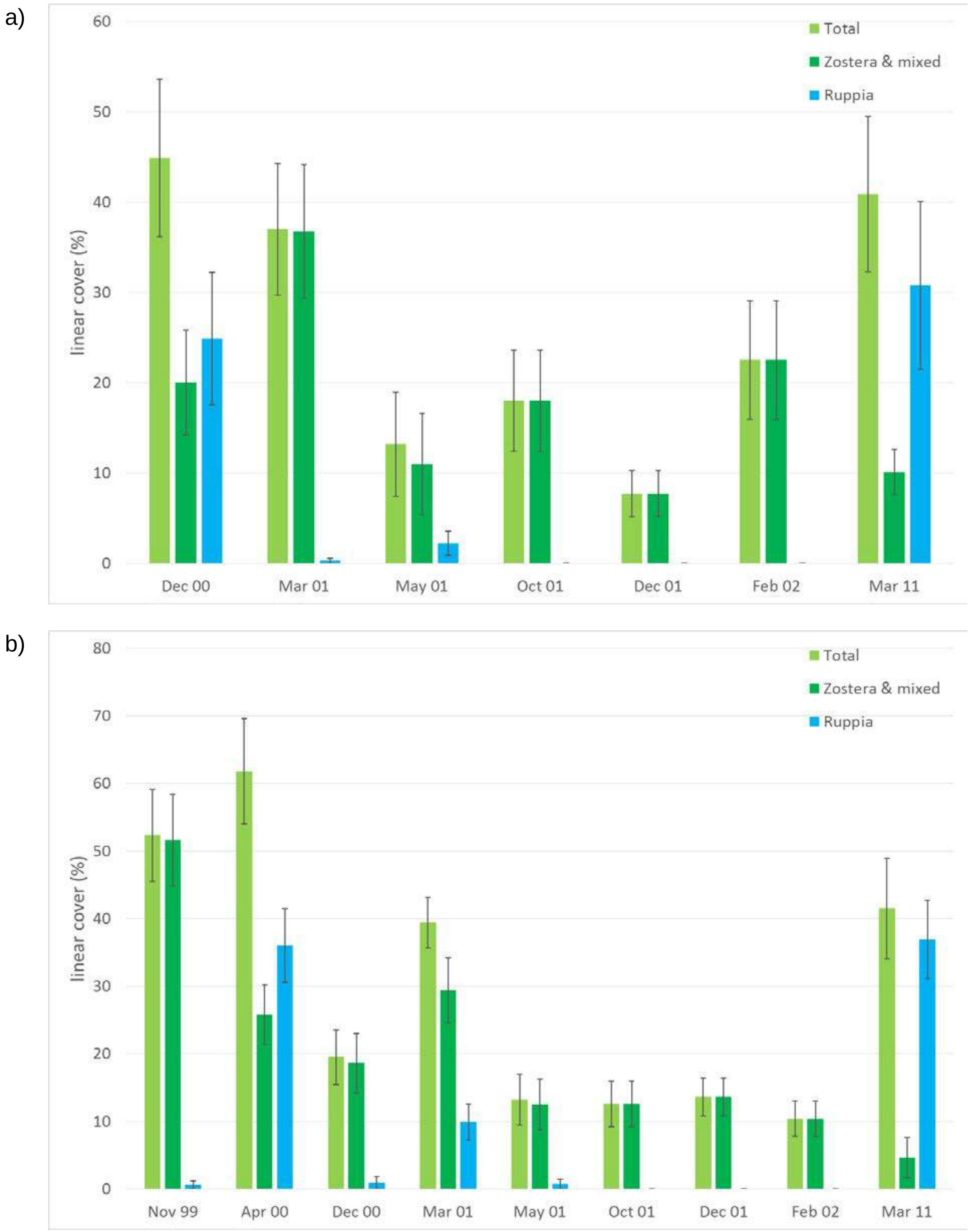


Figure 55. Mean percent cover (+/- s.e.) of seagrass across transects in a) Painkalac and b) Anglesea estuaries. Note: Anglesea records from Nov 99 to Dec 00 are derived transect data from a different mapping technique that measured edges of beds directly.

Wingan Inlet and Mallacoota Inlet were sampled on the 6th and 7th of March 2012 at geolocated ground truthing positions sampled by Blake et al. (2000) as part of a mapping program in 1999. Forty seven locations in two lagoonal sections of Mallacoota Inlet and the entirety of the known seagrass habitat in Wingan Inlet (Figure 56, Figure 57) were sampled at a similar time of year to Blake et al. (2000) (26-30 March 1999). At each location, observations were made by a snorkeler in a 10m diameter region around the spot site. Where no seagrass was found, further observations were made in the direction of areas where seagrass had been previously mapped (typically towards shallower water and the shoreline).

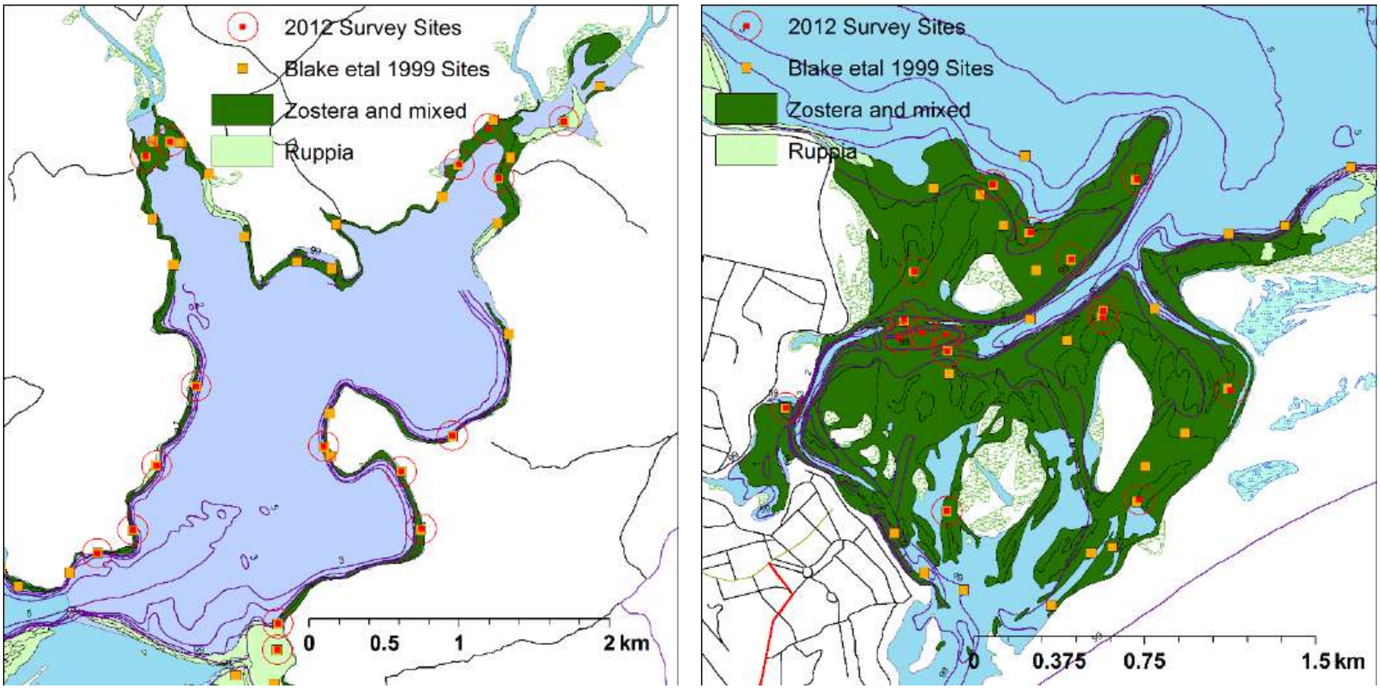

a) b)

Figure 56. Locations of ground-truthing sites from Blake et al. (1999) resampled for the IEC at Mallacoota Inlet a) Harrison Arm and b) Mallacoota Entrance Shoals. Seagrass extent as mapped in 1999.

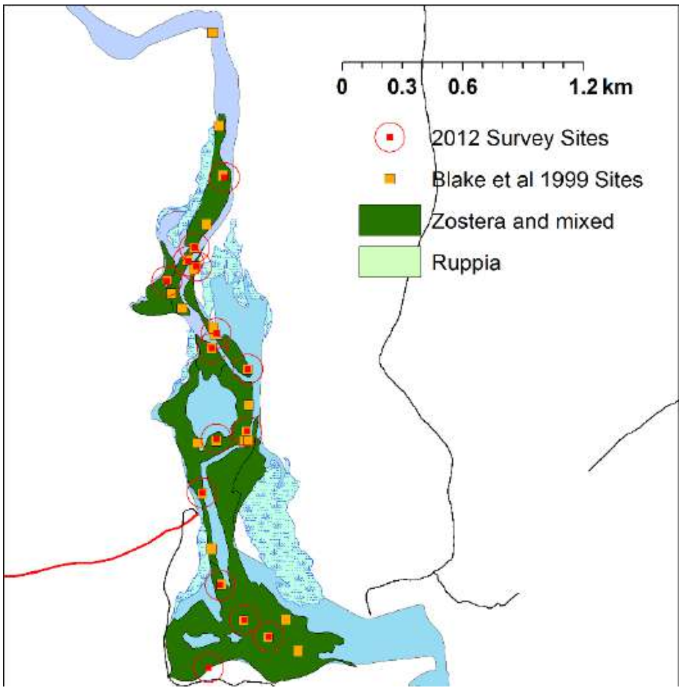


Figure 57. Locations of ground-truthing sites from Blake et al. (1999) resampled for the IEC at Wingan Inlet. Seagrass extent as mapped in 1999.

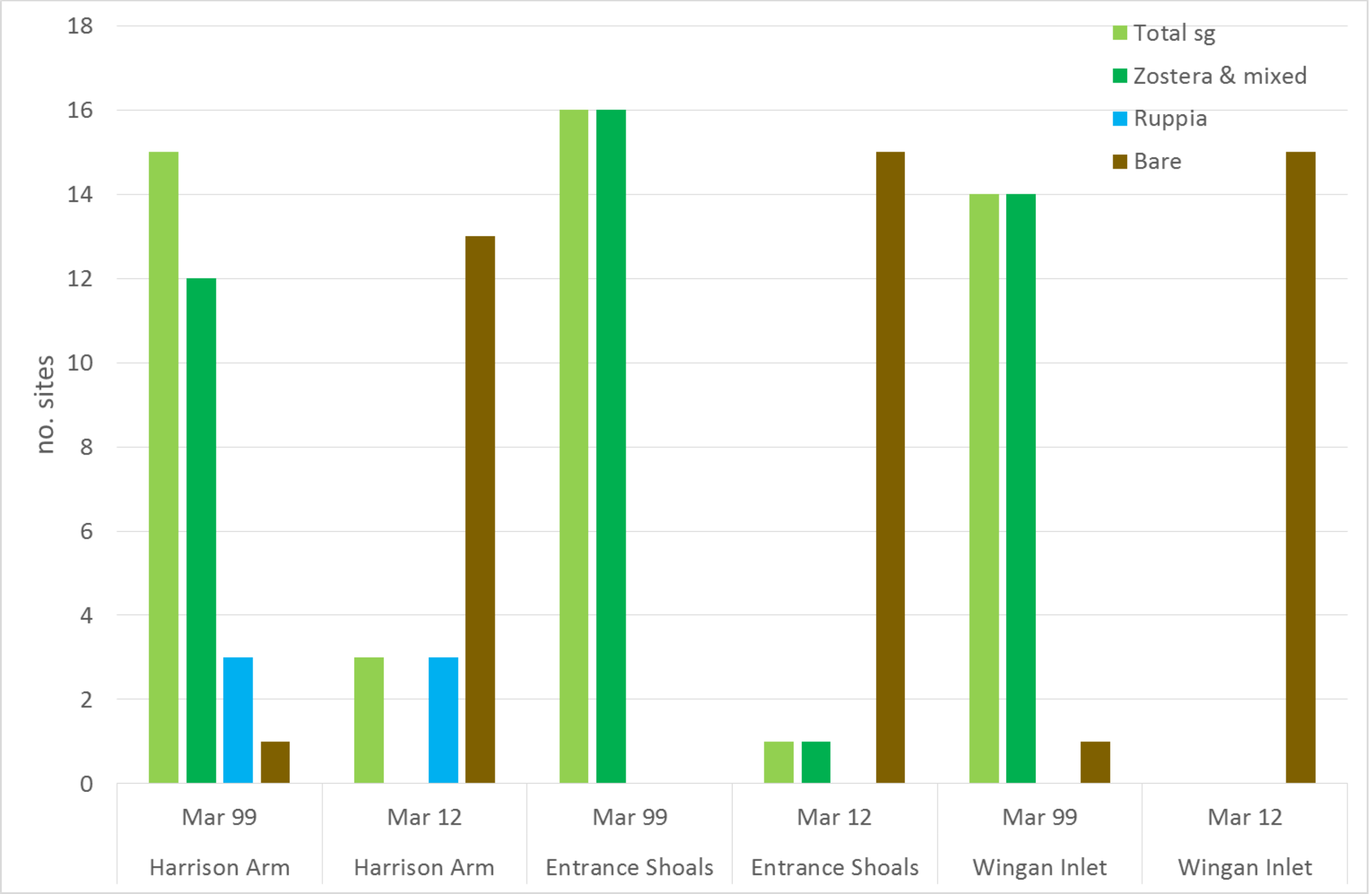


Figure 58. Seagrass presence at spot locations sampled in 1999 and 2012 at Mallacoota Inlet and Wingan Inlet.

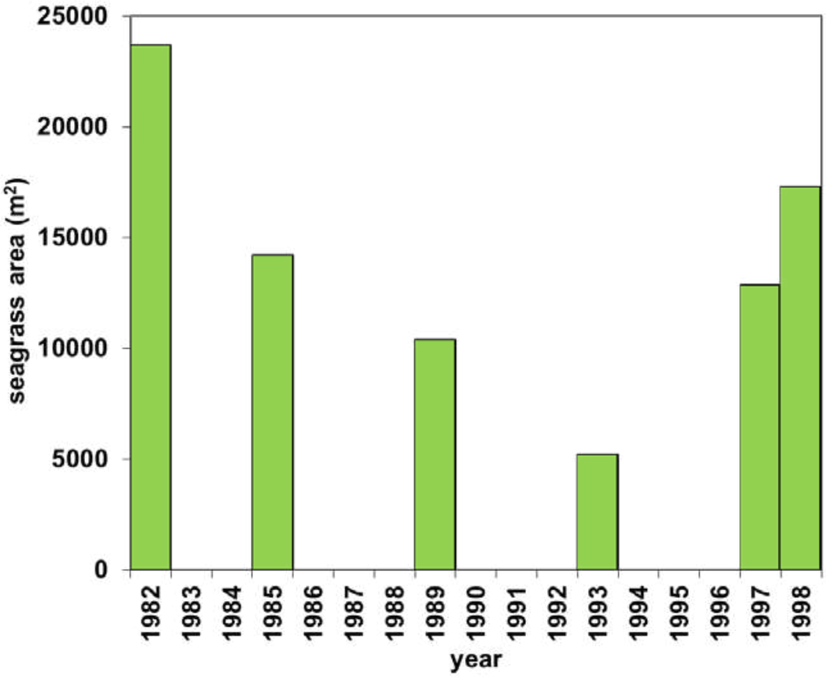


Figure 59. Seagrass area change in Anglesea River estuary from aerial photography from 1982 to 1998 (Pope 2006).

The absence of *Zostera* in the Harrison Arm and the presence of only isolated plants at one of 16 sites where dense beds previously existed suggest that there has been an extraordinarily large reduction in seagrass extent in Mallacoota Inlet despite the full extent of Blake et al. (2000)'s mapped area not having been resampled. Similar results in Wingan Inlet, and generally consistent results from an independent survey (M. Edmunds pers comm.), indicate a large reduction in seagrass extent in those estuaries and one that is most likely due to natural causes given large floods in the region in March 2011 and the minimal modification of Wingan Inlet's catchment. Further, large reductions in seagrass extent had been previously observed anecdotally following floods in 1971 with recovery observed in aerial photos of a bank in the entrance shoals taking ten to fifteen years (Blake et al. 2000). A similar pattern of decadal change was observed in Anglesea River estuary (Figure 59) by Pope (2006).

Scoring method

The scoring method for aquatic macrophytes was changed from that recommended in Arundel et al. (2009) as a result of workshops during the trial implementation. Due to uncertainties associated with natural variability and measurement accuracy, a three-level scoring method was recommended at this stage, using the combined extent of all seagrass species and densities. Thresholds recommended are shown in Table 101.

Table 101. Scoring for aquatic macrophyte extent (13a), % change in aquatic macrophyte extent and cover.

% decrease from historical	IEC Score
<20%	5
20% to 40%	3
>40%	1

Although quarterly collection of data was tentatively recommended in the IEC (Arundel et al. 2009) seasonal variability could be addressed by sampling in late summer-early autumn when macrophyte extent and density is often highest. Sampling should be done at least twice during an assessment period, due to interannual variability.

As a comparison, NSW seagrass extent scoring thresholds are: very good >10% gain, (good ≤10% gain to -10% loss, fair >- 10 to -40% loss, poor >-40 to -70% loss and very poor >-70 to -100% loss (Roper et al. 2011). Changes of between -10% and +10% in extent were interpreted as being within the order of accuracy of the methods (Roper et al. 2011).

Score confidence

Confidence in this score depends on having a reliable baseline, accounting for natural variability in extent and composition of aquatic macrophytes in a given estuary. Without sufficient knowledge of the potential extent of seagrass in an estuary, expert opinion must be relied on and while data from a few estuaries provide a gauge of potential long term variability, the transferability of these is unknown. Patterns of seasonal variability in extent are somewhat unpredictable and multiple sampling occasions in an assessment period are required. Given the large, unpredictable and short term changes in extent of *Ruppia* and *Lepilaena* confidence in scores is decreased when changes in extent have large contributions from saline aquatic meadow species.

Table 102. Score confidence criteria for aquatic macrophyte extent (13a), % change of macrophyte extent.

Confidence	Criteria
High	Seagrasses mapped multiple times previously to provide a baseline & determine locations for IEC assessment. Assessment based on at least 2 sampling times during the assessment period. Proportion of saline aquatic meadow species in total extent estimates varies < 20% between baseline & assessment estimates.
Medium	Baseline may be based on expert opinion but is guided by prior mapping. Assessment based on >1 sampling in the assessment period. Proportion of saline aquatic meadow species in total extent estimates is between 20% & 75%
Low	Baseline based on expert opinion with no prior mapping OR Assessment based on a single sampling occasion OR Proportion of saline aquatic meadow species in total extent estimates varies by more than 75%.
Unknown	Unable to establish if data exist

Scores

Based on data from this trial and the interim criteria above, interim scores for the four estuaries have been derived (Table 103). Low confidence is associated with a single sampling time but the importance of more ephemeral species in this assessment is illustrated in both Painkalac Creek and Anglesea River estuary assessments (Figure 58).

Table 103. Aquatic macrophyte extent (13a) scores for estuaries sampled in the trial implementation.

Estuary	Baseline	Score	Confidence	Notes
Painkalac Creek	March 2001	5	L	Single sampling time, large change in proportion of *Ruppia*.
Anglesea River	April 2000/ March 2001	3	L	Single sampling time, large change in proportion of *Ruppia*.
Wingan Inlet	March 1999	1	L	Baseline from single mapping. Single sampling time for assessment.
Mallacoota Inlet	March 1999	1	L	Baseline from single mapping but likely a time of high cover (Blake et al. 2000). Single sampling time for assessment.

Discussion

Despite natural variability, seagrass extent is known to be affected by anthropogenic changes to sediment and nutrient loads, flow and altered marine exchange (e.g. Figure 60*).* Scoring of this method is based on overall extent of aquatic macrophytes as a whole. A recommendation that was not included in trials here was for estimates of percentage cover to be incorporated into the scoring. An approach to this that could be included in future development of the IEC is the assessment of cover at known sites of major beds within estuaries (Blake and Ball 2001; Ball et al. 2010) using remote sensing in conjunction with spot or transect surveys in estuaries where this is possible.

Differences between the two groups of aquatic macrophyte in terms of variability in extent have been incorporated in score confidence for this measure. It is also likely that there are differences in function that relate to habitat value of each group but these differences are likely to be substantially less than those between areas with and without any aquatic macrophytes.

The baseline for this measure requires substantial knowledge of the estuary being assessed. While a baseline based on data is much preferred the approach of using expert opinion as a baseline has been successfully used in South Africa.

Future development:

- Review applicability of Woodland et al. (2015) habitat mapping with aerial photography and video field survey.
- Collect data from a wider range of estuaries and review the thresholds.
- Incorporate species composition into measure to account for changes in more/less ephemeral species.
- Incorporate estimates of percentage cover into the scoring. This could be done by the assessment of cover at known sites of major beds within estuaries using remote sensing in conjunction with spot or transect surveys in estuaries where this is possible.
- Use models incorporating bathymetry and likely light and salinity conditions to determine potential seagrass habitat to enhance baselines.

Figure 60. Exposed seagrass bed after the mouth opened in Painkalac Creek.

8.1B MACROALGAL COVER (13B1)

Aquatic macroalgal cover (13b1): recommended with further development of sampling design, methodology score thresholds and score confidence.

Macroalgae naturally occur in estuaries, however nutrient supply when combined with a range of physicochemical factors can result in excessive growth of opportunist macroalgae (e.g. Figure 61) (Giordani et al. 2009; Neto et al. 2013) such as filamentous and mat forming species *Enteromorpha* and *Cladophora* (Arundel et al. 2009). Increased growth of epiphyte plants (and periphyton) is often observed in response to increased nutrient loads entering the estuarine or marine environment (Scheltinga et al. 2004). However, decreased flow/changed hydrodynamics (increased residence times) and/or decreased turbidity (increased light penetration), (i.e. the increasing eutrophication status) may also result in a change in epiphyte growth (Scheltinga et al. 2004). Effects of algal mats on estuarine condition are summarised in Scanlan et al. (2007) as creating a hostile physicochemical environment (i.e. low oxygen and high sulphides) in underlying sediment, smothering seagrass beds, impacting on birds, particularly feeding behaviour of waders, interfering with waterway activities such as swimming and boating and causing offensive odours.

Aggregations of unattached, filamentous macroalgae, or drift-algae showed high temporal and spatial dynamics, such that variability in algal cover may be undetected in monthly assessments (Rasmussen et al. 2013). This highly dynamic nature of filamentous macroalgal aggregations in seagrass beds should be considered when evaluating implications of macroalgal blooms for seagrass growth and survival (Rasmussen et al. 2013). A frequent relocation of drift-algae at small spatial scale may moderate the formation of poor oxygen conditions within mats and shorten the duration of exposure experienced by individual shoots (Rasmussen et al. 2013).

In many estuaries, large beds of macroalgae can form and it is likely that some knowledge of the extent and productivity of these beds will be required to interpret data for both microphytobenthos (15) and phytoplankton (16).

This method is based on the percent cover of macroalgae.

Aquatic macroalgal cover (13b1) = % cover (summer)

Baseline = current state-wide data (best available)

Depending on the available data it is likely that the baseline for this measure will be based on levels of cover seen in estuaries with least human impact. Historical, pre-European settlement data are not available so the baseline cannot be historical.

Data used

Existing data on macroalgal cover in Victorian estuaries are limited, with the most comprehensive data to date described in Ball and Blake (2009b) and more data has recently become available from a Monash University research project (Woodland et al. 2015). Sampling protocol is still to be determined and will depend on available resources. Temporal and spatial variability of macroalgae mean that the protocol may need to be more intensive than that proposed for aquatic macrophytes. This measure will probably involve remote sensing (such as aerial photography or multispectral scanning) in addition to field assessment requiring diving, video survey and taxonomic expertise. Collection of data quantifying percent cover in at least four years of an IEC reporting period is tentatively recommended. Immediate implementation of this measure will be hard to achieve because of the high skill level required, method development needed and amount of data collection required due to lack of existing data.

Scoring method

Either end of the scoring range has been suggested as poor is >50% macroalgal cover and good <15%. A review by Scanlan et al. (2007) includes a decision table which combines algal biomass and percentage cover to assign quality status levels of 1 to 5 (Arundel et al. 2009). This scoring method was refined by Patricio et al. (2007) for a 1 to 4 score when biomass data is not available. They also examined how scores differed if data were collected during different sampling periods. Data from estuaries state-wide are required to confirm the description for good and poor and assign intermediate scores (Arundel et al. 2009).

Table 104. Scoring for aquatic macroalgal cover (13b1).

% cover (summer)	IEC Score
<5%	5
5–15%	4
15–25%	3
25–50%	2
>50%	1

Score confidence

Table 105. Score confidence criteria for aquatic macroalgal % cover (13b1).

Confidence	Criteria
High	*To be developed in conjunction with monitoring/reporting system*
Medium	*To be developed in conjunction with monitoring/reporting system*
Low	*To be developed in conjunction with monitoring/reporting system*
Unknown	Unable to establish if data exist

Scores

No scores were generated for this measure for individual estuaries.

Discussion

The scoring thresholds and measurement frequency for this measure are tentative because of the lack of data on macrophytes cover in Victorian estuaries, to be able assess its spatial and temporal variability. A recently completed ARC linkage project (Woodland et al. 2015) has surveyed macroalgal cover in 14 estuaries across the state and this data should be considered in the further development of this method.

Future development:

- Review applicability of Woodland et al. (2015) habitat mapping with aerial photography and video field survey.
- Sample macroalgal cover in Victorian estuaries for the refinement of the scoring thresholds, score confidence and measurement frequency.
- Sample macroalgal cover in Victorian estuaries to assess spatial and temporal variability.

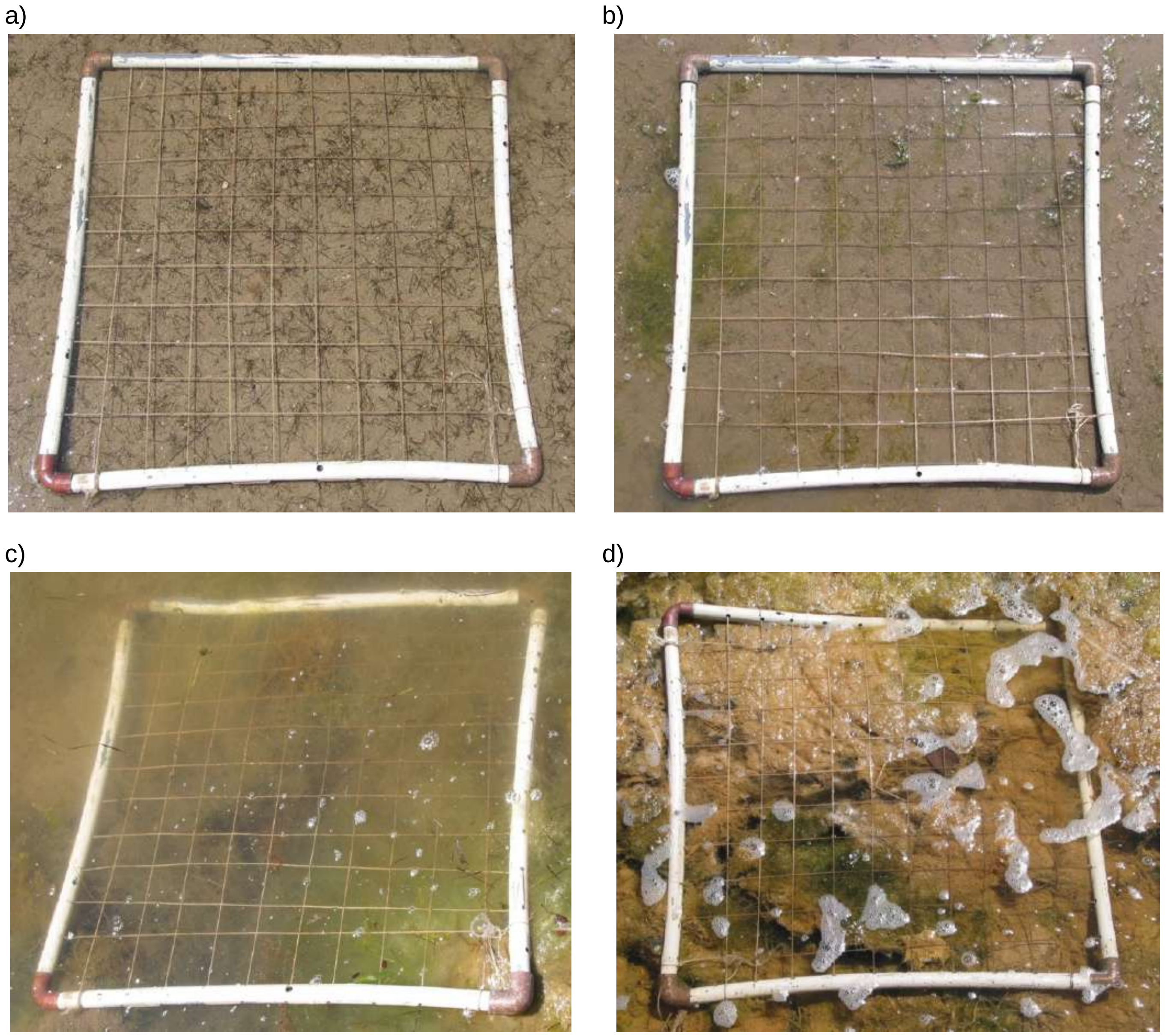


Figure 61. Macroalgal cover from a) none, b) minimal, c) extensive and d) extreme (Barton 2006).

8.1C Number of macroalgal blooms (13b2)

Aquatic macroalgal blooms (13b2): recommended with further development of sampling design, methodology, score thresholds and score confidence.

Documenting macroalgal blooms requires regular observations and monthly monitoring is recommended. Concentration of observations during the warmer months should be considered. This measure could be developed so that it is suitable for community monitoring through EstuaryWatch (Iervasi et al. 2012).

Aquatic macroalgal blooms (13b2) = # of % estuary with excessive macroalgal growth (blooms)

Baseline = current state-wide data (best available)

As no comparable data exist for this measure, the baseline must use a reference method and so can be described as being based on best available data.

Data used

There has been no systematic reporting of macroalgal blooms in Victorian estuaries except in Gippsland Lakes. Immediate implementation of this measure was thought to be hard to achieve as the sampling protocol needs to be developed (Arundel et al. 2009).

Scoring method

This was extended and refined in the development of AVIRA which recommended scoring based on the % of estuary with excessive instream plant growth with very poor >25% of the estuary area and very good<1%.

Table 106. Scoring for aquatic macroalgal blooms (13b2).

% estuary with excessive macroalgal growth	IEC Score
<1%	5
1-25%	3
>25%	1

Score confidence

Table 107. Score confidence criteria for aquatic macroalgal blooms (13b2).

Confidence	Criteria
High	*To be developed in conjunction with monitoring/reporting system*
Medium	*To be developed in conjunction with monitoring/reporting system*
Low	*To be developed in conjunction with monitoring/reporting system*
Unknown	Unable to establish if data exist

Discussion

Future development:

- Monitor and report aquatic macroalgal blooms in Victorian estuaries, potentially by developing methods to be incorporated with the EstuaryWatch and other regular water quality monitoring programs.
- Use monitoring data to refine scoring thresholds and measurement frequency, spatial and temporal variability of blooms and to develop score confidence criteria.

Figure 62. Mangrove shrubland in Tarra River estuary 2010.

8.2 FRINGING MACROPHYTES (EXTENT AND CONDITION) (14)

Fringing macrophytes (14): recommended with further development of score confidence

Vegetation around the fringe of the estuary, such as mangroves (Figure 62), scrub, saltmarsh, wetlands and reedbeds (Figure 63), provides important habitat for invertebrates, bats, reptiles, birds and fish (EEMSS 2006; Victorian Saltmarsh Study 2011; Whitfield et al. 2012; Saintilan and Rogers 2013). These vegetated areas can be highly productive habitats, a rich source of nutrients and organic matter, and provide important larval habitat for many fish species (Victorian Saltmarsh Study 2011). In addition to their habitat values they provide stormwater control and natural bank stabilisation, trap sediment, and reduce lateral erosion and littoral water velocity during river flooding (Adams and Riddin 2007; Whitfield et al. 2012).

There are thirteen or so fringing macrophyte Ecological Vegetation Classes with connectivity to estuaries (EEMSS 2006; Victorian Saltmarsh Study 2011; Sinclair and Boon 2012). Some, like Coastal saltmarsh (EVC 9), can be wide spread along the Victorian coast (EEMSS 2006; Victorian Saltmarsh Study 2011). Others can have very restricted distribution, like the Seasonally inundated sub-saline herbland (EVC 196) in Salt Swamp in Barwon Estuary, Point Lonsdale or Littoral and Warm temperate rainforests (EVC 32) which are restricted to East Gippsland (EEMSS 2006). Coastal saltmarsh (EVC 9) consists of primarily low shrubby to herbaceous or grassy vegetation of salinized coastal soils and occurs along the entire Victorian coast. It has been proposed that this aggregate of coastal saltmarsh types be divided into six new EVCs: Wet saltmarsh herbland; Wet saltmarsh shrubland; Coastal saline grassland; Coastal dry saltmarsh; Coastal hypersaline saltmarsh; Coastal tussock saltmarsh; and Saltmarsh-grass swamp (Victorian Saltmarsh Study 2011). These divisions would better identify the topography, hydrology and resultant vegetation communities for conservation and management purposes (Victorian Saltmarsh Study 2011).

Estuarine wetland (EVC 10) consists of moderate height (<1 m) rush/sedge wetland vegetation, with a component of small halophytic herbs on estuarine flats, it is scattered along the Victorian coast and is extensive in association with larger estuarine floodplains. Brackish herbland (EVC 538) consists of low herbland (<0.15 m) dominated by species tolerant of mildly saline conditions and intermittent inundation. Scattered in restricted habitat, it often occurs in mosaic or complex with other wetland components. Estuarine reedbed (EVC 952) is dominated by tall reeds (2 – 3 m) in association with a sparse ground-layer of salt tolerant herbs, excluding samphires. It is subject to surface salinity as well as flushing by freshwater (including via groundwater), but is beyond direct inundation from normal tidal inputs and is known from the Otways and East Gippsland. Brackish sedgeland (EVC 13) is dominated by salt-tolerant sedges (<1.5 m tall) with a low grassy/herbaceous ground-layer, a halophytic component, and is found scattered in near-coastal areas. Estuarine flats grasslands (EVC 914) are tussock grasslands (<1 m) of coastal flats, beyond the zone of normal tidal inundation. Brackish grassland (<1 m) (EVC 934) includes limited component of tussock grasses and forbs of Plains grassland in association with halophytic species such as *Distichlis distichophylla* and some forb species shared with Brackish herbland (EVC 538). Most Brackish herbland communities are critically endangered, and remnants are few and generally highly modified (Victorian Saltmarsh Study 2011).

Swamp scrub (EVC 53) and Estuarine scrub (EVC 953) were once both widely distributed in association with lower reaches of watercourses throughout Victoria and have been greatly cleared for agriculture. They both consist of Myrtaceous shrub species (2–4 m), *Melaleuca ericifolia* in eastern Victoria and *Leptospermum lanigerum* in western Victoria, with different ground-layers. Swamp scrub is essentially a freshwater habitat, often on the outer verges of Estuarine scrub and further upstream with freshwater inputs from the creek and from groundwater. Estuarine scrub occurs where groundwater is fresh but saline surface inputs maintain a halophytic ground-layer. Mangrove shrubland (EVC 140) is found along the Victorian coast from Barwon River east to NSW. It characteristically occurs as open to closed scrub on the tidal Mud-flats (EVC 990) of the lower inter-tidal zone of sheltered embayments as mono-specific stands of *Avicennia marina*. In some stands, species from adjacent Coastal saltmarsh (EVC 9) or Sea-grass meadow (EVC 845) can also be present. It can also extend inland as narrow bands along tidal creeks and river estuaries (Victorian Saltmarsh Study 2011).

Major threats to these vegetation communities are land-clearing and invasion by weeds, and some like the Brackish grassland (EVC 934) are highly endangered (EEMSS 2006; Sinclair and Boon 2012). Some EVCs (Coastal saltmarsh, Estuarine wetland, Brackish herbland and Swamp scrub) are particularly vulnerable to changed hydrological regimes including prolonged inundation or decreased freshwater (EEMSS 2006). Macrophytes have specific requirements/tolerances regarding the length of time they are inundated, period since they were last inundated and the salinity of the overlying water (EEMSS 2006; Whitfield et al. 2012). They are therefore likely to be impacted by both altering flow to the estuary (6) and activities or structures that change either the entrance opening regime (5) or inundation of the riparian area (Turpie et al. 2012; Ribeiro et al. 2013). The implication for management of fringing macrophytes within intermittent-open estuaries therefore relates especially to how long these plants can survive prolonged mouth closure with a high water level and high or low salinity (Turpie et al. 2012; Whitfield et al. 2012). Physical disturbance by stock or recreation activities are major threat to Coastal saltmarsh, Estuarine reedbed, Estuarine flats grasslands, Brackish grassland and Mangrove shrubland (EEMSS 2006; Sinclair and Boon 2012).

Development pressure around estuaries often results in physical destruction of macrophyte beds by trampling and/or construction of infrastructure (4). Also, decreased water quality has been identified as a major threat to Coastal saltmarsh, Estuarine reedbed and Mangrove shrubland (EEMSS 2006).

Specifications and techniques for remote sensing mapping of the condition of the streamside zone using LiDAR has been developed for the Index of Stream Condition (Johansen et al. 2011). As such it is capable of deriving a whole of reach assessment of the condition of the streamside zone. Unfortunately this study was not completed until well into the implementation trial. Transfer and modification of these techniques to estuaries had not yet been undertaken. Remote sensing methods for vegetation condition assessment is still being developed in NSW (Roper et al. 2011).

This measure considers the extent and condition of fringing macrophytes, including mangroves. The measure for assessing fringing macrophytes uses the detailed mapping of the Victorian Saltmarsh Study (Victorian Saltmarsh Study 2011; Sinclair and Boon 2012). The study assessed the distribution, condition, threats and management of fringing macrophytes in Victoria (Victorian Saltmarsh Study 2011; Sinclair and Boon 2012). It provides an overview of the current ecological condition of fringing macrophytes, suitable for regional planning and investment processes. The fringing macrophyte measure would be remapped once every eight years in the IEC reporting period.

Figure 63. Fringing macrophytes in Aire River estuary.

Fringing macrophytes (14) = extent and condition

Baseline type= natural/pristine condition (Pre-European)

The Victorian Saltmarsh Study (2011) collated and assessed early European settlement documents and maps to establish Pre-European fringing wetland extent.

Data used

The fringing macrophyte extent and condition measure relies on the methods and mapping from the Victorian Saltmarsh Study (2011). The results were presented in 30 bio-regionalised sections of coast, but mapping for individual estuaries can be derived from the GIS layers (Figure 64). Mapping (1:5,000) was from direct observation (70%) and aerial photos (Victorian Saltmarsh Study 2011; Sinclair and Boon 2012). The mapping included coastal saltmarsh (EVC 9) aggregate which incorporated six proposed and more specific coastal saltmarsh EVCs, and five other coastal fringing macrophyte EVC's. The other coastal EVC's were: Estuarine wetland (EVC 10); Seasonally inundated sub-saline herbland (EVC 196); Estuarine reedbed (952); Estuarine scrub (EVC 953); and Mangrove shrubland (EVC 140). Co-occurring, more dry-land specific, coastal vegetation (EVCs 3, 48, 160, 311, 858, 914, & 953) was also mapped (Victorian Saltmarsh Study 2011). To make comparisons with pre-European extent the mapping is aggregated to coastal marsh which consists predominately of coastal saltmarsh and estuarine wetland (Sinclair and Boon 2012).

Mapping of fringing vegetation has also been undertaken at 1:50,000 scale for seven estuaries in the Glenelg Hopkins CMA (Sinclair and Sutter 2008b), eight estuaries in the Corangamite CMA (Osler et al. 2010)

Scoring method

Scoring is based on extent and condition of the fringing macrophytes as coastal marsh, which is coastal saltmarsh combined with other fringing macrophytes (usually estuarine wetland) and mangrove shrubland. Extent is the percent change from historical (pre-European) distribution with a score of 1 as largely no remaining fringing macrophytes. A score of 5 is no change in extent or condition and no structures or activities present likely to affect extent or condition.

Table 108. Scoring for fringing macrophytes, extent and condition.

Fringing macrophytes extent and condition	IEC Score
Intact, no discernible impacts	5
Detrimental impact discernible with close inspection or measurement but essentially intact. Impact in relatively small, localised places, < ~5% of original area	4
Visibly structurally modified and of reduced biological diversity. Impact in relatively small, localised places (~5% of original area)	3
Visibly structurally modified and of reduced biological diversity. Impact affecting > 5% of original area	2
Largely destroyed or lost, massive visual and ecological impact	1

NSW scored saltmarsh extent as very good >10% gain, (good ≤10% gain to -10% loss, fair >- 10 to -40% loss, poor >-40 to -70% loss and very poor >-70 to -100% loss (Roper et al. 2011). Mangrove extent was scored as good if stable, and the need for further work to determine if positive or negative changes and the size of those changes were good or bad ecologically in estuaries (Roper et al. 2011). Changes of between -10% and +10% in extent for both macrophyte habitats were interpreted as being within the order of accuracy of the methods (Roper et al. 2011).

Score confidence

Table 109. Score confidence criteria for fringing macrophytes, extent and condition.

Confidence	Criteria
High	*To be developed when scores for more estuaries are derived*
Medium	*To be developed when scores for more estuaries are derived*
Low	*To be developed when scores for more estuaries are derived*
Unknown	Unable to establish if data exist

Scores

Only one estuary, Anderson Inlet, was scored as a demonstration of the method. Current vegetation included thirteen distinct vegetation types (Figure 64). Pre-settlement vegetation extent was mapped as either Mangrove Shrubland or Saltmarsh and/or Estuarine Wetland (Figure 64). The hectares of coastal marsh lost since settlement was estimated at 660 ha, or 45% of the original areal extent. The majority of this loss was in Saltmarsh and Estuarine Wetland, with the Mangrove Shrubland not having measurably changed. The overall loss of 45% extent of fringing macrophytes is nine times the threshold for a score of 1 (very poor) for Anderson Inlet. Condition assessment showed Anderson Inlet had widespread land-reclamation and *Spartina* invasion, high localised landfill and spoil (Victorian Saltmarsh Study 2011). It also had low widespread over development, and low localised stormwater, vehicle access, stock grazing, weed invasion, inappropriate rehabilitation, inappropriate recreation and boat wash. The condition was also compromised by artificial and land-use landward barriers (Victorian Saltmarsh Study 2011).

Discussion

The Victorian Saltmarsh Study (2011) also devised a detailed condition-assessment method suitable for application by land managers and planners, which was able to detect finer-scale patterns of ecological condition in line with other vegetation condition measures (Victorian Saltmarsh Study 2011). They considered their approach simpler than that taken by IWC or Habitat Hectares. It assessed cover of different groups of plants, according to their critical life form groups (i.e. medium to small succulent herbs in Wet saltmarsh herbland), was assessed against 1750 mapping to get % change. The cover of each critical life-form grouping; cover of structural dominants that are healthy; proportional cover of weeds; absolute cover of weeds; cover of vehicle tracks; cover severely affected by introduced herbivores; and cover noticeably but not severely affected by introduced herbivores was assessed. Scoring was generally not recommended for late summer and autumn when weeds may not be apparent. The Victorian Saltmarsh Study (2011) developed assessment and benchmark sheets for its condition evaluation. When deciding whether the life-form groups meet the benchmark criteria, the threshold is that shown on the benchmark scoring sheet. Weed cover was considered to be one of the most reliable and useful indicators of vegetation condition, particularly as saltmarsh has only a handful of weed species (Victorian Saltmarsh Study 2011). Weed cover should be assessed as a possible addition the current fringing vegetation extent and condition measure, but be assessed in spring or early summer. The Victorian Saltmarsh Study (2011) classified weed cover into six categories from substantially absent, then in 20% bands until >80%.

The Victorian Saltmarsh Study (2011) is an intensive mapping method. It should be investigated if future assessment of the extent and condition of fringing macrophytes can be done at a coarser but still meaningful scale from remote sensing methods with targeted ground truthing. LiDAR mapping has been investigated for stream vegetation mapping and it should be assessed for estuary fringing vegetation. Photos of banks from the implementation trial bank erosion measure may assist in validating LiDAR fringing vegetation condition assessments. Future mapping or aerial photo validation could be done with a small remote controlled drone with a camera.

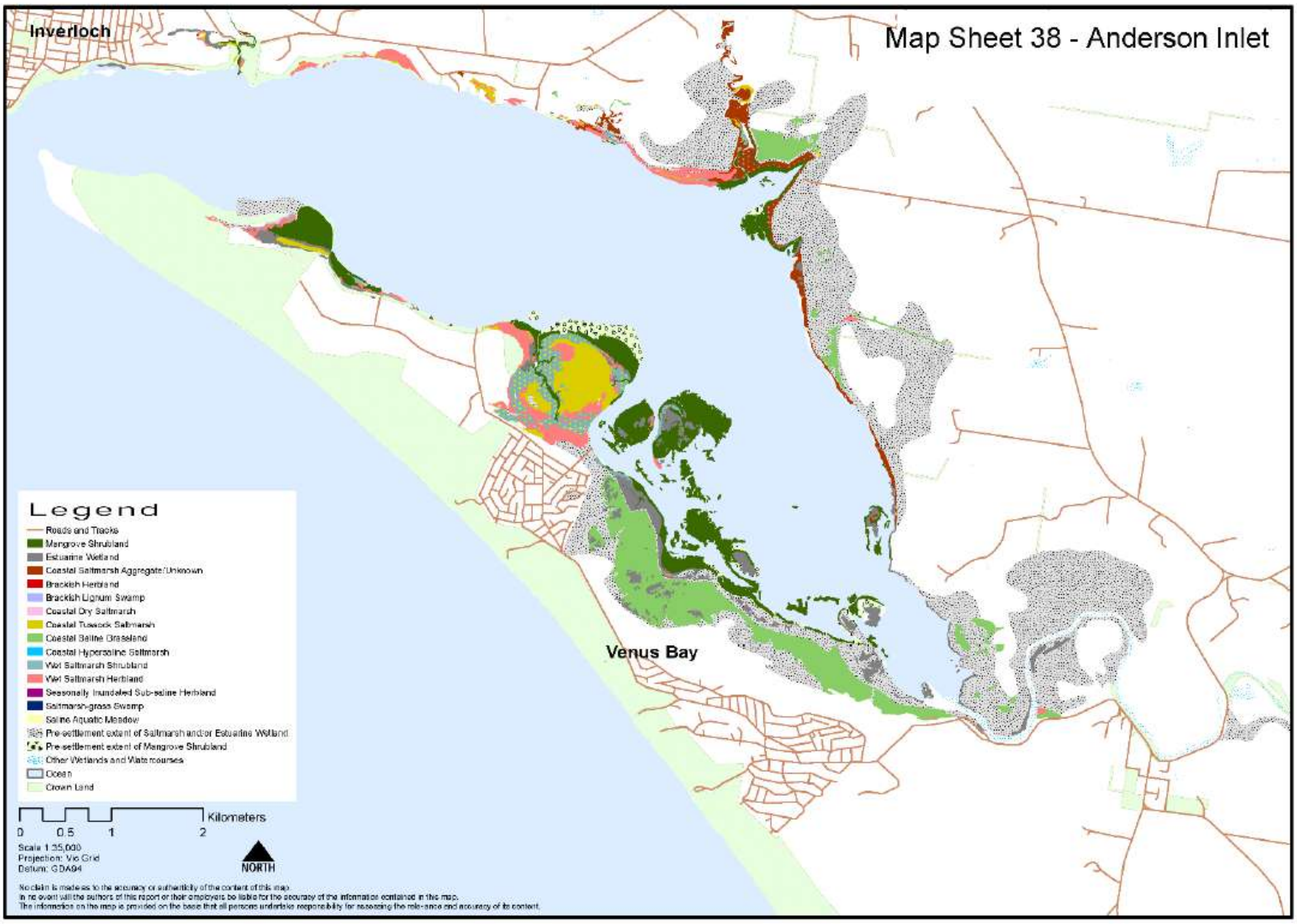


Figure 64. Coastal marsh mapping of Anderson Inlet, current vegetation and pre-settlement extent (in stipple) (Victorian Saltmarsh Study 2011).

Future development:

- Review the coastal wetlands included in the Index of Wetland condition to ensure that they are not within the estuary, as defined by the estuary head (GIS layer).
- Assess remote sensing such as LiDAR mapping at a coarser scale.
- Assess using a small remote controlled drone with a camera for field validation.
- Score confidence criteria need to be developed when scores for more estuaries are derived.
- Review Victorian Saltmarsh Study (2011) measure of extent and condition to maximise applicability on a broad scale.

8.3 MICROPHYTOBENTHOS (15)

Microphytobenthos biomass (15): not recommended, needs substantially more development

Microphytobenthos refers to the photosynthetic unicellular organisms associated with estuarine sediments including what can look like bare sediment to the naked eye (EVC 990) (Figure 65). These organisms are important for oxygen production at the sediment surface thereby directly and indirectly influencing nutrient cycling (Potts et al. 2009). They are important in taking up nutrients fluxing from the sediment that would otherwise go to the water column (Brito et al. 2012b). They also stabilise sediments and are an integral component of food webs (Whitfield et al. 2012). Microphytobenthos can play a key role in interactions between the sediment and the water column, and as such be important in determining the ecological health of shallow estuaries with good light penetration to the sediment (Potts et al. 2009; Roper et al. 2011; Brito et al. 2012b).

Microphytobenthos can represent the majority of microalgal chlorophyll *a* in shallow estuaries (Brito et al. 2012b; Whitfield et al. 2012). Due their high proportion in relation to pelagic microalgae, their influence in the water column due to resuspension due to winds and tides can be large (Brito et al. 2012a; Brito et al. 2012b; Hall et al. 2013). Shallow coastal lagoons, especially the ones with clear waters and well lit substrata, are likely to have large microphytobenthos biomass (Brito et al. 2012a; Brito et al. 2012b; Hall et al. 2013). Poor light penetration may occur naturally in intermittent estuaries that are supplied by humic-stained streams or rivers confining microphytobenthos to the shallow littoral areas (Whitfield et al. 2012). With mild eutrophication microphytobenthos biomass is likely to increase until it is shaded out and decreases by increasing phytoplankton or high turbidity (Lukatelich and McComb 1986).

When an estuary mouth closes after a flooding event, benthic microalgal populations recover and begin to build up over a period of weeks to months (Perissinotto et al. 2002). Some intermittent estuaries have high microphytobenthos biomass even when the mouth is open (Whitfield et al. 2012). However, the wet-sediment surface area available to these algae during this phase remains limited because of the reduced and fluctuating water level within the estuary (Whitfield et al. 2012). For this reason, if an estuary opens more frequently than natural as a result of manipulations of water inflow or dredging of the mouth, the benthic microalgae may not reach their optimum densities and high levels of diversity (Whitfield et al. 2012).

Observed increases in the biomass of microphytobenthos in individual waterbodies may be related to increased nutrient concentrations, decreased flow/changed hydrodynamics and/or decreased turbidity (Scheltinga et al. 2004). The microphytobenthos measure was recommended as the biomass of the live photosynthesising microphytobenthos determined with surface sediment chlorophyll *a* concentrations (Arundel et al. 2009). Phaeophytin *a* biomass was also recommended, as Barton (2006) found a significant relationship between the biomass of this degradation pigment and land use intensity for the functional group of east-facing estuaries. The immediate implementation of this measure was considered hard to achieve as the majority of the data to enable baselines and scores to be developed had to be derived (Arundel et al. 2009).

A high level of skill is required for the collection of this measure in the field, and analysis in the laboratory, although the latter can be outsourced to commercial laboratories (Arundel et al. 2009). For the implementation trial, microphytobenthos samples were taken in the upper, middle and lower zone of each estuary or subestuary during summer fieldwork over three years (Appendix 5). Sampling required wading or snorkelling and many sites required boats for access. Thirty-seven estuaries were sampled but not all zones or subestuaries were able to be sampled in each estuary (Appendix 11). In addition, microphytobenthos samples were also collected monthly from November to February 2011 as part of the incubated core study in lower zone of four Great Ocean Road estuaries (St George, Wye and Painkalac Rivers, and Spring Creek).

Five replicate microphytobenthos sediment cores, 1-cm deep, were haphazardly collected with a modified 60-mL syringe (30-mm diameter, 7.07-cm^2 area) from the submerged flats immediately adjacent to the main channel in a 10 x 2 m area (Light and Beardall 1998; McKenzie et al. 2011). Samples were kept on ice and frozen as soon as possible. Pigment extraction occurred within one month of sample collection. Chlorophyll *a* was extracted using acetone, following the method of Light and Beardall (1998). Technical details followed USEPA Method 446.0 (Arar 1997) for determining chlorophyll *a* by visible spectrophotometry.

Large variation in the phaeophytin *a* concentrations from the Victorian wide field sampling indicated interference from other substances (other phytopigments, humics etc) in the sediment and so phaeophytin *a* concentrations were not included in the assessment of the microphytobenthos measure. Caution was also taken in the interpretation of the spectrophotometric chlorophyll *a* concentrations as they could be overestimated (10%) due to this extraction interference (Lukatelich and McComb 1986).

Discussion

Microphytobenthos biomass in estuaries has been investigated by many but it has not been incorporated into an index of condition as far as literature searches could establish. It was thought with the early stage of development of this measure the baseline and subsequent scoring would be based on the analysis of the available data and expert opinion.

Figure 65. Surface of a sediment core showing the green colouration indicative of high microphytobenthos biomass.

The chlorophyll *a* concentrations measured as part of the implementation trial ranged from below detection (<1 mg/m^2) to a maximum of 403 mg/m^2 (mean 48, median 30 mg/m^2). The maximum chlorophyll *a* value was in LaTrobe Creek a subestuary of Gellibrand River where the range was from 80 to 403 mg/m^2. Other estuaries with chlorophyll *a* above 200 mg/m^2 were the lower Nicholson River a subestuary of the Mitchell/Nicholson River estuary complex (range 134 to 216 mg/m^2), Swan Lake subestuary of Sydenham Inlet (range 72 to 264 mg/m^2), Brodribb River subestuary of Snowy River (range 65 to 249 mg/m^2) and Lake Craven subestuary of Aire River (range 38 to 205 mg/m^2).

The implementation trial maximum was higher than that (~250 mg/m^2) found in the shallow subtidal sediments in off Werribee in Port Phillip Bay (Light and Beardall 1998). It was also considerably higher than that measured in subtidal sediment in small NSW estuary lagoons around Wollongong, which ranged from 6.4 to 49.2 mg/m^2 (Potts et al. 2009). The implementation trial maxima was more similar to Peel-Harvey estuary in Western Australia (range 45 to 391 mg/m^2) and that in Mpenjati Estuary (616 mg/m^2), on the Kwazulu-Natal south coast, South Africa (Perissinotto et al. 2002).

The monthly sampling of the lower zone of four estuaries as part of the incubated core trial did not have phaeophytin *a* interference problems, probably due the sandy nature of the sediments. The total sediment chlorophyll concentration (chlorophyll *a* + phaeophytin *a*) increased across an increasing land use intensity and population density gradient (Figure 66). The variability around this biomass estimate also increased across this gradient (Figure 67). These results looked promising for developed a scoring system for microphytobenthos as a measure for IEC.

All the chlorophyll *a* data collected across Victoria, including the four incubated core estuaries, were extensively plotted and examined. There were no obvious breaks or slope changes that indicated different scores. There was some suggestion of higher biomass with possible mild eutrophication (Figure 67) as would have been expected. However, many estuaries had low biomass with medium land use intensity (1 to 200, Figure 67a), and across all population densities (Figure 67b). There was no obvious relationship with phytoplankton biomass from the same sites.

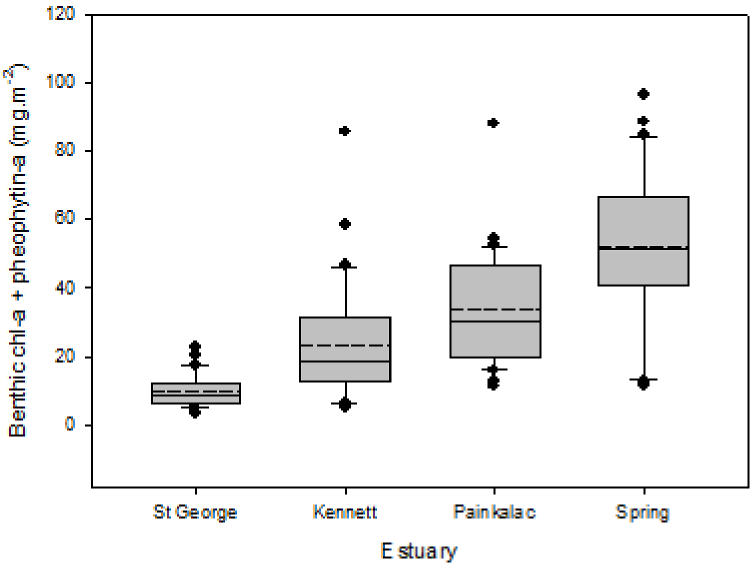


Figure 66. Total benthic chlorophyll, combined chlorophyll *a* and phaeophytin *a* from four estuaries in the CCCMA region sampled over the summer of 20102/2011 as part of the incubated core trial. There is an increase in land use intensity and population density from St George River to Spring Creek estuaries.

These results and some other preliminary investigations of the data indicated that a lot more work is required before microphytobenthos biomass, as assessed with chlorophyll *a* and/or phaeophytin *a,* can be used as a measure for the IEC. The lack of established monitoring or scoring protocols, and problems differentiating natural changes in microphytobenthos biomass from anthropogenic induced change make their inclusion in the IEC at this stage difficult. A more detailed analysis of all the collected benthic chlorophyll *a* data in relation to other driving factors such as water depth, water clarity and colour, sediment redox, organic matter and grain size, and estuary characteristics and type is needed. Further work is needed determine which pigments or combinations of pigments best differentiate estuary condition, and how to best deal with measurement interference from other pigments or compounds.

Microphytobenthos on intertidal sand and mud flats has been found to be very heterogeneous due to small and large scale spatial and temporal gradients (Spilmont et al. 2011; Tirok and Scharler 2013). The small scale variability of microphytobenthos driven by temperature can be nearly twice as high in summer and autumn compared to winter (Zetsche et al. 2012). The large spatial variability has been shown to influence the measurement of both microphytobenthos biomass and production of up to 40% (Spilmont et al. 2011). It is thought this issue can be circumvented using field spectrometry or PAM fluorescence measurements coupled with traditional sediment sampling techniques, and the establishment of unified protocols for the routine use of these combined methods (Spilmont et al. 2011).

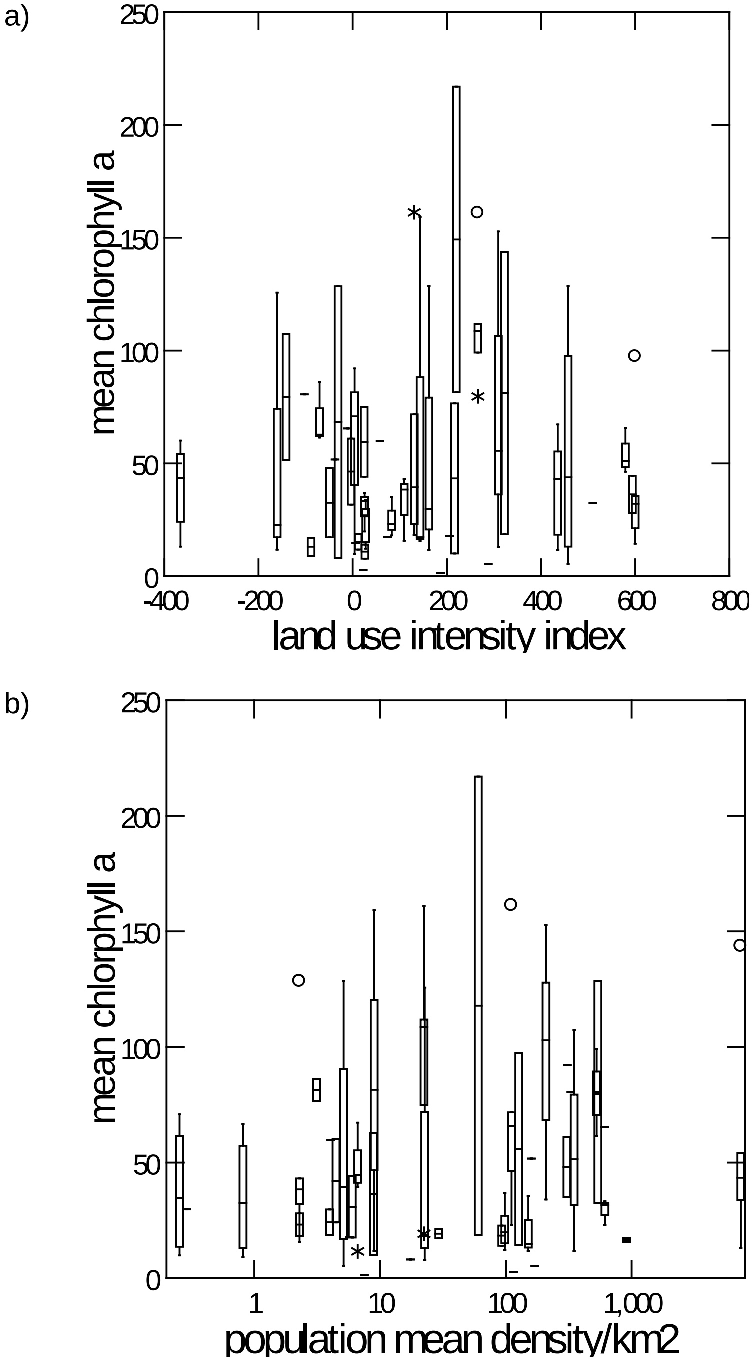


Figure 67. Box plots of the mean microphytobenthos from forty-one estuaries across Victoria against a) land use intensity and b) population density (log scale) from Barton et al. (2008).

Future development:

- Detailed analysis of all collected benthic chlorophyll *a* data in relation to other driving factors such as water depth, water clarity and colour, sediment redox, organic matter and grain size, and estuary characteristics and type.
- Determine which pigments or combinations of pigments best differentiate estuary condition.
- Determine how to best deal with measurement interference from other pigments or compounds.

8.4 PHYTOPLANKTON (16)

Phytoplankton biomass (16): recommended

The phytoplankton (plant plankton), which includes cyanobacteria and photosynthetic protists, use light energy and simple chemicals in the water to grow and multiply (Turner et al. 2004). Phytoplankton is an important component of aquatic food webs (Tirok and Scharler 2013). However, excessive growth often in response to high nutrient levels, coupled with physical factors such as increased temperature and light, and reduced flow (6) or decreased flushing rates, can have a negative effect on estuarine condition (e.g. Figure 68) (Roper et al. 2011). The interaction of bathymetry, light, hydrology and salinity can result in longitudinal variation in water quality and phytoplankton (Roper et al. 2011). Increases in river inflow have been correlated with increases in phytoplankton biomass, suggesting a close link between terrestrially derived inorganic nutrients and elevated chlorophyll *a* (Roper et al. 2011). However, this is not always the case and factors such as light penetration, zooplankton grazing rates and settling out of phytoplankton from the water column all influence biomass and primary production (Roper et al. 2011). Phytoplankton blooms can increase turbidity (8), the magnitude of diurnal oxygen changes (9) and can be toxic (e.g. blue-green algae *Anaebena, Nodularia* and *Microcystis)* to aquatic species, wildlife and humans (Arundel et al. 2009; Liu et al. 2013).

Intermittent estuaries especially when closed and can have a long water residence time that can result in nuisance or even harmful algal growth (Roper et al. 2011; Whitfield et al. 2012; Ortega-Cisneros et al. 2014). When an estuary mouth is closed, stable water column conditions behind the berm can be created that can lead to the proliferation of phytoplankton and epiphytic algae (Whitfield et al. 2012). Plankton standing stocks during the closed phase can be 26 to 10 000 times higher than during the open phase (Ortega-Cisneros et al. 2014). In intermittent South African estuaries plankton biomass can attain pre-breaching levels 10 days after mouth closure (Ortega-Cisneros et al. 2014).

Chlorophyll *a* concentrations provide a measure of the biomass of phytoplankton and hence the primary productivity of the system (Carvalho et al. 2009; Roper et al. 2011). Techniques and collection methods for phytoplankton biomass as measured by chlorophyll a are well established (Giordani et al. 2009; Roper et al. 2011). National indicator guidelines have been developed by the former NLWRA (Roper et al. 2011) as well as specific Victorian guidelines (EPA Victoria 2010). Limited detailed data exist for this measure in Victorian estuaries (EPA Victoria 2010) and the trial of this measure concentrated on collecting new data to ensure a wide range of Victorian estuaries were represented (Arundel et al. 2009).

Phytoplankton biomass (16) = Chlorophyll *a*

Baseline = current state-wide data (best available)

Data for phytoplankton biomass in Victorian estuaries are sparse, with the majority collected in the lower estuary or lagoon. EPA's (2010) guidelines were developed from targeted sampling in the lower estuary along the western and central Victorian coast. The trigger guidelines were developed from the best-available estuaries, those with the lower intensity land-use. As these trigger guidelines form the basis of the IEC phytoplankton measure scoring, the baseline can be described as being based on best available data. Historical, pre-European settlement data are not available so the baseline cannot be historical.

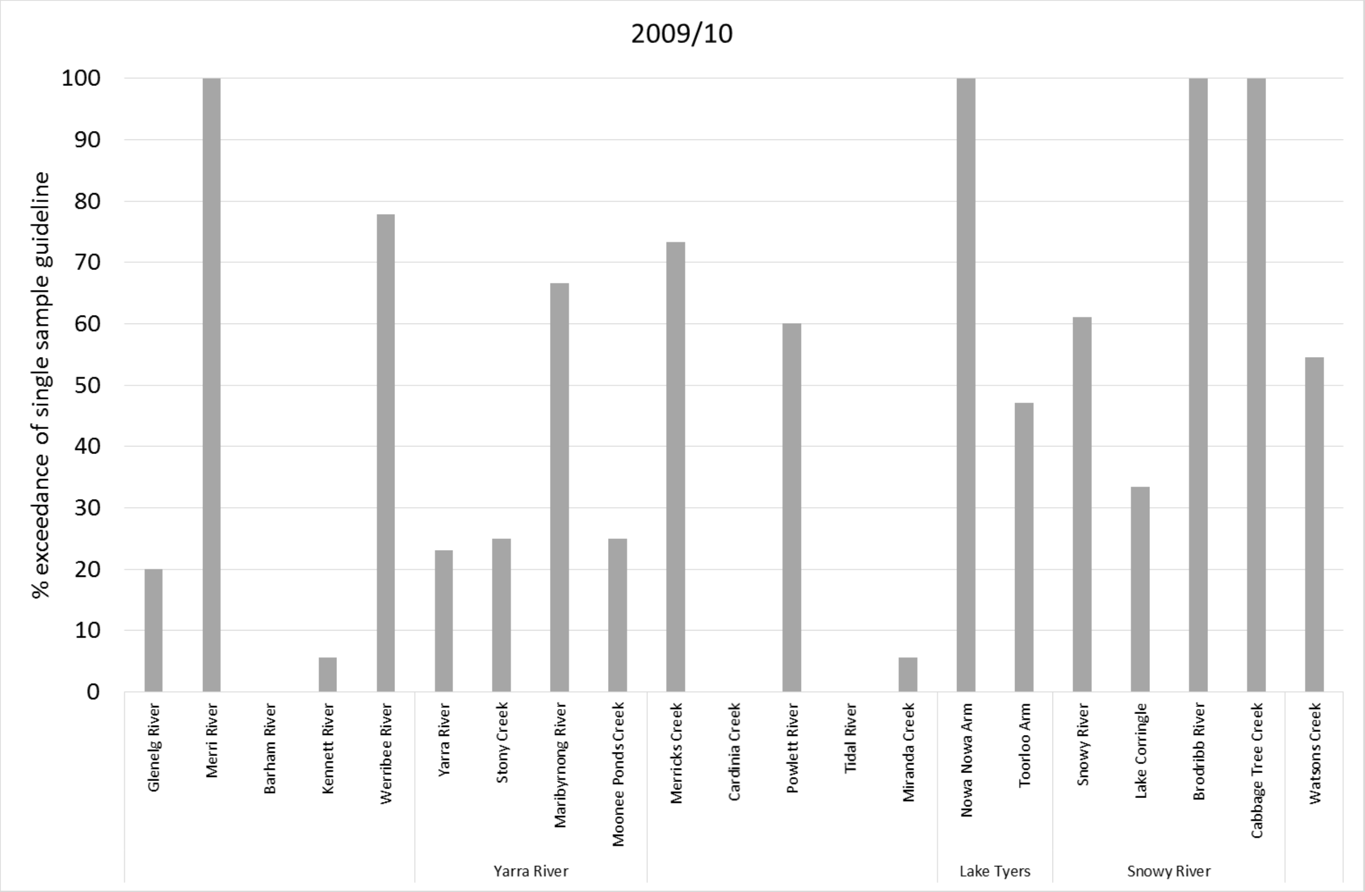
Data used

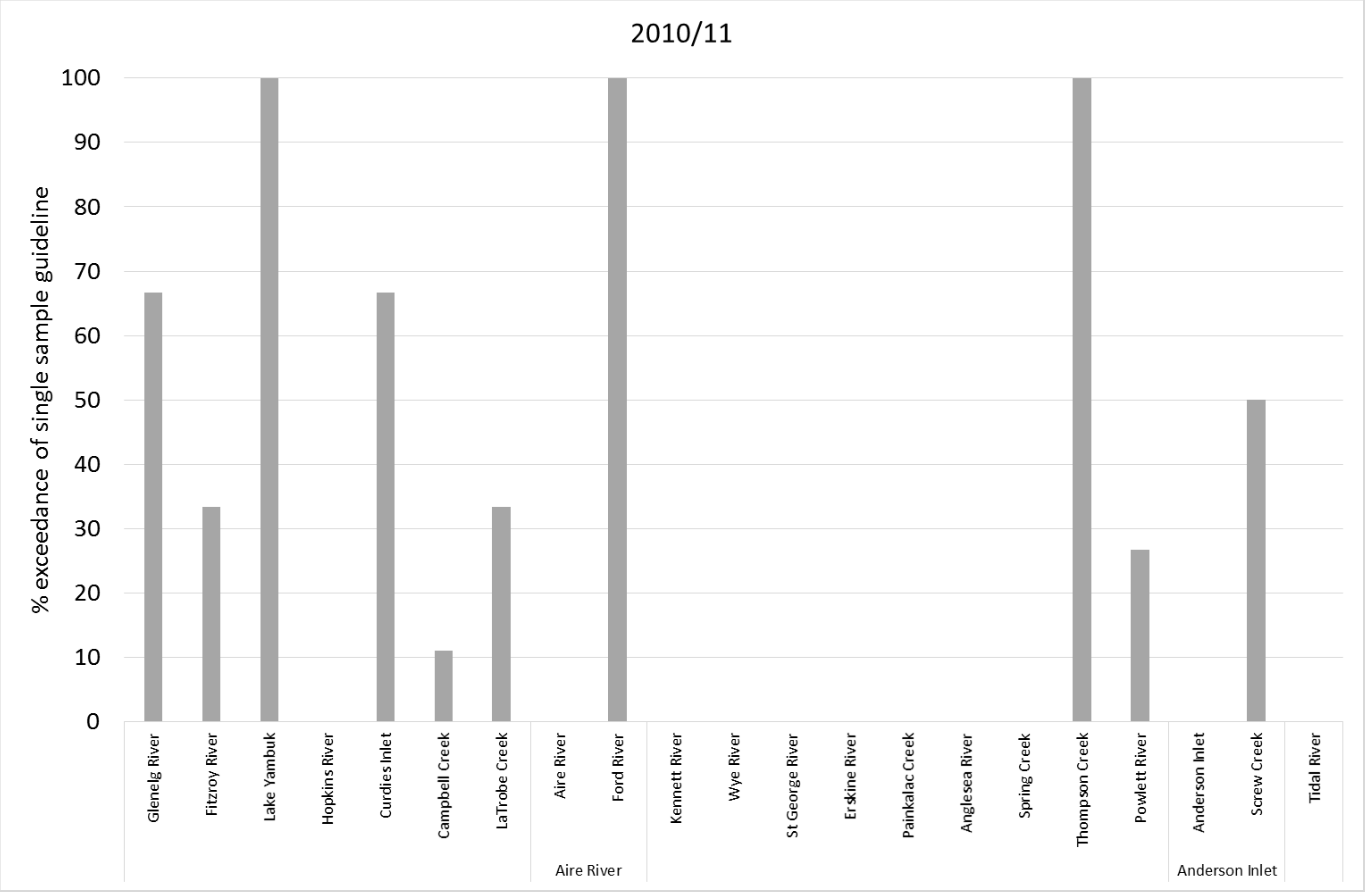
The assessment and implementation of the phytoplankton measure and development of scoring categories were based on surface water samples of chlorophyll *a* collected over three summers from fieldwork in forty-four estuaries across Victoria. Sampling was based on the broad estuary zones of upper, middle and lower estuary (Table 2, Appendix 5) as recommended (Arundel et al. 2009). Each zone had one site and three replicates of two litres of surface water per site collected mid-channel. The majority of estuaries require boating access to be able to collect the samples. Chlorophyll *a* was then assessed for the estuary as a whole (Figure 69). The implementation trial was not able to replicate the recommended temporal sampling of once every six weeks (Arundel et al. 2009).

Water samples were filtered within eight hours, the filter paper frozen and the sample analysed within 30 days as per standard protocol (Arar 1997; ANZECC and ARMCANZ 2000). Chlorophyll *a* was extracted using acetone, following a modified method of Light and Beardall (1998). Technical details followed USEPA Method 446.0 (Arar 1997) for determining chlorophyll *a* by visible spectrophotometry. With this method, all samples were corrected for phaeo-pigments and thus measurements of chlorophyll *a* actually represent concentrations of all magnesium-containing pigments (Carlson and Simpson 1996).

Storage of small phytoplankton samples for the determination of the cell count of dominant groups for algal blooms (high chlorophyll *a* concentrations) was also recommended (Arundel et al. 2009). Samples were taken during the implementation trial but cell counts have not been undertaken due to the high resources required (Garmendia et al. 2013).

Figure 68. Large phytoplankton and filamentous algae biomass in Merricks Creek.


2009/10
% exceedance of single sample guideline
0
10
20
30
40
50
60
70
80
90
100
Glenelg River
Merri River
Barham River
Kennett River
Werribee River
Yarra River
Stony Creek
Maribyrnong River
Moonee Ponds Creek
Merricks Creek
Cardinia Creek
Powlett River
Tidal River
Miranda Creek
Nowa Nowa Arm
Toorloo Arm
Snowy River
Lake Corringle
Brodribb River
Cabbage Tree Creek
Watsons Creek
Yarra River
Lake Tyers
Snowy River


2010/11
% exceedance of single sample guideline
0
10
20
30
40
50
60
70
80
90
100
Glenelg River
Fitzroy River
Lake Yambuk
Hopkins River
Curdies Inlet
Campbell Creek
LaTrobe Creek
Aire River
Ford River
Kennett River
Wye River
St George River
Erskine River
Painkalac Creek
Anglesea River
Spring Creek
Thompson Creek
Powlett River
Anderson Inlet
Screw Creek
Tidal River
Aire River
Anderson Inlet

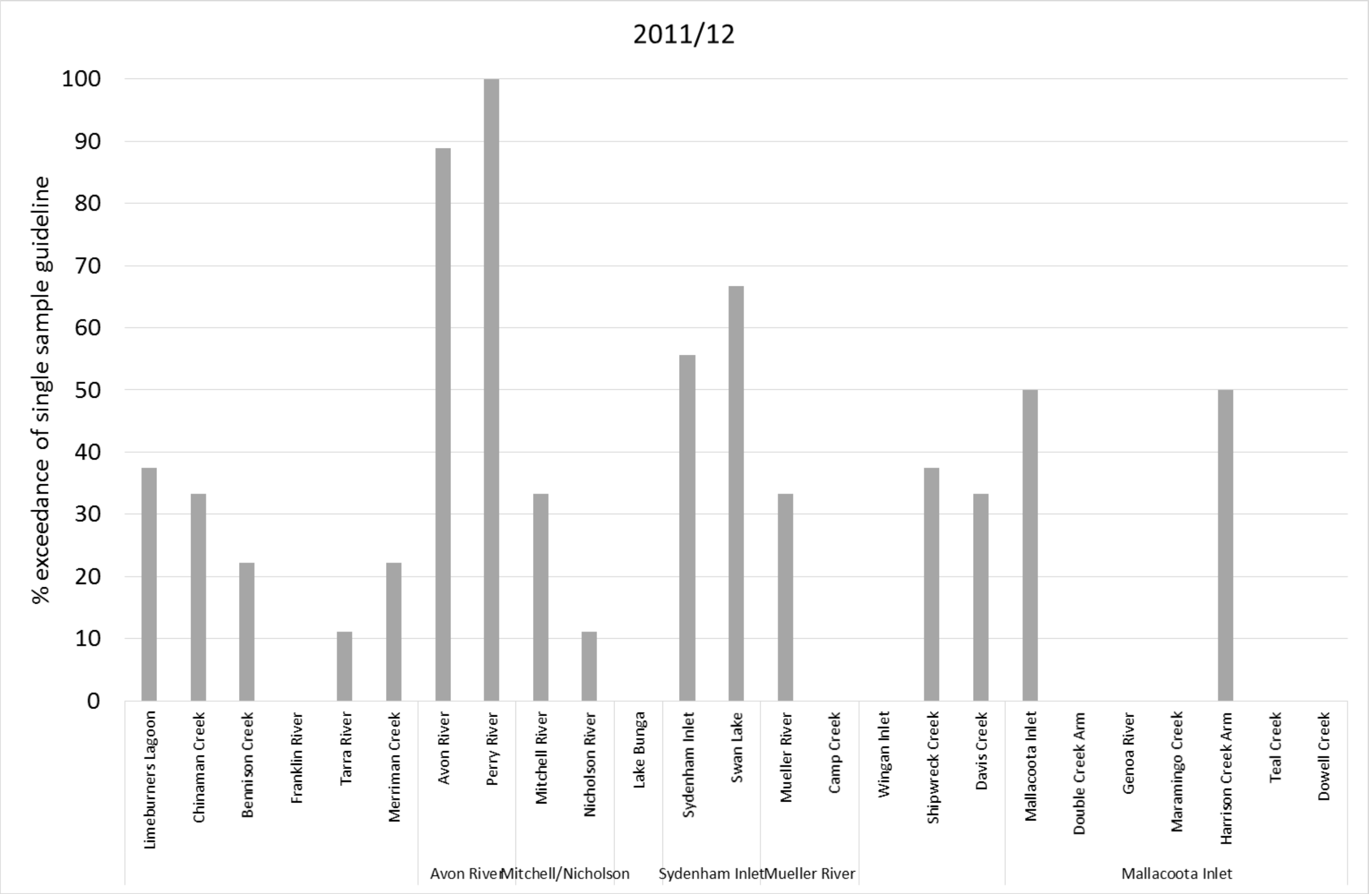


Figure 69. Summarised chlorophyll a data. Represented as percent of samples exceeding the EPA single sample guideline by year and subestuary.

Scoring method

The environmental water quality guidelines (EPA 2010) provided a baseline and assisted in the allocation of condition scores. The chlorophyll *a* concentration was assessed against the surface water single sample guidelines (trigger 6µg/L) for each water year (EPA 2010). For each estuary zone (upper, middle, lower) the aggregated three replicates per site were summarised as % single samples exceeded, minimum value, maximum value and number of samples for each water year. Based on a simple estuary with only one upper, middle and lower zone a maximum of nine samples would be collected per sampling time. The threshold between scores 1 and 2 was set at 85% of samples exceed guidelines, so for a simple estuary with only nine samples if only one does not exceed the guidelines it is scored as 1.

As the scoring was based on the data collected for the implementation trial it was not possible to consider median scores. Monthly sampling is recommended so that chlorophyll a can be assessed against median scores as per Table 111 (EPA 2010).

Table 110. Scoring for phytoplankton biomass.

% single samples exceed guidelines	IEC Score
0%	5
1-19%	4
20-50%	3
51-85%	2
>85%	1

Table 111. Scoring using both annual median thresholds and % of single sample for chlorophyll a for exceedance of EPA (2010) guidelines for. Annual medians require at least 10 samples in a water year.

Exceedance of EPA guidelines (EPA 2010): annual median threshold & % single sample (SS) – surface only	IEC Score
Neither exceeded or SS exceedances <10%	5
Annual median not exceeded AND SS exceedances >10% OR No annual median BUT single sample not exceeded	4
Annual median < 1.1µg/L OR single sample exceedances < 25%	3
Annual median 1.1µg/L<90th percentile threshold (value to be determined) OR single sample exceedances 25<50%	2
Annual median > 90th percentile threshold (value to be determined) OR > 50% of single samples above guideline	1

NSW developed their chlorophyll *a* trigger values as the 80th %ile of reference based on three estuary types, Lake, River and Lagoon, with River estuary triggers spatially divided into lower, mid and upper (Roper et al. 2011). The ‘Lake’ class included bays, drowned river valleys and lakes either permanently or intermittently open, ‘River’ included mature barrier river estuaries all of which were permanently open and ‘Lagoons’ included intermittently open lagoons and creeks. The estuary class grouping was based on estuaries response to catchment loads of nutrients and sediments, their dilution capacity and flushing times which were quantified for all NSW estuaries (Roper et al. 2011). The triggers for chlorophyll *a* were 3.6 µg/l in Lake, 2.3 µg/l lower, 2.9 µg/l mid and 3.4 µg/l upper River, and 2.0 µg/l in Lagoon class estuaries (Roper et al. 2011). NSW scoring intervals are based on the % exceedance above the relative trigger and were based on expert opinion from very poor ≥90 %, poor 75% < 90%, fair 50% < 75%, good 10% < 50% and very good <10% (Roper et al. 2011). The NSW chlorophyll *a* triggers are lower than that for Victoria and are separately defined for different functional groups.

Chlorophyll *a* is also part of the Qld EPA approach and they score out of five based on the percentage of sites or zones that exceed their guidelines (Scheltinga and Moss 2007).

South Africa based their phytoplankton assessment around abundance, recognising that this may decrease or increase with a decrease in estuarine health (DWAF 2004). Their assessment is therefore expressed as a % similarity rather than a % change, so while a decrease in abundance to 60% of original scores 60, an increase to 130% of original would score 70 (100 – 30% change).

For the Ria Formosa lagoon in Portugal, the standards for water chlorophyll high–good boundary were set to be 6–8 µg/L and for the good–moderate boundary were set to be 9–12 µg/L (Brito et al. 2012b). During periods of closure, Portugal lagoons have conditions favouring phytoplankton growth and their highest chlorophyll *a* level of 290 µg/L was recorded (Pereira Coutinho et al. 2012). During comparable open periods, the same estuary was about one fifth lower at 64 μg/L (Pereira Coutinho et al. 2012). This estuary is now artificially maintained open and high chlorophyll levels are now only 7 μg/L (Pereira Coutinho et al. 2012).

McLaughlin et al. (2014) summarised the chlorophyll *a* thresholds for USA eutrophication indices as "no effect" levels is less than 5 to 7 μg/L, moderate effects range from 7 to 10 μg/L, above 20 μg/L submerged aquatic vegetation show declines, and phytoplankton community shifts from diverse mixture to monoculture. At 60 μg/L chlorophyll *a*, high turbidity, and low bottom water dissolved oxygen have been observed in estuaries.

Score confidence

The data used to derive the phytoplankton (16) score were assessed and assigned a category of low, medium or high confidence based on data quality (Table 112). Score confidence considered all estuarine zones were sampled, with at least one site per zone and three replicates in each site.

Table 112. Score confidence criteria for phytoplankton biomass taking into account the number of years, zones and replicates sampled.

Confidence	Years sampled (out of 6)	Zones sampled (in any year)	% sampled (of year and zone combinations)	Annual median for zones?	3 or more replicates?
High	4-6	>50%	>75%	All	Yes
Medium	4-6	>50%	>75%	All	No
Medium	4-6	>50%	>75%	Some	
Low	4-6	>50%	>75%	None	
Medium	4-6	>50%	<=75%	All or some	
Low	4-6	>50%	<=75%	None	
Medium	4-6	<=50%	>75%	All or some	
Low	4-6	<=50%	>75%	None	
Low	4-6	<=50%	<=75%		
Medium	2-3	>50%	>75%	All or some	
Low	2-3	>50%	>75%	None	
Low	2-3	>50%	<=75%		
Low	2-3	<=50%			
Low	1				

Scores

Forty-four estuaries could be scored for phytoplankton biomass, with insufficient data available to score the remaining fifty-seven estuaries (Figure 70, Table 113, Appendix 11). Most of these estuaries without sufficient data occurred on the central and east coast (Table 127). The majority of scored estuaries had scores of either 5 (30%) or 3 (36%) and occurred across the Victorian coast (Table 114). Four estuaries: Lake Yambuk; Merri River; Thompson Creek; and Avon River (upper Perry River) all scored 1. All score confidences were low because they were based only one or two sampling times assessed against single sample guidelines (Table 112 & Table 113).

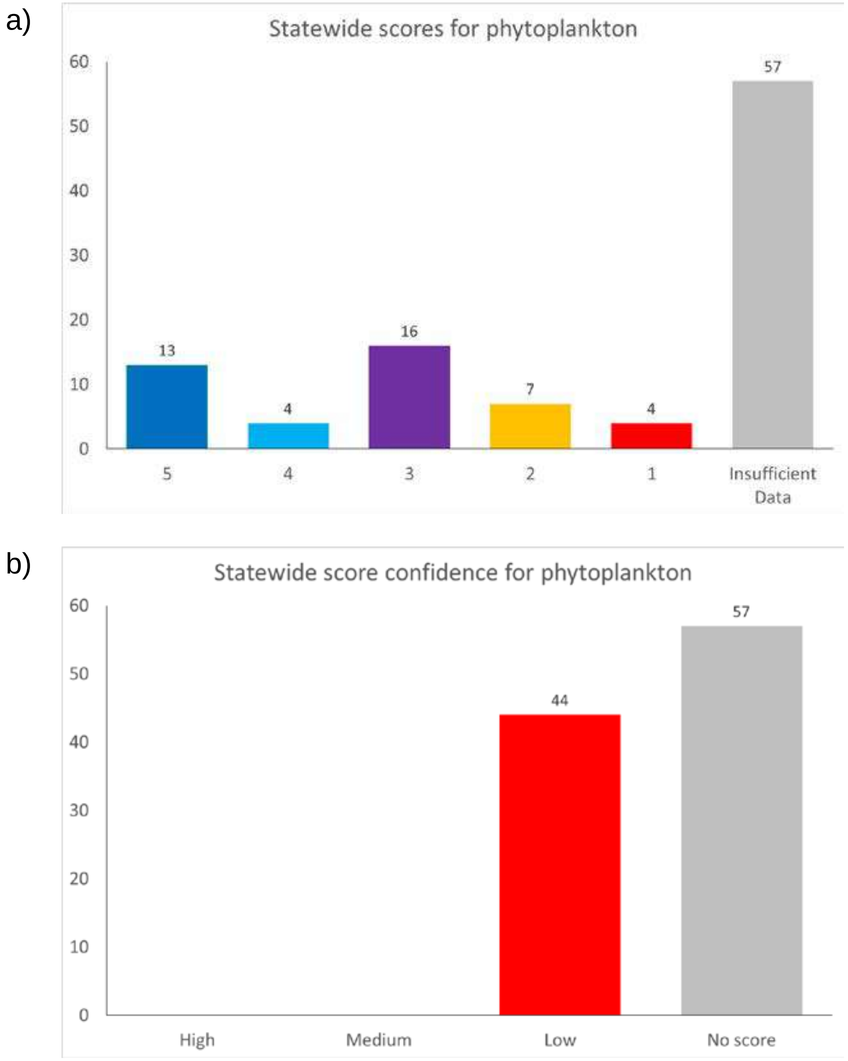


Figure 70. Statewide estuary a) scores and b) score confidence for the phytoplankton biomass measure.

Table 113. Numbers of estuaries by score and data confidence for the phytoplankton biomass measure.

Data Confidence	IEC Score				
	5	4	3	2	1
High					
Moderate					
Low	13	4	16	7	4

Table 114. Phytoplankton biomass scores and data confidence for estuaries summarised by CMA region.

CMA region	Scores (# estuaries/CMA)						Score confidence (where scored)		
	5	4	3	2	1	NS	H	M	L
GH	1		2		2	3			5
C	7	2	3	1	1	3			14
MW/PPWP	1		1	3		17			5
WG	2	2	5		1	18			10
EG	2		5	3		16			10

Discussion

The draft IEC (Arundel et al. 2009) recommends the collection of chlorophyll samples every six weeks over the six year sampling period (since revised to eight years). In reality it is probably more feasible to collect the samples monthly in a monitoring program with turbidity and dissolved oxygen samples. The majority of estuaries require boating access to be able to collect the samples in the middle of the channel. All this would pose a major resource challenge to management agencies both financially and technically.

NSW undertook targeted sampling over 18 months and determined the annual seasonal chlorophyll maxima for different sections of their coast (Roper et al. 2011). The maxima were correlated to water temperature and so they have developed targeted chlorophyll monitoring only around the warmer months of the year (Roper et al. 2011), as has been done in other monitoring programs (Abramic et al. 2012). Care needs to be taken with this approach; the maxima needs to be identified for Victorian estuaries as there can be variation around the maxima timing due to differences in phytoplankton species (Liu et al. 2013) and driving forces (Tirok and Scharler 2013). Targeting sampling around the seasonal chlorophyll maxima in Victorian estuaries would reduce cost of implementing the phytoplankton measure if similar relationships to those in NSW (Roper et al. 2011) were found.

As the scoring was based on the data collected for the implementation trial, it was not possible to consider median scores as available data were limited to those collected on annual field trips. Comparisons of single sample scores between years show broad self-consistency between estuaries (condition scores between years did not change by more than one point) but also highlighted the temporal variability of this measure, for example with both increases and decreases of ~40% exceedances seen in different estuaries between 2009-10 and 2010-11.

An *in situ* fluorometer was used in a selection of the estuaries in the implementation trial to assess the consistency of the relationship between spectrophotometric laboratory based and *in situ* fluorometric chlorophyll *a* determination. The implementation trial ran out of resources to analyse these data and it should be done as it may save costs. NSW found in their estuaries that *in situ* fluorometry did not work well in tannin waters (Roper et al. 2011).

Future developments:

- Explore the potential for use of seasonal chlorophyll maxima in Victorian estuaries as has been done in NSW.
- Refine thresholds for median scores when more monthly data are collected.
- Assess how well the EPA (2010) guidelines apply to the entire estuary, and to all estuary zones.
- Assess the effect of estuary section size, length and area, for potential bias and optimum number of sample sites.
- Analyse the relationship between *in situ* fluorometry and spectrophotometric laboratory based chlorophyll *a* from the implementation trial.

9 RESULTS OF IMPLEMENTATION OF FAUNA MEASURES

The fauna of an estuary (Figure 71 & Table 115) includes fish and birds as well as meiofauna and macrofauna associated with the sediment, water column and plants (Arundel et al. 2009). Trialling of fauna measures were not part of the initial DSE funded trial of the IEC. The recommended fish and bird (Table 115) measures were thought to be difficult to immediately implement due to the large amount of development needed (Arundel et al. 2009). Melbourne Water commissioned Arthur Rylah Institute (ARI) to develop and trial the fish and bird measures in eleven estuaries in Port Phillip Bay and Western Port Bay. It also supported Deakin in trialling the other IEC measures in these eleven estuaries. DWELP then supported the trial of fish and birds in 20 estuaries in stage two, the focus in 2011 was West and East facing functional group estuaries and in 2012 Gippsland or South facing functional group estuaries. ARI concentrated on comparing and refining sampling techniques. Data from both the Melbourne Water and DWELP trials were assessed at the end of stage two and baselines and scoring distributions established and response and sensitivity assessed.

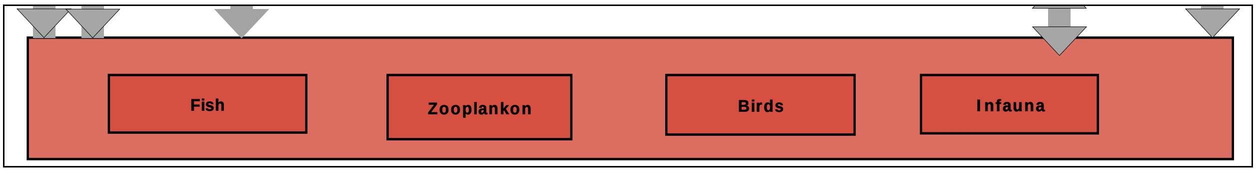


Figure 71. Fauna components of conceptual model. (Full model shown in Figure 1).

Table 115. Recommended measures within Fauna theme from Arundel et al. (2009).

PHYSICAL FORM	HYDROLOGY	WATER QUALITY	SEDIMENT	FLORA	FAUNA
					17. Naturalness of fish 18. Naturalness of birds

9.1 FISH (17)

Naturalness of fish (17a) structural: recommended

Naturalness of fish (17b) functional: recommended

The majority of Victorian estuaries are too small to support commercial fishing except for the major bays and inlets (Port Phillip Bay, Western Port Bay, Corner Inlet, and Gippsland Lakes). Several of the smaller estuaries do support eel fisheries, which are considered to be managed sustainably (McKinnon 2002). Fish as a measure for the IEC (Figure 1) was assessed separately by ARI and is reported in detail in a separate report (Warry and Reich 2014). A large suite of proposed metrics were developed and assessed for applicability, response to disturbance and redundancy. Below is a summary of the recommended measures from Warry and Reich (2014), including how to sample the fish assemblages, calculate specific structural and functional aspects, and how to score and combine these specific aspects. Warry and Reich (2014) recommended two measures for assessing fish naturalness based on specific aspects of the guilds of the sampled fish assemblage. The two measures are a structural measure consisting of seven specific aspects, and a functional measure consisting of two specific aspects of fish nitrogen stable isotope ratios.

Naturalness of fish (17a) structural: guild based multi-aspect measure incorporating the proportion and number of taxa of seven guilds

This measure consists of the summation of seven structural aspects to determine the naturalness of the fish assemblages. Catch and release sampling is used to characterise fish assemblages, and ecological guilds. The sampling protocol is designed as a rapid assessment methodology to characterise fish assemblage composition rather than to quantify absolute abundances or biomass. The estuarine fish sampling methodology is repeatable and robust. It facilitates the formulation of structural aspects of the fish assemblage that are responsive to perceived threats and can be aggregated into a meaningful measure of fish ecological condition.

Baseline = best available data.

Data for fish assemblages in Victorian estuaries are sparse and difficult to compare due to different sampling gear and effort. The baseline for this measure is based on best available data collected during the implementation trial.

Data used

Sampling was undertaken in thirty-one estuaries within Victoria during 2010 to 2012 (Table 116). Estuaries were surveyed using a rapid assessment methodology that could be completed within twelve hours and all upper, middle and lower zones in the estuaries and subestuaries were sampled.

Table 116. Estuaries sampled by ARI as part of the development of fish measures for the IEC.

West Coast Estuaries Sampled 2011	Port Phillip & Western Port Bay Estuaries Sampled 2010, 2011 & 2012	East Coast Estuaries Sampled 2012
Fitzroy River	Little River	Chinaman Creek
Lake Yambuk	Werribee River	Bennison Creek
Hopkins River	Kororoit Creek	Franklin River
Curdies Inlet	Yarra River	Tarra River
Gellibrand River	Balcombe Creek	Merriman Creek
Aire River	Merricks Creek	Avon River
Kennett River	Warringine Creek	Lake Bunga
Anglesea River	Watsons Creek	Wingan Inlet
Spring Creek	Cardinia River	Shipwreck Creek
Thompson Creek	Bunyip River	Davis Creek
	Bass River	

A core sampling protocol of fyke (3 each zone) and mesh (1 each zone) nets was conducted. Trawls and seines were also conducted opportunistically in the lower estuary zone, where the substrate, tidal currents and estuarine geomorphology permitted effective gear use. Fyke nets (5 mm mesh, a 5 m long wing and a 50 cm high D-shaped entrance ring) were set at a 45º angle to the banks over dusk for approximately four hours. Multi-panel mesh nets (1.5 m deep, five 10 m long panels of different mesh sizes (2.5, 3.8, 5.0, 6.3, 7.6 cm)) were deployed parallel to the bank over dusk, on a flood tide, for a minimum of two hours. Where possible, otter trawls (2cm stretch green, knotted mesh, a maximum mouth width of 2 m) were towed at approximately two knots for around three minutes in daylight hours. Also, seine nets (2 mm knotless mesh, 2.5 m deep, 15 m long) were deployed where possible from a boat or walked out and hauled onto the banks during daylight hours.

Sampling was undertaken in spring and autumn and completed in a single day. Analysis showed that it was only necessary to use autumn sample data. The most reliable data came from netting gear deployed at depths < 2 m. The fish were identified to species, counted and released. Taxa identification was of high precision and included laboratory confirmation. Contextual information, including water depth (m), tidal amplitude category (0m, <1m, 1-1.5m, >1.5m, derived from nearest tidal gauge) and estuary area (km^2), was also recorded.

The fish assemblage data were then categorised into three types of ecological guilds: water column positioning; estuary use; and trophic ecology, aspects of which are then used to assess condition (Elliott et al. 2007). For the IEC structural measure the first two guild types only use taxa from one guild each, demersal-associated species and freshwater migrant species (Table 117). The trophic ecology guilds in the IEC fish structural measure included detritivores; miscellaneous opportunists; zoobenthivores and zooplanktivores (Table 117). Seven structural aspects (or metrics) were then calculated as either a proportion of the taxa (five aspects) or a proportion of the individuals (two aspects) in those guilds in the fish assemblage sample (Table 117).

Table 117. The seven aspects of fish assemblages that make up the IEC fish structural measure. Included are descriptions and rationale of each specific aspect, and predicated response to disturbance.

Guild, proportion of assemblage	Description and Rationale	Predicted response to disturbance
Demersal, taxa	Provide information on the condition of demersal habitats and estuarine flushing as demersal habitats may become anoxic when there is insufficient freshwater or tidal flushing	decrease
Freshwater Migrants, taxa	It will provide information on the condition of estuarine habitat, longitudinal connectivity and function. Under normal estuarine function, a relative balance between the different estuary use guilds is expected.	large decrease or increase
Detritivores, taxa	Under normal estuarine function a relative balance between feeding guilds would be expected.	large decrease or increase
Detritivores, individuals	Under normal estuarine function a relative balance between feeding guilds would be expected.	large decrease or increase
Opportunists, individuals	Under normal estuarine function a relative balance between feeding guilds would be expected.	large decrease or increase
Zoobenthivores, taxa	Provide information on the condition of benthic habitats	decrease
Zooplanktivores, taxa	Provide information on the condition of benthic relative to pelagic production and whether a system may be experiencing eutrophication or production shifts	increase

Each aspect of the fish assemblage sample was scored out of 1, 3 or 5, depending on the degree of deviation from the reference (Table 118). Score thresholds were delineated from the distribution of the sample data and deviation from reference conditions (Table 118). The physical nature of individual estuaries or estuary types did not need to be taken into account when allocating scores. Potential exists to expand the number of scoring categories once additional estuaries are sampled and clearer information on the relationships between individual measures and perceived threats becomes available.

Table 118. Scoring for the seven specific structural aspects of the fish assemblage.

Structural aspect: guild, proportion of	5	3	1
Demersal Species, taxa	> 44.6	44.6 - 36.0	< 36.0
Freshwater Migrants, taxa	> 12.9	12.9 - 6.1	< 3.1
Detritivores, taxa	> 13.0	13.0 - 8.5	< 8.5
Zoobenthivores, taxa	> 43.1	43.1 - 34.5	< 34.5
Zooplanktivores, taxa	< 13.0	13.0 - 19.1	> 19.1
Detritivores, individuals	> 21.0	21.0 - 4.3	< 4.3
Opportunists, individuals	< 5.6	5.6 - 20.5	< 20.5

Once the aspects were scored, the fish naturalness structural measure was calculated by summing the scores of aspects and dividing by seven to get an overall score between 1 and 5. This approach assumes that each specific aspect has an equal contribution to ecological condition.

Score Confidence

Score confidence has not yet been developed for this measure but should be possible with further analysis of the collected data (Table 119).

Table 119. Score confidence criteria for the seven specific aspects of six guilds of the fish assemblage.

Confidence	Criteria
High	*To be developed*
Medium	*To be developed*
Low	*To be developed*
Unknown	Unable to establish if data exist

Scores

Individual estuary scores for the structural measure were not presented in Warry and Reich (2014) but could easily be derived from their data.

Discussion

A general discussion is given at the end of this section.

Naturalness of fish (17b) functional: guild based δ15N of fish in the assemblage

This measure consists of the summation of two functional aspects based on stable isotope ratios of nitrogen to determine the functional naturalness of fish assemblages. Stable isotope approaches compliment structural proxies of estuarine function derived from the fish sample data, as direct measures of ecosystem function, to improve the usefulness and interpretability of the IEC fish measure. The δ15N signature may indicate anthropogenic nutrient loading to estuaries via catchment landuse modification and altered hydrology (McClelland et al. 1997). Functional aspects are based on a mean δ15N value of fish in the zoobenthivore guild and an estimate of trophic niche position of fish in the detritivore guild (Table 120).

Table 120. The δ15N aspects of the two ecological guilds in the fish assemblage data that make up the IEC fish functional measure. Included is a description and rationale of each specific aspect, and predicated response to disturbance.

Aspect	Description and Rationale	Predicted response to disturbance
δ15N Zoobenthivore (‰) - mean	These taxa may provide particularly good indicators as they are generally small bodied and less mobile relative to other guilds and therefore their isotopic niche position may be more closely linked to estuarine condition (Layman et al. 2007)	decrease
Detritivore Adult (‰^{2}) - Standard ellipse area	It represents the trophic niche space occupied by a single member of a community. The niche space occupied by detritivores may indicate terrestrial carbon inputs and longitudinal connectivity of estuaries (Layman et al. 2007)	decrease

Baseline = best available data.

Data for fish assemblages in Victorian estuaries are sparse and difficult to compare due to different sampling gear and effort. The baseline for this measure is based on best available data collected during the implementation trial.

Data used

The estuaries, sampling methodology and fish assemblages are the same as for the structural naturalness measure except that five fish from two functional guilds were collected and sacrificed for stable isotope analysis. Five replicate fish were sacrificed from each estuary zone on each sampling occasion. White muscle tissue, immediately ventral to the anterior region of the dorsal fin, was used for isotope analysis. Samples were washed in distilled water, dried to constant weight (24 hrs at 60ºC) and ground to a fine powder in a mixer mill. Analysis was in a continuous-flow isotope ratio mass-spectrometer and can be commercially outsourced. Stable isotope data are expressed in the delta notation (δ15N), relative to the stable isotopic ratio of atmospheric nitrogen (R Air = 0.0036765).

$$\delta X = [(R\text{sample}/R\ \text{Air}) - 1] \times 103$$

Where X is 15N and R is the corresponding ratio 15N/14N.

Scoring method

Each of the two aspects was given a score of 1, 3 or 5, depending on the degree of deviation from the baseline or reference condition (Table 121). Score thresholds were delineated from the distribution of the sample data and deviation from baseline (Table 121). The physical nature of individual estuaries or estuary types did not need to be taken into account when allocating scores.

Table 121. Scoring for the two specific function aspects of two guilds of the fish assemblage

Functional aspects	5	3	1
Zoobenthivores - Mean δ15N	< 12.0	12.0 - 15.0	> 15.00
Detritivores - δ15N Standard ellipse area -	> 4.0	4.0 - 2.5	< 2.05

Once the two functional aspects were scored, the functional fish naturalness measure was calculated by summing the two scores and dividing by two to get an overall score between 1 and 5. This approach assumes that each of the two specific aspects has an equal contribution to ecological condition.

Score confidence

Score confidence has not yet been developed for this measure but should be possible with further analysis of the collected data (Table 122).

Table 122. Score confidence criteria for the two specific aspects of two guilds of the fish assemblage.

Confidence	Criteria
High	*To be developed*
Medium	*To be developed*
Low	*To be developed*
Unknown	Unable to establish if data exist

Scores

Individual estuary scores for the structural measure were not presented in Warry and Reich (2014) but could easily be derived from their data.

General discussion

Estuaries spanning a range of natural characteristics were scored in the top 20 % of each of the two measures. These included estuaries that are permanently open, intermittently open, flow into embayments or the open coast, were small (< 2 km long) and large (> 5 km long). This suggests that measures are not systematically biased to particular estuarine typologies and that they will be useful for state-wide condition assessment, despite some uncertainty about natural gradients in the landscape.

The process developed for testing for redundancies in measures, defining references and thresholds and inspecting performance can be applied to any suite of measures developed from the sample data, allowing for evolution of the IEC-fish measures as new fish or threat data become available or as management objectives change.

Contextual information and natural variability at the landscape and site scale, including natural variability in hydrological regimes, tidal exchange, hypsometry and in-stream habitat, will influence the structure and function of estuarine fish communities. This contextual information may also help resolve the unexpected relative ranking of some estuaries. It will also assist in the interpretation of scores for estuarine ecological condition.

Future development:

- Investigate co-variance between disturbance gradients and sources of natural variation in the landscape for better interpretation of the data, aspect values and scores, and measure values.
- Include the sampling of consistent, local environmental data, such as in-stream habitat, for assessing measure responsiveness to disturbance and potential threats to estuaries.
- Use local environmental data to assist in developing additional stable isotope measures of the roles of different autotrophs in supporting fish nutrition, this will provide further insight into estuarine trophic function and relationships with landscape scale disturbance.
- Collect fish assemblage and stable isotope data from other estuaries, and at previously sampled estuaries to help understand patterns and variability in fish assemblage structure, how these relate to estuarine condition and which measures best represent the condition of an estuary.
- Include research that improves our understanding of the mechanisms that underlie responses of estuaries (including other IEC components) and their fish fauna to various anthropogenic threats and natural environmental gradients.

9.2 BIRDS (18)

Naturalness of birds (18): not recommended

Naturalness of birds (18) = observed/expected estuarine bird guilds

Birds as a measure for the IEC were assessed separately by ARI and the summary of major findings is given below.

Victoria's estuaries provide important habitat for a broad range of waterbirds and small, insectivorous passerine birds that utilise dense riparian vegetation. Birds which feed on aquatic animals or plants are prominent – members of the following bird feeding guilds: fish-eating species, ducks, swans, large wading birds and grebes. Birds which feed on exposed sand or mud are also well represented – rails and shorebirds – as are raptors, reflecting the productive environment.

Waterbirds are generally relatively easy to see and identify, compared to in-stream organisms for example, and might seem, at first glance, to have potential as a component of an IEC. However, there are some important factors that reduce their usefulness.

- Australian waterbirds tend to be highly mobile and their movements are partly governed by climatic conditions across much of the continent, i.e. there are important uncontrolled variables which strongly influence waterbird numbers at any given locality and time.
- This transient nature precludes the development of simple rules for interpreting the results of estuary bird monitoring programmes. Metrics for monitoring bird population trends in estuaries would need to include significant replication and a long time-series, adding significantly to the overall cost.
- Birds can be missed during surveys due to human disturbance – estuaries being popular sites for human recreation.

The utility of birds as a component of an IEC needs further assessment. The current data, collected during 84 surveys involving 32 Victorian estuaries, provided few meaningful relationships between measures of catchment condition and abundance of bird guilds.

The relationships which have the most potential to reflect trends in overall estuary health are:

- The positive relationship between numbers of gulls and introduced species and Land Use Factor for the catchment.
- The positive relationship between Catchment Disturbance Index and ibis numbers i.e. increasing numbers of Silver Gull and Australian White Ibis, in particular, are likely to reflect increasing disturbance to natural values in the estuary and its catchment.

10 THEME SCORES

Aggregated scores for themes are presented briefly in this section. Theme scores were derived from measures where some form of statewide score was possible in this trial and so may be based on a reduced set of measures. Theme score confidence as shown here is based on an average of measure confidence (L,M,H = 1,2,3), a confidence of zero was included in this average for missing measures, but only those that are otherwise included in these summaries and not for those measures where broad scale measurement was not feasible in the trial. Overall confidence in themes needs to take this into account.

10.1 PHYSICAL FORM

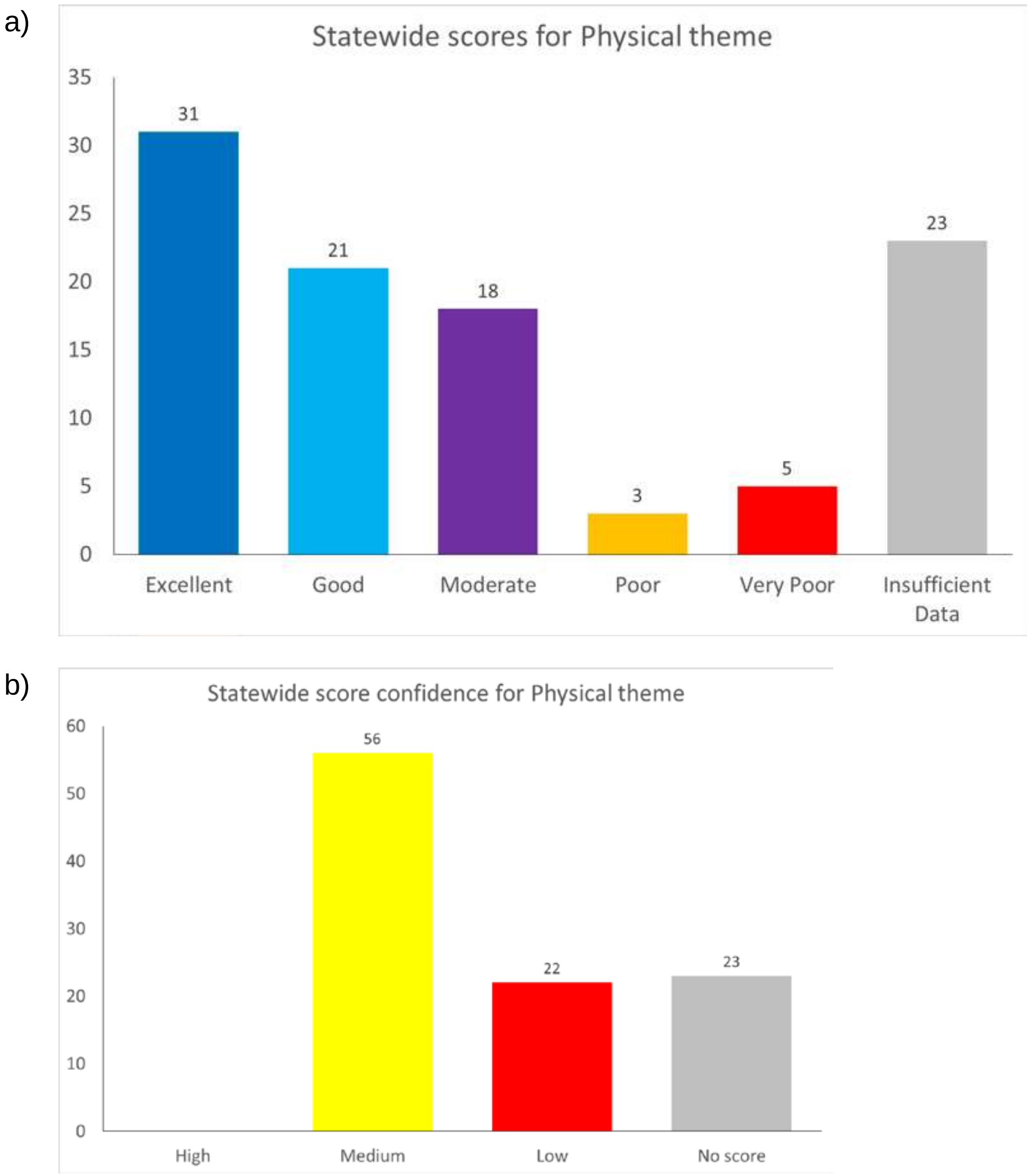
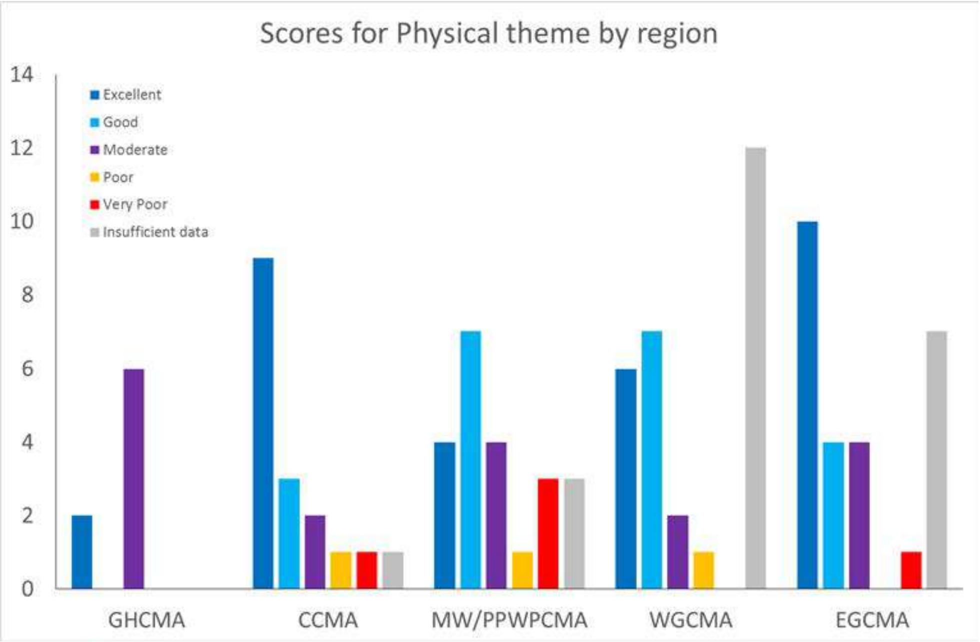


Figure 72.Combined physical form a) scores and b) confidence for estuaries statewide.

Theme scores for physical form were based on the sediment load (2) and upstream barrier (3) measures and did not use changed bathymetry (measure 1) or lateral connectivity (4) information. Only twenty-three estuaries could not be scored at the theme level (Figure 72) and the majority of these estuaries were in the east of the state in West and East Gippsland CMA regions (Figure 73a). The majority of estuaries scored were in excellent to moderate condition (Figure 72a), however the score confidence was only medium to low (Figure 72b), especially in the east of the state (Figure 73b).

a)



b)

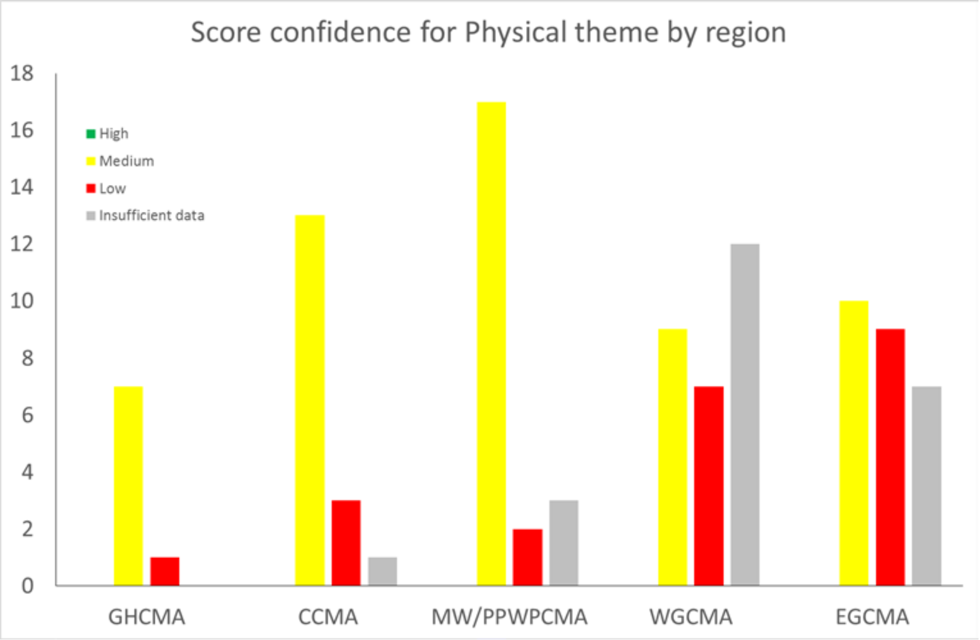


Figure 73. Combined physical form a) scores and b) confidence for estuaries by region.

10.2 HYDROLOGY

Theme scores for hydrology were based on the marine exchange (5) and freshwater flow (6) measures and did not use salinity regime (7). All one hundred and one estuaries could be scored with a good overall distribution of scores post integration (Figure 74). Only nine estuaries were scored as being in excellent hydrological condition with the majority in West and East Gippsland CMA regions (Figure 75a). In Glenelg Hopkins CMA no estuaries were scored as being in excellent hydrological condition (Figure 75a). Eighteen estuaries were scored as being in very poor hydrological condition and were spread across the state with a concentration in the central part of the State (Figure 75a). The majority of estuaries could be scored with good to medium confidence (Figure 75a). The low confidence in scores in Corangamite CMA was due to many estuaries not having ISC reaches from which scores could be derived and the lack of data for artificial mouth opening in intermittent opening estuaries.

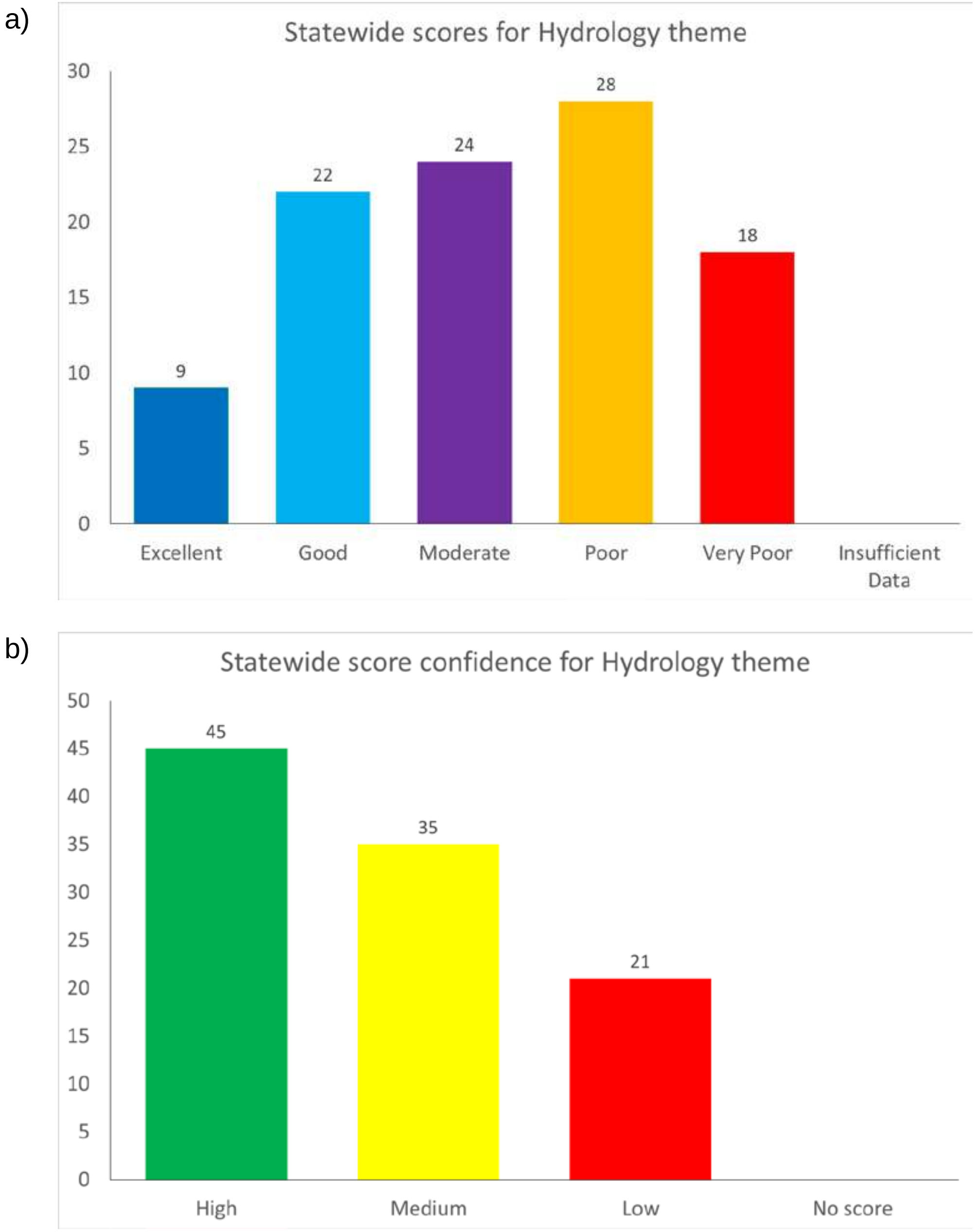


Figure 74. Combined hydrology a) scores and b) confidence for estuaries statewide. All estuaries were scored for this theme.

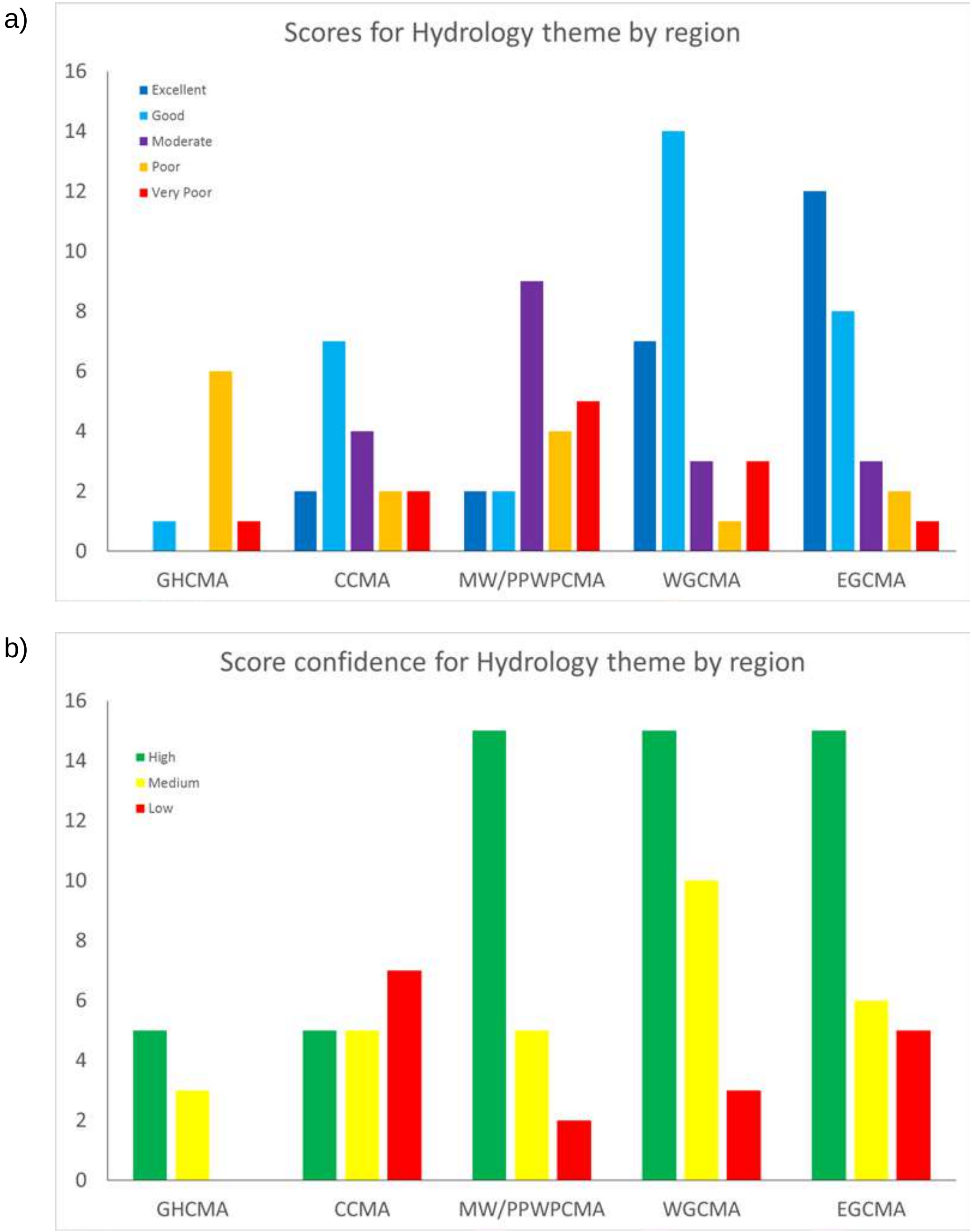
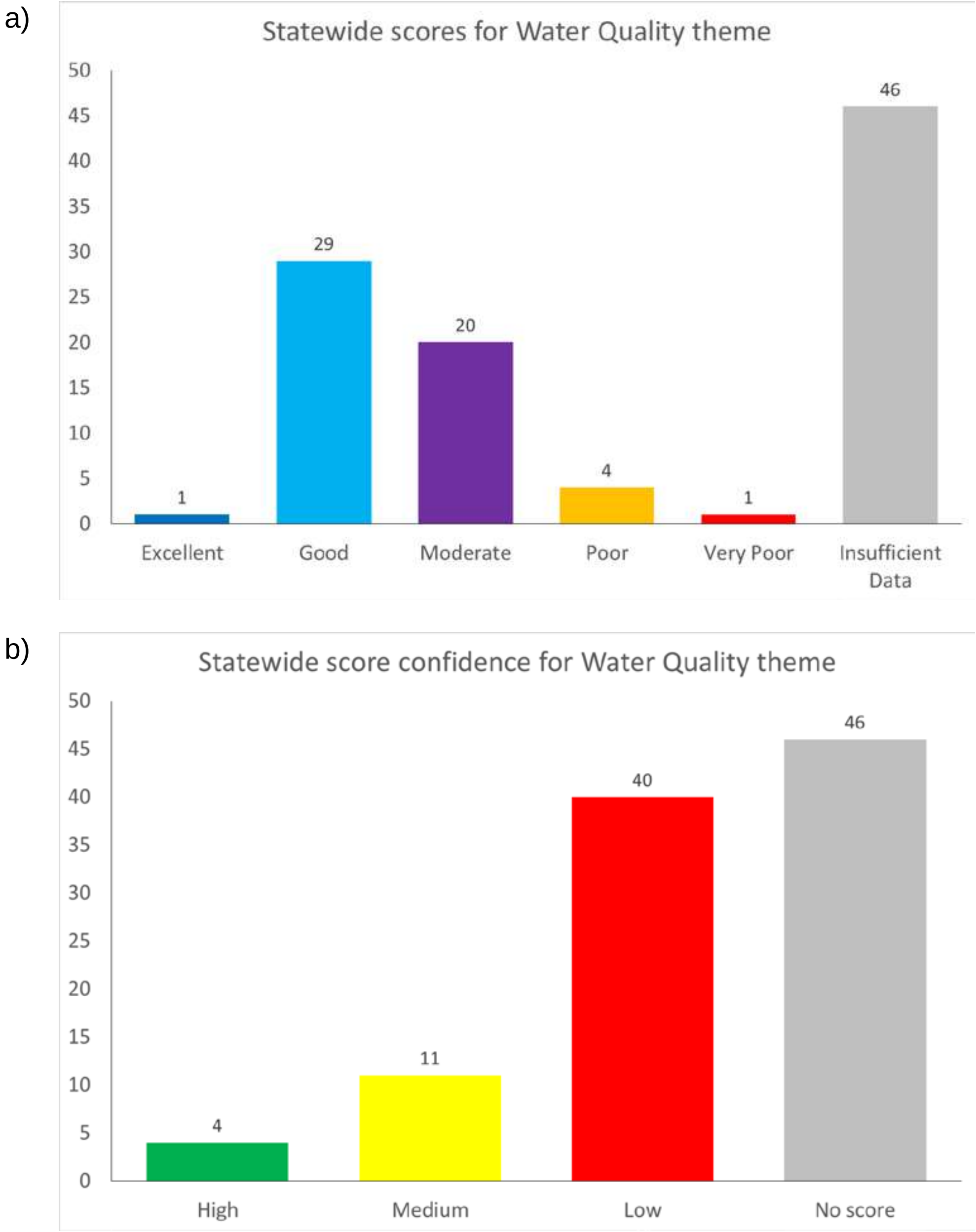


Figure 75. Combined hydrology a) scores and b) confidence for estuaries by region. All estuaries were scored for this theme.

10.3 WATER QUALITY

Theme scores for water quality were based on the water clarity (8) and dissolved oxygen (9) measures. All proposed measures were included. The high number of estuaries that could not be scored (Figure 76) reflects the lack of suitable water quality monitoring in West and East Gippsland CMA regions (Figure 77). There is also quite a large proportion of estuaries in the Melbourne Water/Port Phillip Western Port CMA region that did not have suitable water quality data due a lack of estuary-specific monitoring (Figure 77). For the fifty-five estuaries that could be scored at the theme level, only one (Fitzroy River) had excellent water quality with most having either good or moderate water quality (Figure 77a). Over all four estuaries had poor water quality, one in the west (Campbell Creek), two in the central part of the coast (Mordialloc Creek & Yallock Drain), and one in west Gippsland (Bennison Creek). One had very poor water quality (Bass River) (Figure 77a). The majority of estuaries that could be scored could only be done so with poor confidence reflecting the lack of appropriate water quality monitoring in Victoria's estuaries (Figure 77b).



Statewide scores for Water Quality theme

Statewide score confidence for Water Quality theme

Figure 76. Combined water quality a) scores and b) confidence for estuaries statewide.

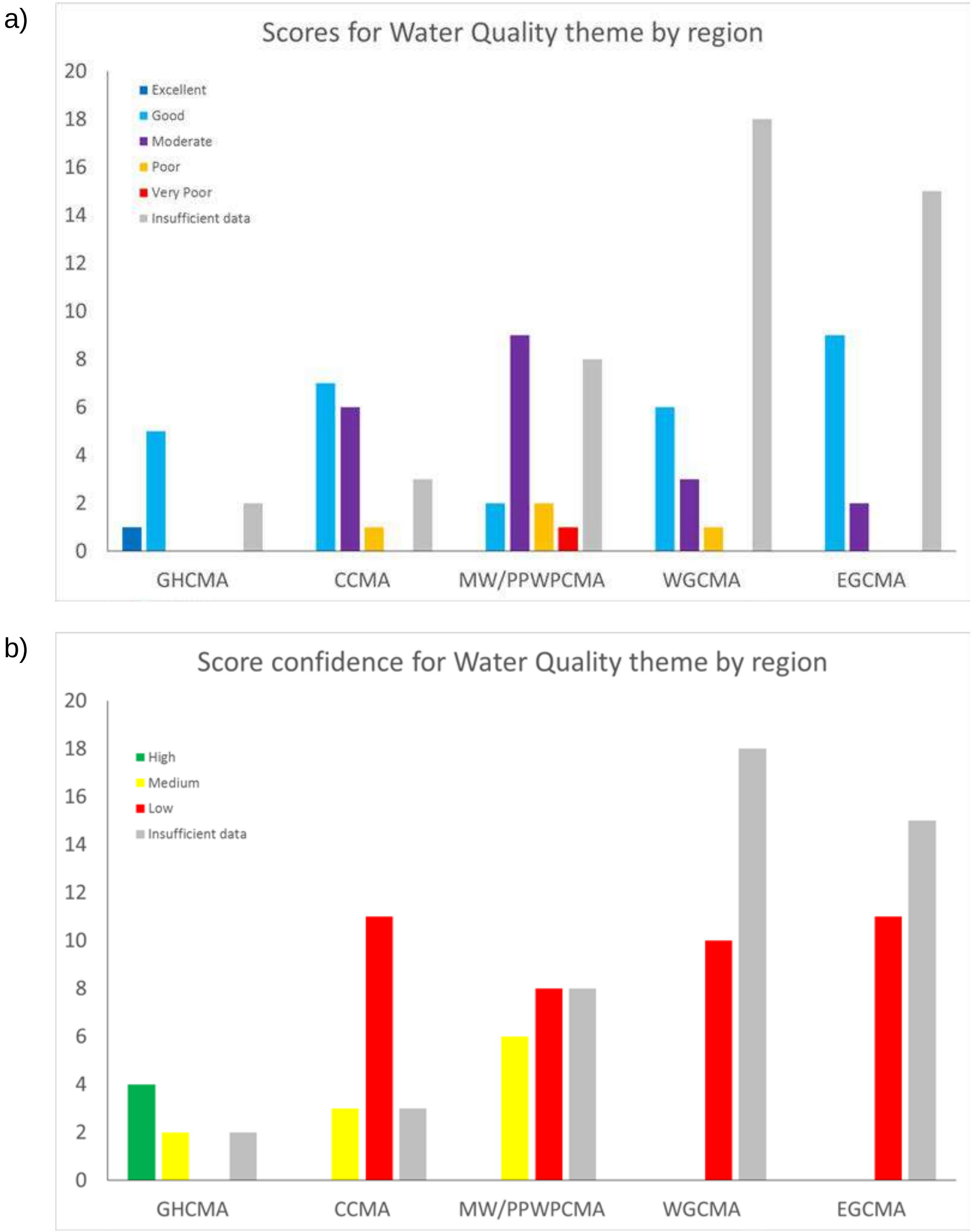


Figure 77. Combined water quality a) scores and b) confidence for estuaries by region.

10.4 SEDIMENT

Theme scores for physical form were based solely on the bank erosion (11) measure and did not use sediment particle size (10) or respiration rate (12). As there were no pre-existing data for these measures only estuaries scored for bank erosion as part of the trial implementation are included. The forty-eight estuaries that were scored had a reasonably even distribution around the middle score range with no estuaries in excellent or very poor condition (Figure 78a). This was reflected across the coast with most regions having estuaries in good, moderate and poor condition (Figure 78a). The Corangamite CMA region had proportionally more estuaries in poor condition than other regions (Figure 78a). The majority of estuaries could be scored with high to medium confidence (Figure 79a). At the regional level Glenelg Hopkins CMA did not have any estuaries that could be scored with high confidence and East Gippsland CMA region only had two estuaries that could be scored with high confidence (Figure 79b).

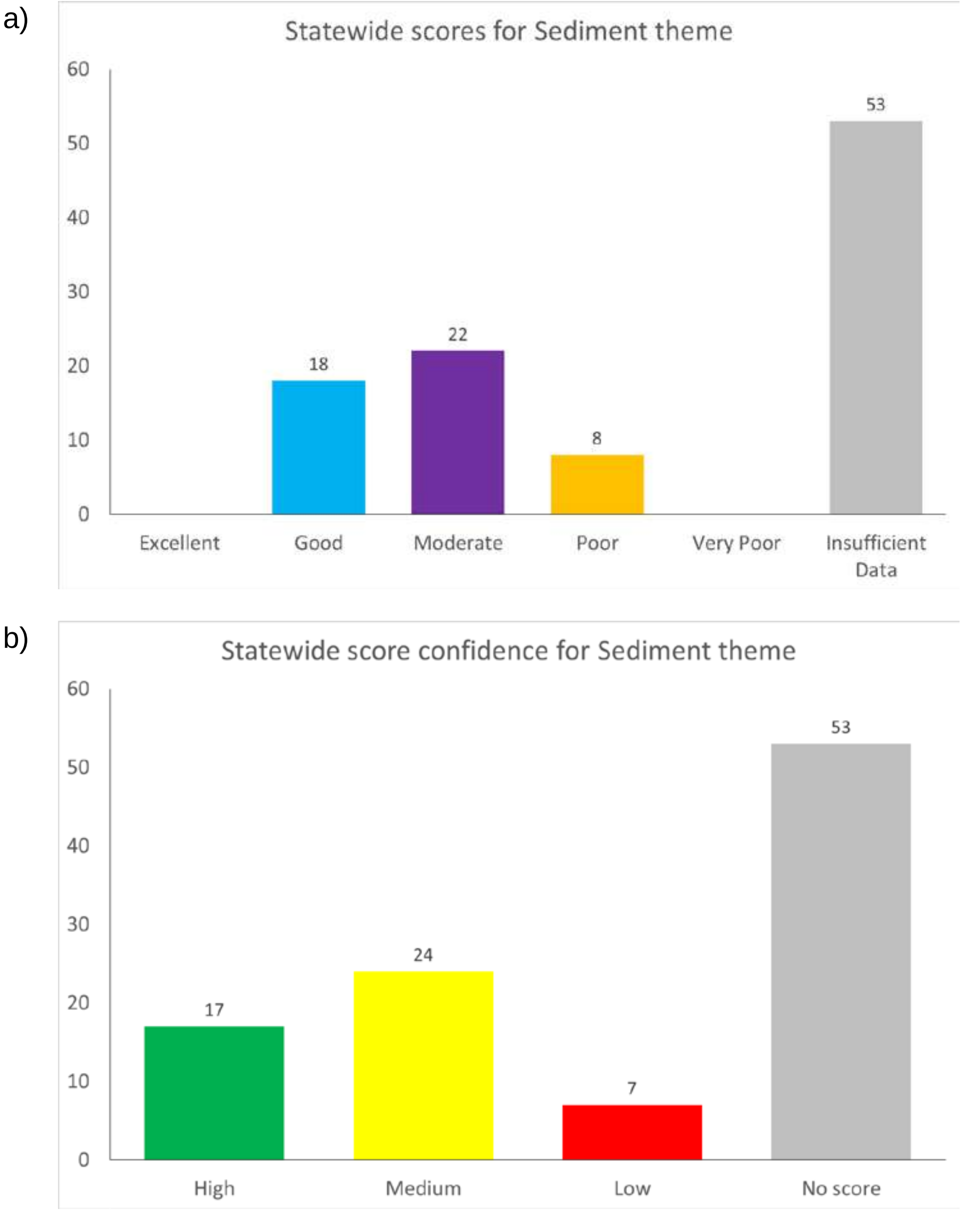


Figure 78. Sediment (bank erosion) a) scores and b) confidence for estuaries statewide.

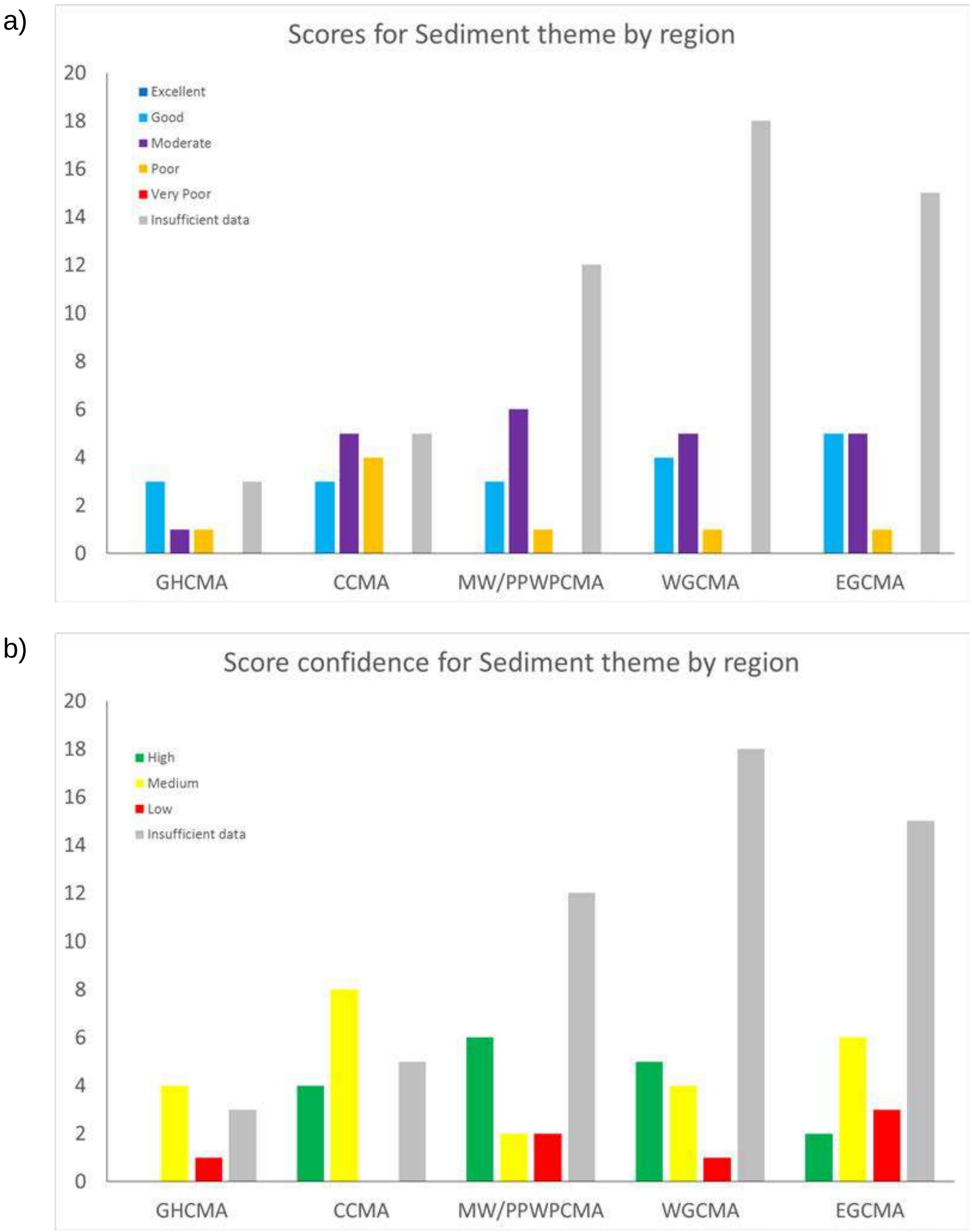


Figure 79.Sediment (bank erosion) a) scores and b) confidence for estuaries by region.

10.5 FLORA

Theme scores for Flora were derived mostly using the phytoplankton (16) measure but including aquatic macrophyte extent (13a) and fringing macrophytes (14) where available. They did not use the macroalgal cover (13b1), number of macroalgal blooms (13b2) and microphytobenthos (15) measures. Aquatic macrophyte extent (13a) was only available for Painkalac, Anglesea, Wingan Inlet and Mallacoota Inlet. The fringing macrophytes measure (14) was only available for Anderson Inlet. Fifty-six estuaries were not able to be scored for the IEC Flora theme (Figure 80), 17 of these estuaries were in the Melbourne Water/Port Phillip Western Port CMA and 32 in the two Gippsland CMAs (Figure 81). Of the 45 that could be scored only six scored as very poor and seven as poor. Eleven estuaries scored as excellent and sixteen as moderate. Corangamite CMA region had six of its thirteen estuaries score as excellent for the flora theme. All the confidence scores for the flora theme were low.

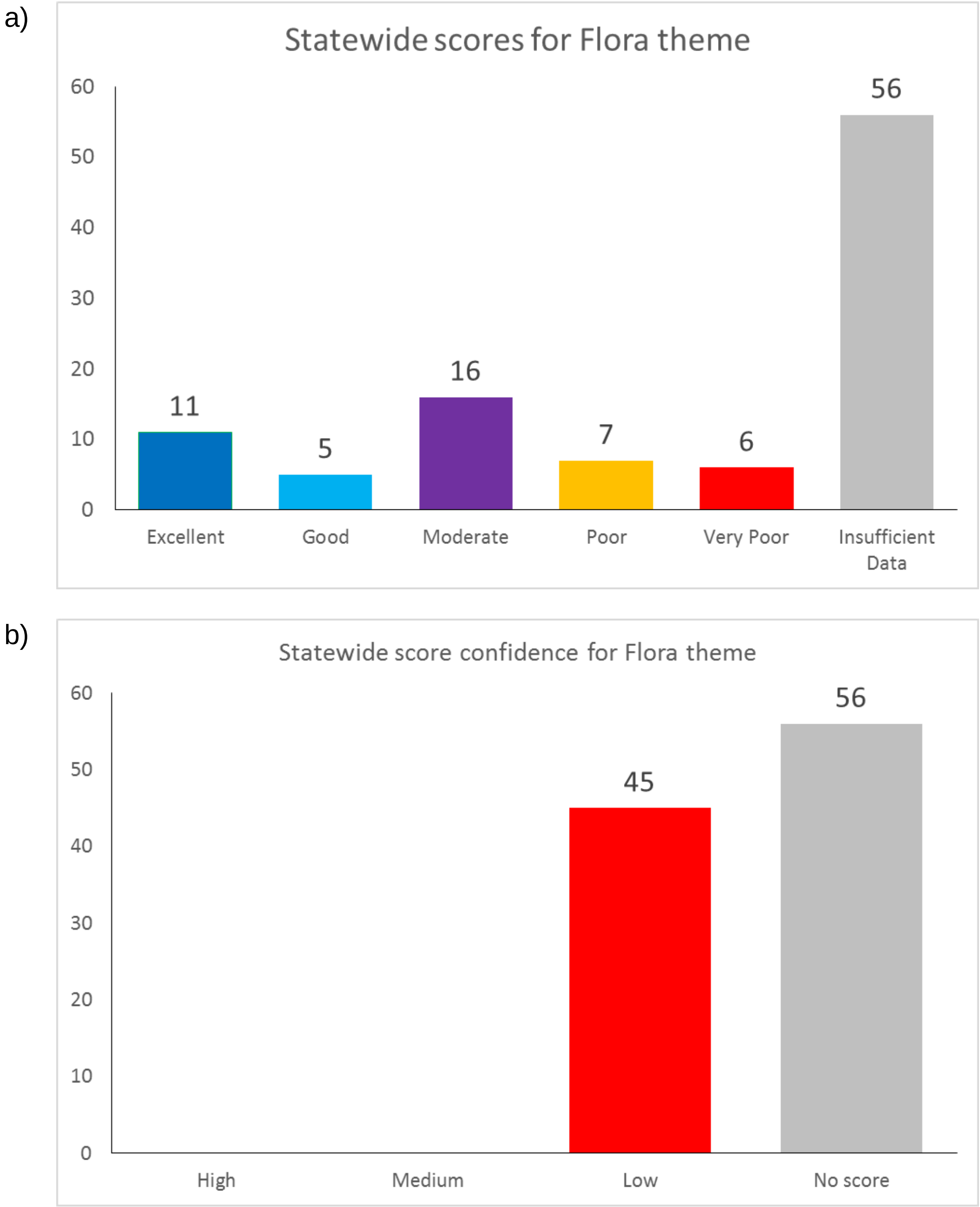


Figure 80. Flora a) scores and b) confidence for estuaries statewide.

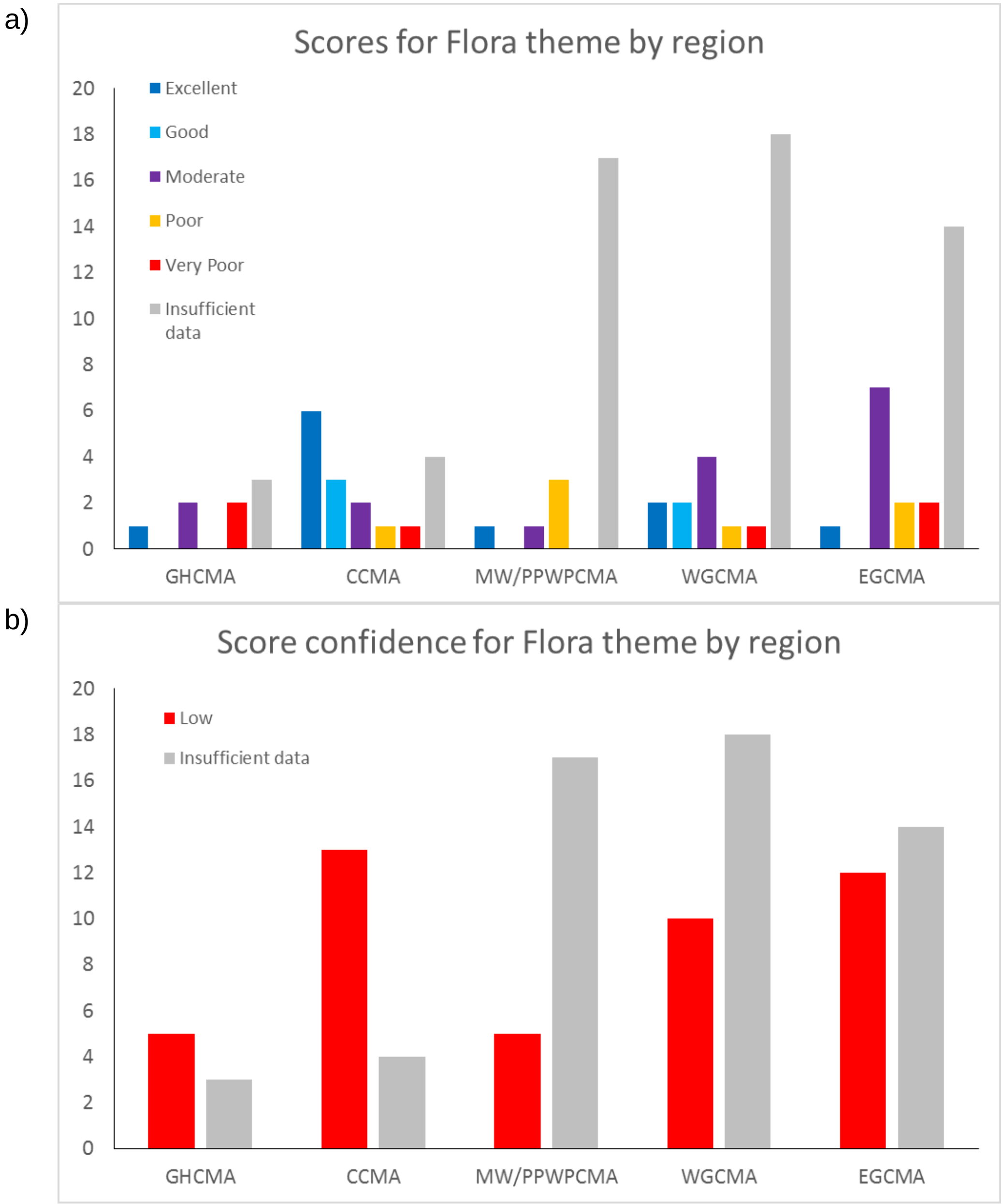


Figure 81. Flora a) scores and b) confidence for estuaries by region.

10.6 FAUNA

The scores for individual estuaries were not reported in Warry and Reich (2014), so a Fauna Theme score could not be calculated.

10.7 OVERALL IEC SCORE

The IEC, with the measures we have been able to develop, has been scored based on at least two measures in each theme. Based on our current understanding we recommend that theme scores be calculated as averages of available measures without weighting. Confidence in the score for a theme is based on the aggregated score confidence of available measures by averaging across measures substituting 3,2 and 1 as values for high, medium and low score confidences respectively. Where no data exists for a measure a confidence level of zero is included. This approach can also be used to aggregate confidence in themes to confidence in an overall IEC score. In the future when more data become available excluding low score confidences should be assessed. Also, with more data the number of measures within a theme can be assessed for redundancy, where more than one measure returns the same information, the less resource intensive measure should be kept and the other discarded.

As per the ISC, each theme contributes equally to the final IEC score and there is no weighting of themes. The Victorian Index of Wetland Condition (IWC) overall score is calculated from weighted subindex scores where the biota, hydrology and water properties subindices are given the highest weight. Other recent waterway condition assessments like the Sustainable Rivers Audit weight biota more highly than physical and hydrological themes (Davies et al. 2012). Consideration was given in the IEC as to whether ecological themes should be weighted higher in score integration than the physical and hydrological themes, for example weight fish and seagrass highly, but was rejected at this stage of IEC development. Any consideration of weighting themes requires more data and may be considered in future development of the IEC. To get an overall estuary score, add up all six theme scores and take the average, for both the score and data confidence (eg Table 123). We recommend that an overall estuary condition score needs to have at least four themes out of the possible six to be able to score an estuary. At least one biological theme of flora or fauna, and water quality, needs to be included.

Table 123. Example of overall score and confidence for Andersons Inlet. Note that no confidence estimates exist for lateral connectivity or fringing macrophytes.

	OVERALL	**PHYSICAL FORM**	**HYDROLOGY**	**WATER QUALITY**	**SEDIMENT**	**FLORA**
SCORE	**3**	**3**	**4**	**3**	**3**	**2**
CONFIDENCE	**L**	**L**	**H**	**L**	**L**	**L**
Measure scores		Sediment load (2L) Upstream barriers (3L) Lateral connectivity (1)	Marine exchange (b) (5H) Freshwater flow (a) (2M)	Water clarity (2L) Dissolved oxygen (3L)	Bank erosion (3L)	Fringing macrophytes (1) Phytoplankton (2L)

11 RECOMMENDATIONS FOR THE INDEX OF ESTUARY CONDITION

11.1 DISCUSSION

Within the timeframe and resources available to the IEC implementation project, the best available and new data and analyses have been incorporated into the IEC evaluation. This represents over four years of effort in collating and interpreting data, three intensive summer field seasons to collect additional data across the entire Victorian coastline, and a number of measure-specific pilot studies. A GIS layer of the 101 IEC estuaries has been produced for DELWP along with layers of current and historical lengths and sections that were used in assessment. From the fieldwork a large proportion of Victorian estuaries now have data for: sediment size in depositional areas, water clarity, surface dissolved oxygen scores, diurnal oxygen sags, and bank erosion (Table 126). In addition, data has been collected on sediment respiration rate for four estuaries; aquatic macrophyte cover for four; microphytobenthos biomass for 41; and phytoplankton biomass for 44 estuaries. Data collected and collated as part of the trial have assessed the modification of freshwater flow in all 101, the modification of marine connection in 86 and sediment load in 56 estuaries. Given the limited resources, we have tried to maximise the use of all existing data. While many data gaps were able to be filled, the process identified further data that would be valuable in extending the current analyses and interpretation. The data collected as part of the implementation trial and any future IECs need a high level of data management to ensure all data are spatially and temporally identified and can be used for future development of the IEC and other estuarine and natural resource management projects.

The measures recommended from this implementation trial for the first formal IEC program are suitable for state-wide application, for assessment in all Victorian estuaries. Further data collection and analysis are needed to determine if scoring of particular measures could be modified when applied to different ‘types’ of estuaries *sensu* Roper et al. (2011). All measures are conceptually linked to the condition of the estuary and where possible direct measures have been used but through necessity these links are less direct for some measures. The scores from each measure are directly comparable across Victoria’s estuaries and the degree of confidence in the measure score is given for each measure in each estuary where data were available. Score confidence is reported with the condition score so personnel can interpret the reliability of the score and relative risk of making decisions based on it (Arundel et al. 2008). Score confidence in aggregated theme scores is based on averaged measure confidence, including zero values for missing data to reflect the reduced confidence in a theme score based on incomplete information. The overall IEC score is used to put an estuary into a condition band compared to all assessed estuaries state-wide. These condition bands (excellent, good, moderate, poor, and very poor) are not all the same width.

Based on our current understanding we recommend that theme scores be calculated as averages of all measures without weighting. Confidence in the score for a theme is based on the aggregated score confidence of available measures by averaging across measures substituting 3,2 and 1 as values for high, medium and low score confidences respectively. Where no data exists for a measure a confidence level of zero is included, to reflect reduced confidence in a theme score with missing measures. This approach can also be used to aggregate confidence in themes to confidence in an overall IEC score. In the future when more data become available excluding low score confidences should be assessed. Also, with more data the number of measures within a theme can be assessed for redundancy, where more than one measure returns the same information, the less resource intensive measure should be kept and the other discarded.

As per the ISC, each theme contributes equally to the final IEC score and there is no weighting of themes. The Victorian Index of Wetland Condition (IWC) overall score is calculated from weighted subindex scores where the biota, hydrology and water properties subindices are given the highest weight. Other recent waterway condition assessments like the Sustainable Rivers Audit weight biota more highly than physical and hydrological themes (Davies et al. 2012). Consideration was given in the IEC as to whether biological themes should be weighted higher in score integration than the physical and hydrological themes, for example weight fish and seagrass highly but was rejected at this stage of IEC development. Any consideration of weighting themes requires more data and may be considered in future development of the IEC.

To get an overall estuary score, the six theme scores are summed and averaged, for both score values and score confidence. We recommend that an overall estuary condition score needs to have at least four themes out of the possible six to be able to score an estuary. At least one biological theme of flora or fauna, and water quality, needs to be included.

Like the ISC, the IEC methodology should be reviewed over time to ensure it remains up to date, incorporates recent advances in science and technology, and provides the best possible information for estuary planning and management (DEPI 2013). Future testing and periodic revision of the IEC are recommended to further develop it as a robust and credible method for the rapid assessment of estuaries. Continued development of the IEC method, information management and training programs will ensure that the IEC provides the most practical and scientifically defensible means of assessing estuarine condition in Victoria.

The IEC was developed primarily for natural resource managers, including Catchment Management Authorities (CMAs), water authorities and state agencies such as the Victorian Department of Environment Land, Water and Planning (DELWP). It was designed for the comparison of estuaries across the state at every reporting period to allow prioritisation and resource allocation. It was also designed to be complementary to the ISC and does not specifically assess threats/pressures separately from condition measures, unlike national, Queensland and NSW approaches (Scheltinga and Moss 2007; Roper et al. 2011). Waterway condition assessment in Victoria is moving away from using reference conditions towards assessing against management target condition (DEPI 2013). It is envisaged that the IEC will adopt that way in the future but this version was developed using deviation from baseline condition.

There are many management actions that can improve estuarine condition, but even if these actions are immediately implemented they may not be reflected in increased measure scores, especially biotic measures, in a single IEC period of eight years. The exact relationships between abiotic and biotic variables are often not well understood and the biotic responses to specific abiotic changes generally occur after an unknown lag period (Van Niekerk et al. 2013). Stressed ecosystems have a lower resilience to change and by management actions increasing or maintaining the resilience of estuaries, the ability of a system to recover, for example after a flood or drought, should be enhanced. The resilience of an estuary is influenced by the intactness of its catchment and estuarine habitats (Van Niekerk et al. 2013). A way to ensure resilience is the determination and implementation of estuarine ecological water requirements and the protection/rehabilitation of the estuarine functional zone (Van Niekerk et al. 2013). The processes underpinning the ecosystem services provided by estuaries, such as the assimilation and cycling of nutrients, also need to be protected if resilience is to be maintained. Obvious management actions to improve estuary condition are the reduction of nutrient load from diffuse and point sources at the both the catchment and subcatchment level. Estuary specific environmental freshwater flows should also be assessed and implemented. The timing, frequency and magnitude of alteration of marine exchange, especially in intermittently open estuaries, can be addressed through management actions. Upstream barriers, or structures altering lateral connectivity such as levy bank can be removed or modified to improve connectivity.

Some characteristics of estuaries would intuitively be expected to indicate vulnerability to a particular threat. For example, estuaries with a history of fish kills would suggest an increased vulnerability to artificially opening entrances; and algal blooms a vulnerability to nutrient loads (Arundel et al. 2008). Further research is required to establish the importance of certain estuarine characteristics for indicating vulnerability to given threats. It is recommended that a summary report that combines elements of inventory, condition and risk reports be produced for a wider audience including national reporting (Arundel et al. 2008). Estuary status reports could provide a summary of physical information about the estuary and provide context for other elements of the report which could include:

- Integrated IEC scores as a summary of the ecological condition and condition targets;
- Key assets and threats including environmental, social and economic values; and
- Critical and high risks for the estuary.

Table 124. Summary of the spatial and temporal replication needed for the first formal IEC program.

Theme	Measure	Spatial scale	Temporal replication
Physical Form	Sediment load	Estuary	Eight yearly
	Upstream barriers	Estuary	Eight yearly
	Lateral connectivity	Section	Eight yearly
Hydrology	Marine exchange:		
	- mouth openings (a)	Estuary	Continuous & event
	- structures & behaviours (b)	Estuary	Event
	Freshwater flow		
	- ISC Hydrology modification score (a)	Section (tributaries)	Eight yearly
	- catchment dam density (b)	Estuary	Eight yearly
Water Quality	Water clarity (turbidity)	Section	Monthly
	Dissolved oxygen:		
	vertical profile	Section	Monthly
	overnight decrease	Section	Monthly
	Additional parameters		
	bottom pH	Section	Monthly
	bottom conductivity	Section	Monthly
	top conductivity	Section	Monthly
	stratification status	Section	Monthly
	daily flow	Section	Week before sampling
Sediment	Particle size	Zone	Eight yearly
	Bank erosion	Section	Eight yearly
Flora	Aquatic flora		
	- macrophytes (a)	Estuary or Section (large systems)	Late summer-early autumn, twice/ Eight years
	- macroalgae (b)	Zone	Eight yearly (summer or quarterly TBD)
	- macroalgal blooms (c)	Zone	Monthly & event
	Fringing macrophytes		Eight yearly
	Phytoplankton	Zone	Monthly
Fauna	Naturalness of fish:	Zone	Autumn Eight yearly
	- structural (a)		
	- functional (b)		

Table 125. Summary table of themes and measures for the first formal IEC program. Numbers assigned to measures are consistent with those used throughout the report. For some measures there are several components.

PHYSICAL FORM	HYDROLOGY	WATER QUALITY	SEDIMENT	FLORA	FAUNA
2. Sediment load (proportion change from pre-European) 3. Upstream barriers (% area affected) 4. Lateral connectivity (% estuary perimeter artificial & naturalness of lateral wetland connection)	5. Marine exchange a) mouth openings (% of artificial openings) b) structures & behaviours (dredging, # of training walls, minor structures, ‘parent system’ artificial increase) 6. Freshwater flow a) ISC Hydrology modification score) OR b) catchment dam density (catchment megalitres of storage/km^2)	8. Water clarity (% turbidity exceeding EPA (2010) guidelines) 9. Dissolved oxygen (% dissolved oxygen exceeding EPA (2010) guidelines)	10. Sediment particle size (change in surface <125 µm) 11. Bank erosion (ISC 2004 method)	13. Aquatic Flora a) Macrophytes (% change from historical to present) b1) Macroalgae (% cover) b2) Macroalgae (# of blooms) 14. Fringing macrophyte (extent & condition) 16. Phytoplankton (Chlorophyll a exceeding EPA (2010) guidelines)	17. Naturalness of fish a) Structural (proportion & # of taxa of 6 guilds) b) Functional (guild based δ15N)

Table 126. Summary of estuaries with data, and estuaries without by Catchment Management Authority (CMA) for the thirteen recommended measures. GH= Glenelg Hopkins, C = Corangamite, MW/PPWP = Melbourne Water / Port Phillip Western Port, WG = West Gippsland, EG = East Gippsland.

Theme	Measure	# of estuaries with data	# of estuaries/CMA without data				
			GH	C	MW/ PPWP	WG	EG
Physical Form	Sediment load	56	0	8	9	16	12
	Upstream barriers	67	0	1	4	18	11
	Lateral connectivity	1	8	17	22	27	26
Hydrology	Marine exchange:						
	- mouth openings (a)	37	0	5	2	4	5
	- structures & behaviours (b)	49	0	0	0	0	0
	Freshwater flow						
	- ISC Hydrology modification score (a)	59	0	2	11	16	13
	- catchment dam density (b)	42	0	0	0	0	0
Water Quality	Water clarity (turbidity)	55	2	3	8	18	15
	Dissolved oxygen: vertical profile	51	3	5	12	18	15
Sediment	Particle size	43	4	8	11	20	15
	Bank erosion	48	2	3	9	20	16
Flora	Aquatic flora						
	- macrophytes (a)	4	8	15	22	28	24
	- macroalgae (b)	0	8	17	22	28	26
	- macroalgal blooms (c)	0	8	17	22	28	26
	Fringing macrophytes	1	8	17	22	27	26
	Phytoplankton	44	3	3	17	18	16
Fauna	Naturalness of fish:						
	- structural (a)	31	5	10	11	22	22
	- functional (b)	31	5	10	11	22	22

General recommendations:

- Reguarly review the IEC methodology to ensure it incorporates recent advances in science and technology, and provides the best possible information for estuary planning and management.
- Continued development of the IEC information management and training programs.
- Further research is required to establish the importance of certain estuarine characteristics for indicating vulnerability to given threats.
- Produce an overall IEC summary report after each IEC assessment that combines elements of inventory, condition and risk reports for a wider audience, including national reporting.
- Produce individual estuary status reports that provide a summary of physical information and provide context for other elements such as: IEC scores as a summary of the ecological condition and condition targets; key assets and threats including environmental, social and economic values; and critical and high risks for the estuary.
- Address the lack of appropriate water quality and phytoplankton monitoring in Victoria's estuaries
- With more data assess excluding low score confidences from an IEC assessment.
- With more data the number of measures within a theme can be assessed for redundancy.
- With more data the weighting of individual themes could be considered.
- With more data assess if individual measures need to be modified when applied to different 'types' of estuaries.

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APPENDIX 1 AUGUST 2008 IEC MEASURE WORKSHOP PARTICIPANTS

Name	Agency/Institution
Janine Adams	Nelson Mandela Metropolitan University
Peter Scanes	NSW Department of Environment and Climate Change
Jeremy Hindell	Department of Sustainability and Environment
Vanessa Forbes	WA Department of Water
Mike Weston	Deakin University
Paul Wilson	Department of Sustainability and Environment
Sam Lake	Monash University
Nicole Barbee	University of Melbourne
Tony Roper	NSW Department of Environment and Climate Change
Dave Rissik	EPA QLD
Nina Bate	EPA Vic
David Tiller	Karoo consulting/EPA Vic
Lisa Dixon	EPA Vic
Paul Boon	Victoria University
John Gibson	University of Tasmania
John Sherwood	Deakin University
Jan Barton	Deakin University
Adam Pope	Deakin University
Helen Arundel	Deakin University
Gerry Quinn	Deakin University

APPENDIX 2 15TH AUGUST 2011 SCORING WORKSHOP PARTICIPANTS

IEC Development Team		Advisors and Observers
Deakin Uni	Adam Pope	David Ball (DPI Queenscliff)
	Jan Barton	Greg Jenkins (DPI Queenscliff)
	Gerry Quinn	Marcel Klaassen (Deakin Uni)
ARI	Birgita Hansen	Peter Scanes (NSW DEC)
	Fiona Warry	Randall Lee (EPA Vic)
	Paul Reich	Sam Lake (Monash Uni)
DSE	Paul Wilson	Tony Roper (NSW DEC)
		Dan Borg (Melb Water)
		Trish Grant (Melb Water)
		Cao Lei (U of Science and Technology of China)

Appendix 3 Potential estuary data identified through consultation with coastal CMAs and Melbourne Water for the IEC implementation trial

Abbreviations, GH = Glenelg Hopkins CMA, CC = Corangamite CMA, MW = Melbourne Water, WG = West Gippsland CMA, EG = East Gippsland CMA. Specific data types in each theme relate to the needs of the IEC implementation trial.

Physical form
Changed Bathymetry
Bathymetry surveys:
GH Hopkins Dan Ierodiaconou honours thesis Deakin
Glenelg ground water project Laurie Laurenson Deakin
Submerged vegetation mapping Dave Ball DPI: Lake Yambuk, Surry River, Fitzroy River, Belfast Lough/Moyne River & Rutledges Cutting
CC Barwon, Gellibrand, Aire (transects Ford, Aire, Calder; linear GOR to mouth)
Barham from desnagging project?
MW Werribee flow assessment
Bass environmental flow using EFAM
Lower Yarra – Ports Authority
Parks Victoria Herring Island dredging
Patterson, Mordialloc, Kananook, Kororoit (occasionally) Parks Vic
Saltmarsh & mangrove mapping, used LiDAR data, therefore biased to clear water estuaries
Little, mixing zone study off Werribee, running project Greg Parry MAFRI
Yarra ARC linkage grant Peron Cook Monash, hydrodynamic modelling & bathymetric model.
Balcombe Ck
Flood studies
Western Treatment plant (WTP), Werribee flow assessment
Estuaries up top of Western Port Bay
EG Snowy
Ports for lower reaches of Gippsland Lakes tributaries & Mallacoota
Fish studies
Intrusion of saline water up Gippsland Lakes
Model of Tambo & Mitchell, mouth to road for woody structures project
ISC stream network LiDAR, Paul Wilson DSE
Historical use (changes in bathymetry):
GH Yambuk, Tales of Glenelg Wood, Hopkins Tooram Stones
Martin Boyer, collating historical data
Glenelg Nelson Pub Neil Shelton
Fawthrop, Garry Millach, doing estuary management plan
CC Matt White ARI for Anglesea
MW Very old history of PPB & WPB
Contact local councils, historical societies
Older guys at PV would have an idea for PPB, Wayne Hill
Lisa Kitzen, BBW changes in land use
WG Tarra, Franklin & Powlett
EG Snowy, John EGCMA media history & photos
Old Maps – Aerial photos
GH Coastal board runs
2003 GHCMA catchment
2007 Shire, Moyne flood management, South Warrnambool, Marcus Little GHCMA
CC Barwon:ostracods, past land use Deakin PhD Jessica Reeves
Reedy Lake, environmental water allocation
Lake Connewarre hydrological model, barrier to mouth

MW WTP back to 1950's
Gyrovision showing upstream barriers, camera in front of helicopters up rivers
EG 2004 imaging all private land
Native vegetation Paul Wilson chasing
DSE internal imagery Nicholson St
EGCMA lots of flood imagery, Genoa, Snowy, Cann
Aerial photos at EGCMA
Mitchell, 25 July 2007 1:10400
Mallacoota, 2/2/2007Wallagaraugh & Genoa only estuary head
18/5/2000 most of Mallacoota 2500ft
Snowy 15/5/2000 2500ft lower Snowy. Mouth up main stem to approx above estuary
2/2/2007 1:35000 runs:6 Frames: 71 near Orbost, only head section of estuary

Sediment load (current vs natural)
Sediment modelling:
GH Glenelg SKM
CC SedNet upper Barwon & Leigh
MW E2, entire catchment, big scale, bit like SEDNET <20km
Ports E2 model did land use mapping, scale?
WG Corner Inlet so presumably the estuaries flowing into it
DPI catchment run off modelling
SedNet, vegetated vs agricultural subcatchments,
E2 model of Gippsland Lakes, Chris Barry Gippsland Coastal Board
EG Sediment supply current vs pre estuaries filling up:
Genoa (Mallacoota), Wayne Erskine early 90's 92-94?, expert panel 2000
Cann (Tamboon) late 90's
Tambo late 90's
Snowy
Measured sediment loads:
CC Review of timber harvesting in the Otways
Water harvesting review
MW Flow, TSS, water quality data set
Data warehouse lowest freshwater site, water quality & flow for trial estuaries
Land use mapping:
GH Land use erosion mapping, Dan Ierodiaconou PhD thesis, Blue gums green triangle
CC land capability study
MW DPI land use & land use change, same batch as used for Barton et al. 2008
WG fluvial geomorphology of CI tributaries, land use, estimated sediment loads, estimated current bed loads & move down system
Upstream barriers:
GH GHCMA fish barriers
Works on waterways:
Works on waterways permits, seawalls etc?
Fish barrier data base
CC Upstream barriers: prioritisations hit list to take out, report, removal last 10 years
MW Old Maps – Aerial photos
Gyrovision showing upstream barriers, camera in front of helicopters up rivers
WG Bennison, stops salt wedge at road structure, lower Franklin road
EG Mapping for fish movement as part of Nicholson Dam decommission
Paul Bennett systematic state-wide survey for fish

Lateral Connectivity (# & type of artificial structures on foreshore)
Old Maps – Aerial photos
MW WTP back to 1950's
WG CMA to list estuary aerial photo coverage. All their photos are digital and rectified
Works on waterways:
CC record of last 10 years, seawalls, jetties, levees, platforms
MW Development services group MW, record of what done in estuarine sections

PV manages moorings & jetties + some construction
Councils manage boat ramps
Local safety & env. Management plans for local ports, Wayne Hill PV
Werribee, council jetty, other PV
Kororoit council
Melbourne Port Authority, Peter Gipps Manager Env Services re Yarra & Maribrynong
WG Geoff Taylor WGCMA
Gippsland Coastal Board
EG Penny Neumann EGCMA stat planning officer for E & W: seawalls, jetties & levies.
Hydrology
Marine Exchange-
mouth openings (AHD & number)
GH EEMS records last 1.5 years description of berm height & max width,
MW Balcombe, check assets report, EEMSS, friends group photos point.
CC since 2001
WG Powlett
Merriman, has flow as town water supply for Seaspray
Wreck & Bourne Ck, council opens
EG record of notification for last 2 years Snowy
PV records Sydenham, Thurra, and Mallacoota
DSE Lake Tyers
dredging:
GH Fawthrop want to dredge
Moyne Ports Board dredging
CC none known
WG Gippsland Port Authority
Artificial structures keeping mouth open:
GH Fawthrop, Moyne, Merri
CC old Anglesea, old Gellibrand, rock wall Wild Dog, marina Barham
MW Merricks, Patterson, Mordialloc, Kananook
EG Gippsland Lakes, reinforcing/armouring silt jetties

Freshwater Flow
Farm dams:
GH Southern Rural Water
Waterway & Wetland manager GHCMA, dams, extraction licenses
CC sustainable diversion project, State-wide GIS layer 2004
MW Little River & Mornington Peninsula
Sustainable diversion limit assessment
EFLOW or Diversion grp
Freshwater flow records
GH Surrey 2 telemetric flow gauge, State-wide Thesis
MW Hydrographic team, modelling
Cardinia & Bunyip Flow studies, Werribee & Bass detailed Flow studies
EG DPI Maffra & Gippsland Regional Water Monitoring Network contact?
Harvested coastal streams:
CC Barham, Erskine, St George, Painkalac (Barwon Water), Gellibrand (Wannon Water)
WG Merriman & Tarra stressed rivers flow study
Powlett, flow risk assessment
La Trobe & Avon environmental flow studies, Anderson Inlet current
Tarra, Tarwin, Powlett, Thompson, Latrobe, Avon & East Gippsland estuaries, REALM reports, SKM modelling.
Corner Inlet, hydrological model for entire catchment, Water Technology & Melbourne Uni
Southern Basins SRM, Paul Wilson DSE
Off take upstream of estuaries Gippsland Water
Southern Rural Water & West Gippsland Water extraction licences

Extraction:
EG East Gippsland, Gippsland and South Gippsland Water Authorities unregulated systems
Southern Rural and Melbourne Water for regulated systems
Groundwater:
GH Glenelg PhD Darren Herpic SA

Salinity Regime
GH Estuary monitoring program, monthly fixed sites 7 estuaries
Darlot, salinity from Lake Condah fish project
Glenelg 2 telemetric EC logging (recent)
CC Estuary Watch, plus two loggers Gellibrand & ?
MW Yarra & Werribee fish studies
Friends of Watsons Creek, integrated catchment project
EG Snowy, pre-opening surveys Theiss & Waterwatch
PV pre-opening monitoring

Water quality
Water Clarity (turbidity)
GH Estuary monitoring program
CC estuary watch (categorical data)
MW In estuary, check which freshwater fixed sites in estuaries
Werribee WTP collected across mouth
WG Estuary watch, Franklin surface waters
EG Theiss, Waterwatch (Snowy) & PV pre-opening monitoring

Dissolved Oxygen (mg/L & %)
GH Estuary monitoring program, 7 estuaries
Telemetry stations record level, DO, temp
EEMS records last 1.5 years
Surrey water quality, nutrients study (N&P) Deakin report
Hopkins Estuary watch
CC Estuary watch does not do DO
MW Check which freshwater fixed sites in estuaries
Werribee WTP collected across mouth
WG Waterwatch Franklin surface waters, DO from 2008
EG Theiss, Waterwatch (Snowy) & PV pre-opening monitoring

Sediment
Sediment Particle size
GH Surrey benthic chamber work & nutrient study
CC Connewarre, Peter Dalhouse Ballarat Uni, Aire mouth, Gellibrand (Chris Gippel)
Thompson from decommissioning sewage pipe under mouth Barwon Water
MW EIS
DPI fisheries, MAFI fisheries, fisheries habitat assessment
Bass, Peter Dan, Phillip Island Nature Park Reserve, have an idea of studies & grey literature
WG John Hinwood & E McClaine sediment cores – mouths of CI/Nooramunga estuaries, raw data

Bank Erosion (ISC method)
Photos of best & worst bank conditions
GH Glenelg Parks Vic boat wash
Hopkins around Rowans Lane, Fitzroy mouth
Fitzroy & Darlot, Lake Condah project ARI
CC Est Watch initial condition assessment
MW Watson Creek
WG Desalination Plant EIS
EG Records of bank stability work since 2005

Shoreline erosion Gippsland Lakes report, Eric Sjerp Ethos NRM

Sediment Respiration Rate (incubated core tubes)
None

Flora and Fauna
Aquatic Macroalgae
Vegetation mapping:
GH All estuaries but Hopkins, MAFRI
MW MAFRI

Fringing Macrophyte (extent & condition)
Vegetation mapping:
State-wide fringing vegetation mapping Boon 2010
GH All estuaries but Hopkins, fringing, condition measure = weeds
Index of Wetland Condition, doesn't do tidal wetlands does do coastal saline
Brad Harkey LIDAR coastal 0.5m contours (talk to Dan)
Flood studies: Surrey inundation extent mouth closure, Moyne, South Warrnambool
Glenelg Shire Council 2m contour across all shire LIDAR
CC Curdies, Gellibrand, Aire, Barham, Painkalac, Anglesea, Spring, Thompson, like GHCMA
MW Management Plan Cardinia, Inlets, terrestrial vegetation, Jeff Yugovic study
Kororoit, bend below big bridge detailed veg mapping
Warringine park around estuary managed by council, might have management plan
WG High value rivers in Gippsland, weed mapping, spatial layers
Spartina mapping Parks Vic Dowd Morass
Wetland mapping Gippsland Lakes, Parks Vic?
Fringing veg historical photos:
CC Gellibrand, Aire (Alluvium study), Barwon, Yugovic study, RAMSAR listing
Connewarre Values Project Parks Vic
MW Management plan of WTP include broad mapping & assessment Jeff Carr 1987, 1999
Major vegetation changes, Paul Boon, Steve Sinclair, Matt White Tom Hurst projects
old land survey, pre WW2 & post WW2
WG Index of Wetland Condition, doesn't do tidal wetlands does do coastal saline
EG EVC mapping Snowy to Brodribb
Check Sjerp report, composition changes in vegetation
PV fringing wetland Lake Wellington
Estuarine Nodes Disturbance project, weed control/revegetation with PV
Lake Tyers Eastwards, not Snowy
Coastal weed survey, finished by June 2010, single site visit
High value rivers in Gippsland, weed mapping, spatial layers
Review of the condition of the lower Snowy floodplains & wetlands, Water Technology

Microphytobenthos
None

Phytoplankton (Chlorophyll a)
Records of algal blooms, macro & b/g:
Water boards should keep records of blue green blooms, have overall regional co-ordination
GH Phytoplankton & macroalgae, last 1.5 years GHCMA.
Wannon Water
CC Parks Vic keeps records for Curdies
Estuary Watch observations of macroalgal blooms
MW Werribee, Vicky Brown
Balcombe & Merricks councils
Patterson Lakes, B/G *Spiralinga*
WG Southern Rural Water

DSE in south Gippsland
EG Cabbage Tree Ck has a history of algal blooms
DSE

Naturalness of Fish –
Fish surveys
GH Surrey (Becker) & Yambuk (Bishop) Deakin PhD thesis
Fitzroy & Darlot Lake Condah study
Rutledge (Merri) & Fitzroy commercial eel fisheries
Fishing diaries
CC Environess
WG South Gippsland Water
Tarwin & Powlett freshwater fish
Anderson Inlet MAFRI/ARI
EG Nicholson R, EG Water. GHD survey, SKM initial study
fish species lists:
GH Estuary management plans, list species found
CC collected for EEMSS sites
DPI
MW ARI
WG Powlett through EEMSS
EG Fisheries management plan, DPI fisheries Lake Tyers, Mallacoota &Gippsland Lakes

Naturalness of Birds
Surveys
Birds Australia has been involved in a lot of estuary surveys
GH Orange bellied parrot surveys
Yambuk Parks Victoria
Portland Field Naturalists
EG Lower Snowy, bird surveys last three years
Bird species lists:
CC collected for EEMSS sites
DPI
MW lots of data Birds Australia
Data sharing agreement with MW, so can get ones in their area, other need to pay for.
WG Powlett through EEMSS
EG Bairnsdale Field Naturalists

APPENDIX 4 SECTIONS OF IEC ESTUARIES SAMPLED IN IMPLEMENTATION TRIAL

Table 127. Estuaries, subestuaries and sections sampled in the trial implementation of the IEC by year.

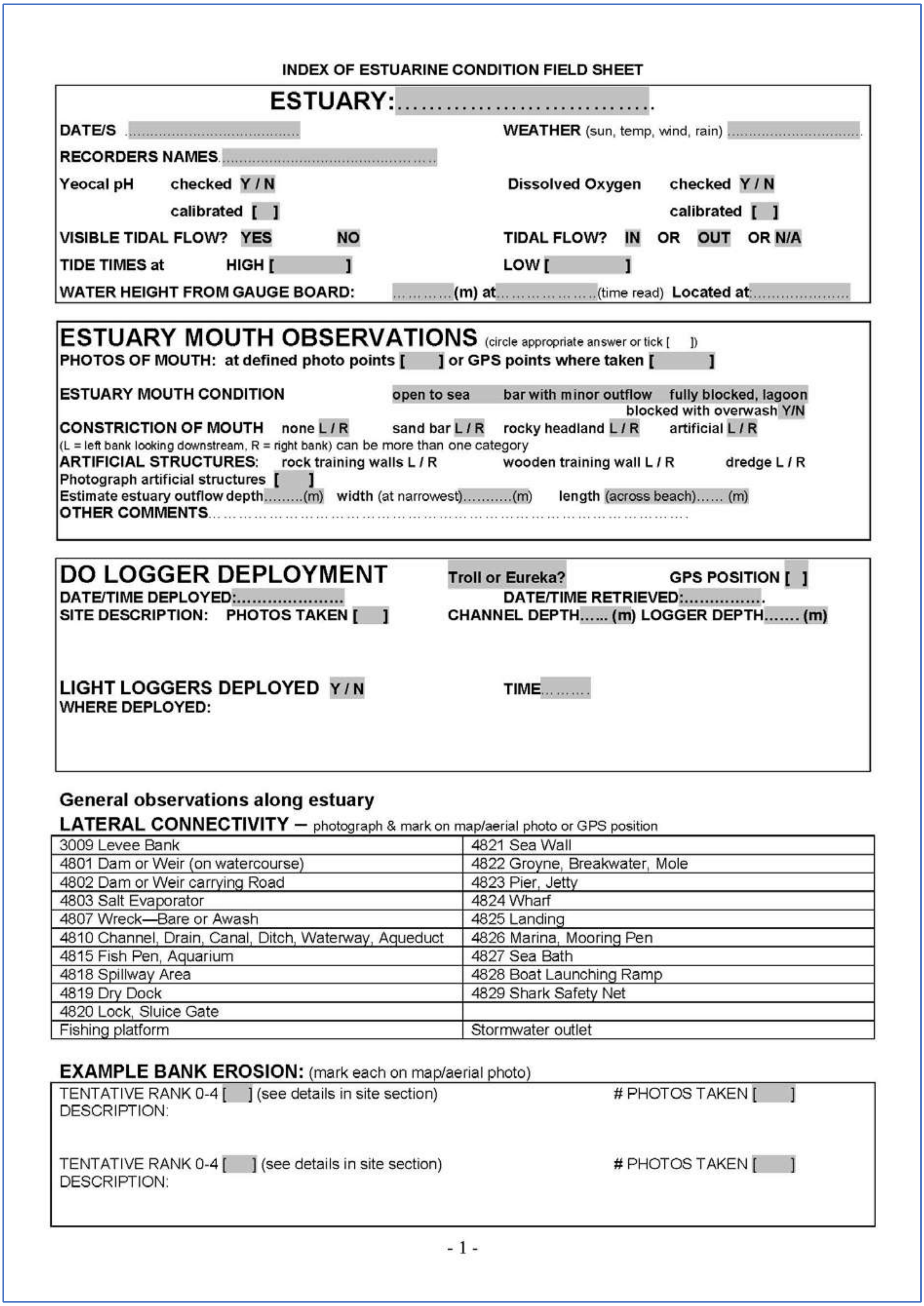
Basin ID	Estuary	Subestuary	Section name	Sect ID	2010	2011	2012
38_00	Glenelg River	Glenelg River	Glenelg River Lagoon	001_1_01	Y	Y	
38_00	Glenelg River	Glenelg River	Mud Lagoon	001_1_02	Y	Y	
38_00	Glenelg River	Glenelg River	Glenelg River	001_1_03	Y	Y	
37_00	Fitzroy River	Fitzroy River	Fitzroy River Lagoon	004_1_01		Y	
37_00	Fitzroy River	Fitzroy River	Fitzroy River	004_1_02		Y	
37_00	Lake Yambuk	Lake Yambuk	Lake Yambuk	005_1_01		Y	
37_00	Lake Yambuk	Lake Yambuk	Eumeralla River	005_1_02		Y	
36_00	Merri River	Merri River	Merri River	007_1_01	Y		
36_00	Merri River	Merri River	Saltwater Swamp	007_1_02	Y		
36_00	Hopkins River	Hopkins River	Hopkins River Lagoon	008_1_01		Y	
36_00	Hopkins River	Hopkins River	Hopkins River	008_1_02		Y	
35_00	Curdies Inlet	Curdies Inlet	Curdies Inlet	009_1_01		Y	
35_00	Curdies Inlet	Curdies Inlet	Curdies River	009_1_02		Y	
35_00	Campbell Creek	Campbell Creek	Campbell Creek	010_1_01		Y	
35_00	Gellibrand River	Gellibrand River	Gellibrand River Lagoon	012_1_01		Y	
35_00	Gellibrand River	Gellibrand River	Gellibrand River	012_1_02		Y	
35_00	Gellibrand River	LaTrobe Creek	LaTrobe Creek	012_2_03		Y	
35_00	Aire River	Aire River	Aire River Lagoon	014_1_01	Y	Y	
35_00	Aire River	Aire River	Aire River	014_1_02	Y	Y	
35_00	Aire River	Ford River	Ford River	014_2_03		Y	
35_00	Aire River	Ford River	Lake Hordern	014_2_04		Y	
35_00	Aire River	Lake Craven	Lake Craven	014_3_05	Y	Y	
35_00	Barham River	Barham River	Barham River Lagoon	015_1_01	Y		
35_00	Barham River	Barham River	Barham River	015_1_02	Y		
35_00	Barham River	Barham Lagoon South	Barham Lagoon South	015_2_03	Y		
35_00	Kennett River	Kennett River	Kennett River	016_1_01	Y		
35_00	Wye River	Wye River	Wye River	017_1_01		Y	
35_00	Erskine River	Erskine River	Erskine River	019_1_01		Y	
35_00	Painkalac Creek	Painkalac Creek	Painkalac Creek Lagoon (Aireys Inlet)	020_1_01	Y		
35_00	Painkalac Creek	Painkalac Creek	Painkalac Creek	020_1_02	Y		
35_00	Anglesea River	Anglesea River	Anglesea River Lagoon	021_1_01		Y	
35_00	Anglesea River	Anglesea River	Anglesea River	021_1_02		Y	
35_00	Anglesea River	Anglesea River	Coogoorah Park	021_1_03		Y	
35_00	Spring Creek	Spring Creek	Spring Creek	022_1_01	Y		
35_00	Thompson Creek	Thompson Creek	Thompson Creek	023_1_01		Y	
35_00	Thompson Creek	Thompson Creek	Thompson Creek	023_1_02		Y	
32_00	Limeburners Lagoon	Limeburners Lagoon	Limeburners Lagoon	025_1_01			Y
32_00	Limeburners Lagoon	Limeburners Lagoon	Hovells Creek	025_1_02			Y

Basin ID	Estuary	Subestuary	Section name	Sect ID	2010	2011	2012
32_00	Little River	Little River	Little River	026_1_01	Y		
31_00	Werribee River	Werribee River	Werribee River Lagoon	027_1_01	Y		
31_00	Werribee River	Werribee River	Werribee River	027_1_02	Y		
31_00	Kororoit Creek	Kororoit Creek	Kororoit Creek	030_1_01	Y		
29_30	Yarra River	Yarra River	Yarra Port Area	031_1_01	Y		
29_30	Yarra River	Yarra River	Yarra River	031_1_02	Y		
29_30	Yarra River	Stony Creek	Stony Creek	031_2_03	Y		
29_30	Yarra River	Maribyrnong River	Maribyrnong River	031_3_04	Y		
29_30	Yarra River	Moonee Ponds Creek	Moonee Ponds Creek	031_4_05	Y		
28_00	Balcombe Creek	Balcombe Creek	Balcombe Creek Lagoon	036_1_01	Y		
28_00	Balcombe Creek	Balcombe Creek	Balcombe Creek	036_1_02	Y		
28_00	Merricks Creek	Merricks Creek	Merricks Creek	037_1_01	Y		
28_00	Cardinia Creek	Cardinia Creek	Cardinia Creek	038_1_01	Y		
28_00	Bunyip River	Bunyip River	Bunyip River	040_1_01	Y		
27_00	Bass River	Bass River	Bass River	044_1_01	Y		
27_00	Powlett River	Powlett River	Powlett River Lagoon	047_1_01	Y	Y	
27_00	Powlett River	Powlett River	Powlett River	047_1_02	Y	Y	
27_00	Powlett River	Bridge Creek	Bridge Creek	047_2_03		Y	
27_00	Anderson Inlet	Anderson Inlet	Anderson Inlet	049_1_01	Y	Y	
27_00	Anderson Inlet	Anderson Inlet	Tarwin River	049_1_02	Y	Y	
27_00	Anderson Inlet	Screw Creek	Screw Creek	049_2_03	Y	Y	
27_00	Tidal River	Tidal River	Tidal River	052_1_01	Y	Y	
27_00	Miranda Creek	Miranda Creek	Miranda Creek	055_1_01	Y		
27_00	Chinaman Creek	Chinaman Creek	Chinaman Creek	056_1_01			Y
27_00	Bennison Creek	Bennison Creek	Bennison Creek	059_1_01			Y
27_00	Franklin River	Franklin River	Franklin River	060_1_01			Y
27_00	Franklin River	Franklin River	Franklin River	060_1_02			Y
27_00	Tarra River	Tarra River	Tarra River Lagoon	065_1_01	Y		Y
27_00	Tarra River	Tarra River	Tarra River	065_1_02	Y		Y
27_00	Merriman Creek	Merriman Creek	Merriman Creek Lagoon	070_1_01			Y
27_00	Merriman Creek	Merriman Creek	Merriman Creek	070_1_02			Y
25_00	Avon River	Avon River	Avon River	073_1_01			Y
25_00	Avon River	Perry River	Perry River	073_2_02			Y
24_23	Mitchell/Nicholson	Mitchell River	Mitchell River	077_1_01	Y		Y
24_23	Mitchell/Nicholson	Jones Bay	Jones Bay	077_2_02	Y		Y
24_23	Mitchell/Nicholson	Nicholson River	Nicholson River	077_3_03	Y		Y
23_00	Lake Bunga	Lake Bunga	Lake Bunga	082_1_01	Y		Y
23_00	Lake Tyers	Nowa Nowa Arm	Lake Tyers (Lower)	083_1_01	Y		
23_00	Lake Tyers	Nowa Nowa Arm	Nowa Nowa Arm (Lower)	083_1_02	Y		
23_00	Lake Tyers	Nowa Nowa Arm	Nowa Nowa Arm (Upper)	083_1_03	Y		
23_00	Lake Tyers	Toorloo Arm	Fishermans Arm	083_2_04	Y		
23_00	Lake Tyers	Toorloo Arm	Toorloo Arm (Lower)	083_2_05	Y		

Basin ID	Estuary	Subestuary	Section name	Sect ID	2010	2011	2012
23_00	Lake Tyers	Toorloo Arm	Toorloo Arm (Upper)	083_2_06	Y		
23_00	Lake Tyers	Toorloo Arm	Blackfellows Arm	083_2_07	Y		
22_00	Snowy River	Snowy River	Snowy River Lagoon	084_1_01	Y		
22_00	Snowy River	Snowy River	Frenchs Narrows	084_1_02	Y		
22_00	Snowy River	Snowy River	Snowy River	084_1_03	Y		
22_00	Snowy River	Lake Corringle	Lake Corringle	084_2_04	Y		
22_00	Snowy River	Brodribb River	Brodribb River	084_3_05	Y		
22_00	Snowy River	Brodribb River	Lake Curlip	084_3_06	Y		
22_00	Snowy River	Brodribb River	Brodribb Diversion Channel	084_3_07	Y		
22_00	Snowy River	Cabbage Tree Creek	Cabbage Tree Creek (below lagoon)	084_4_08	Y		
22_00	Snowy River	Cabbage Tree Creek	Cabbage Tree Creek Lagoon	084_4_09	Y		
22_00	Snowy River	Cabbage Tree Creek	Cabbage Tree Creek (above lagoon)	084_4_10	Y		
21_00	Yeerung River	Yeerung River	Yeerung River Lagoon	085_1_01	Y		
21_00	Yeerung River	Yeerung River	Yeerung River	085_1_02	Y		
21_00	Sydenham Inlet	Sydenham Inlet	Sydenham Entrance Channel	086_1_01			Y
21_00	Sydenham Inlet	Sydenham Inlet	Sydenham Inlet	086_1_02			Y
21_00	Sydenham Inlet	Sydenham Inlet	Bemm River	086_1_03			Y
21_00	Sydenham Inlet	Swan Lake	Swan Lake Channel	086_2_04			Y
21_00	Sydenham Inlet	Swan Lake	Swan Lake	086_2_05			Y
21_00	Mueller River	Mueller River	Mueller River Lagoon	089_1_01			Y
21_00	Mueller River	Mueller River	Mueller River	089_1_02			Y
21_00	Mueller River	Camp Creek	Camp Creek	089_2_03			Y
21_00	Wingan Inlet	Wingan Inlet	Wingan Inlet	090_1_01	Y		Y
21_00	Wingan Inlet	Wingan Inlet	Wingan River	090_1_02	Y		Y
21_00	Shipwreck Creek	Shipwreck Creek	Shipwreck Creek	095_1_01	Y		Y
21_00	Davis Creek	Davis Creek	Davis Creek	097_1_01			Y
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Entrance Shoals	098_1_01			Y
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Bottom Lake	098_1_02			Y
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Top Lake	098_1_03			Y
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Gypsy Point Reach	098_1_04			Y
21_00	Mallacoota Inlet	Mallacoota Inlet	Wallagaraugh River	098_1_05			Y
21_00	Mallacoota Inlet	Double Creek Arm	Double Creek Arm	098_2_06			Y
21_00	Mallacoota Inlet	Double Creek Arm	Double Creek	098_2_07			Y
21_00	Mallacoota Inlet	Genoa River	Genoa River	098_3_08			Y
21_00	Mallacoota Inlet	Maramingo Creek	Maramingo Creek	098_4_09			Y
21_00	Mallacoota Inlet	Harrison Creek Arm	Harrison Creek Arm	098_5_10			Y
21_00	Mallacoota Inlet	Harrison Creek Arm	Harrison Creek	098_5_11			Y
21_00	Mallacoota Inlet	Teal Creek	Teal Creek	098_6_12			Y

Basin ID	Estuary	Subestuary	Section name	Sect ID	2010	2011	2012
21_00	Mallacoota Inlet	Dowell Creek	Dowell Creek	098_7_13			Y
28_00	Watsons Creek	Watsons Creek	Watsons Creek	998_1_01	Y		
28_00	Warringine Creek	Warringine Creek	Warringine Creek	999_1_01	Y		

APPENDIX 5 PROFORMA FIELD SHEET FOR IMPLEMENTATION TRIAL



INDEX OF ESTUARINE CONDITION FIELD SHEET

ESTUARY:……………………………….

DATE/S ……………………………………… **WEATHER** (sun, temp, wind, rain) ………………………………

RECORDERS NAMES………………………………………………

Yeocal pH checked **Y / N** **Dissolved Oxygen** checked **Y / N**

calibrated **[ ]** calibrated **[ ]**

VISIBLE TIDAL FLOW? YES NO **TIDAL FLOW? IN OR OUT OR N/A**

TIDE TIMES at HIGH [ ] **LOW [ ]**

WATER HEIGHT FROM GAUGE BOARD: …………**(m) at**………………….(time read) **Located at**…………………

ESTUARY MOUTH OBSERVATIONS (circle appropriate answer or tick [ ])

PHOTOS OF MOUTH: at defined photo points [ ] or GPS points where taken [ ]

ESTUARY MOUTH CONDITION open to sea bar with minor outflow fully blocked, lagoon blocked with overwash Y/N

CONSTRICTION OF MOUTH none L / R sand bar L / R rocky headland L / R artificial L / R

(L = left bank looking downstream, R = right bank) can be more than one category

ARTIFICIAL STRUCTURES: rock training walls L / R wooden training wall L / R dredge L / R

Photograph artificial structures **[ ]**

Estimate estuary outflow depth………(m) width (at narrowest)………..(m) length (across beach)…… (m)

OTHER COMMENTS………………………………………………………………………………………….

DO LOGGER DEPLOYMENT

Troll or Eureka? **GPS POSITION [ ]**

DATE/TIME DEPLOYED:………………… **DATE/TIME RETRIEVED:**…………….

SITE DESCRIPTION: PHOTOS TAKEN [ ] **CHANNEL DEPTH…… (m) LOGGER DEPTH……. (m)**

LIGHT LOGGERS DEPLOYED Y / N **TIME**………

WHERE DEPLOYED:

General observations along estuary

LATERAL CONNECTIVITY – photograph & mark on map/aerial photo or GPS position

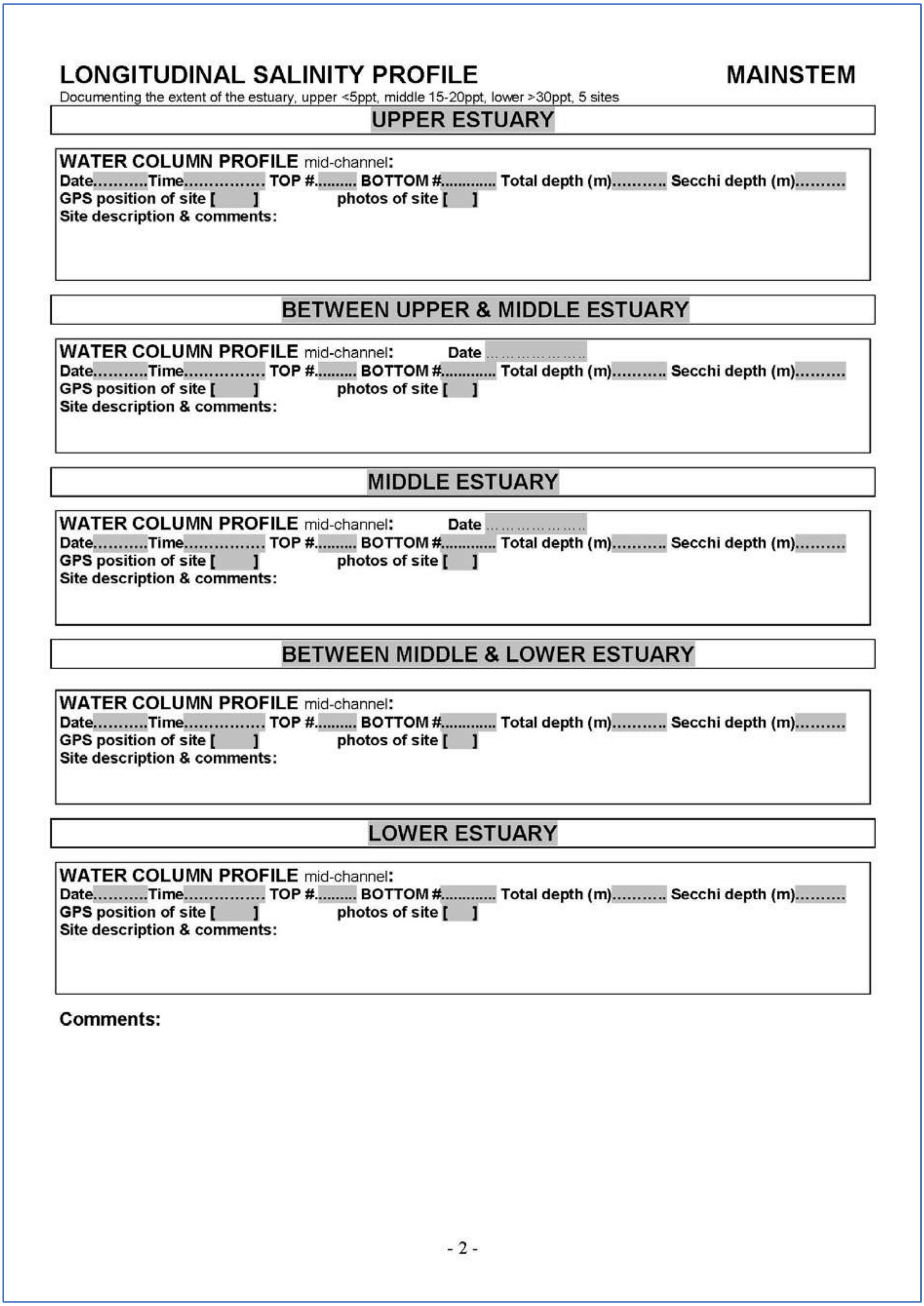
3009 Levee Bank	4821 Sea Wall
4801 Dam or Weir (on watercourse)	4822 Groyne, Breakwater, Mole
4802 Dam or Weir carrying Road	4823 Pier, Jetty
4803 Salt Evaporator	4824 Wharf
4807 Wreck—Bare or Awash	4825 Landing
4810 Channel, Drain, Canal, Ditch, Waterway, Aqueduct	4826 Marina, Mooring Pen
4815 Fish Pen, Aquarium	4827 Sea Bath
4818 Spillway Area	4828 Boat Launching Ramp
4819 Dry Dock	4829 Shark Safety Net
4820 Lock, Sluice Gate	
Fishing platform	Stormwater outlet

EXAMPLE BANK EROSION: (mark each on map/aerial photo)

TENTATIVE RANK 0-4 [ ] (see details in site section) # PHOTOS TAKEN [ ]
DESCRIPTION:

TENTATIVE RANK 0-4 [ ] (see details in site section) # PHOTOS TAKEN [ ]
DESCRIPTION:

- 1 -



LONGITUDINAL SALINITY PROFILE

MAINSTEM

Documenting the extent of the estuary, upper <5ppt, middle 15-20ppt, lower >30ppt, 5 sites

UPPER ESTUARY

WATER COLUMN PROFILE mid-channel:
Date..........Time................ TOP #......... BOTTOM #............ Total depth (m).......... Secchi depth (m)..........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

BETWEEN UPPER & MIDDLE ESTUARY

WATER COLUMN PROFILE mid-channel: **Date** ....
Date..........Time................ TOP #......... BOTTOM #............ Total depth (m).......... Secchi depth (m)..........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

MIDDLE ESTUARY

WATER COLUMN PROFILE mid-channel: **Date** ....
Date..........Time................ TOP #......... BOTTOM #............ Total depth (m).......... Secchi depth (m)..........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

BETWEEN MIDDLE & LOWER ESTUARY

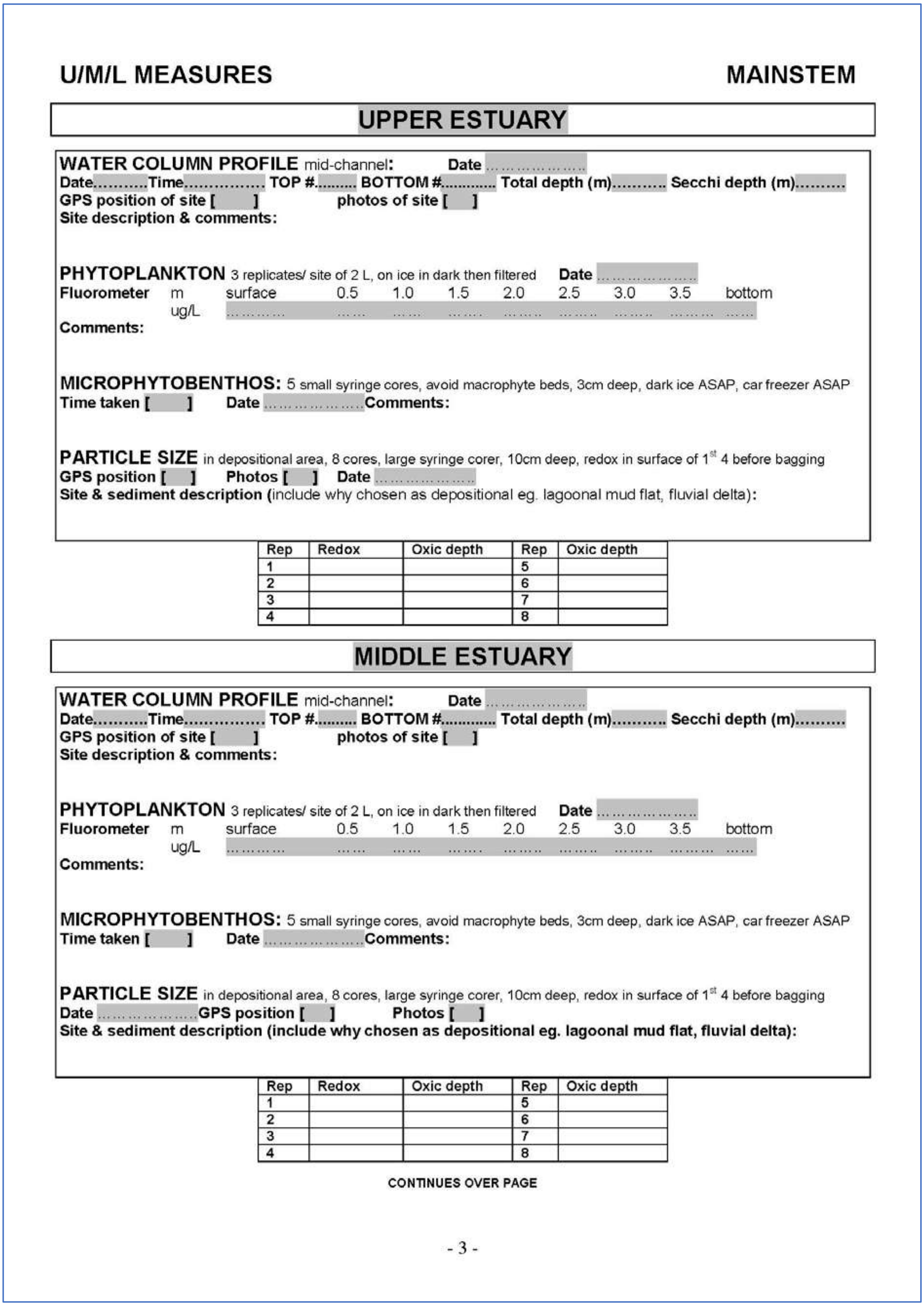
WATER COLUMN PROFILE mid-channel:
Date..........Time................ TOP #......... BOTTOM #............ Total depth (m).......... Secchi depth (m)..........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

LOWER ESTUARY

WATER COLUMN PROFILE mid-channel:
Date..........Time................ TOP #......... BOTTOM #............ Total depth (m).......... Secchi depth (m)..........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

Comments:

- 2 -



U/M/L MEASURES **MAINSTEM**

UPPER ESTUARY

WATER COLUMN PROFILE mid-channel: **Date** ………………..
Date..........Time................ TOP #......... BOTTOM #............ Total depth (m).......... Secchi depth (m).........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

PHYTOPLANKTON 3 replicates/ site of 2 L, on ice in dark then filtered **Date** ………………..

Fluorometer	m	surface	0.5	1.0	1.5	2.0	2.5	3.0	3.5	bottom
	ug/L	…………	……	……	…….	…….	…….	…….	……..	……

Comments:

MICROPHYTOBENTHOS: 5 small syringe cores, avoid macrophyte beds, 3cm deep, dark ice ASAP, car freezer ASAP
Time taken [ ] **Date** ………………..**Comments:**

PARTICLE SIZE in depositional area, 8 cores, large syringe corer, 10cm deep, redox in surface of 1st 4 before bagging
GPS position [ ] **Photos [ ]** **Date** ………………..
Site & sediment description (include why chosen as depositional eg. lagoonal mud flat, fluvial delta):

Rep	Redox	Oxic depth	Rep	Oxic depth
1			5	
2			6	
3			7	
4			8	

MIDDLE ESTUARY

WATER COLUMN PROFILE mid-channel: **Date** ………………..
Date..........Time................ TOP #......... BOTTOM #............ Total depth (m).......... Secchi depth (m).........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

PHYTOPLANKTON 3 replicates/ site of 2 L, on ice in dark then filtered **Date** ………………..

Fluorometer	m	surface	0.5	1.0	1.5	2.0	2.5	3.0	3.5	bottom
	ug/L	…………	……	……	…….	…….	…….	…….	……..	……

Comments:

MICROPHYTOBENTHOS: 5 small syringe cores, avoid macrophyte beds, 3cm deep, dark ice ASAP, car freezer ASAP
Time taken [ ] **Date** ………………..**Comments:**

PARTICLE SIZE in depositional area, 8 cores, large syringe corer, 10cm deep, redox in surface of 1st 4 before bagging
Date ………………..**GPS position [ ]** **Photos [ ]**
Site & sediment description (include why chosen as depositional eg. lagoonal mud flat, fluvial delta):

Rep	Redox	Oxic depth	Rep	Oxic depth
1			5	
2			6	
3			7	
4			8	

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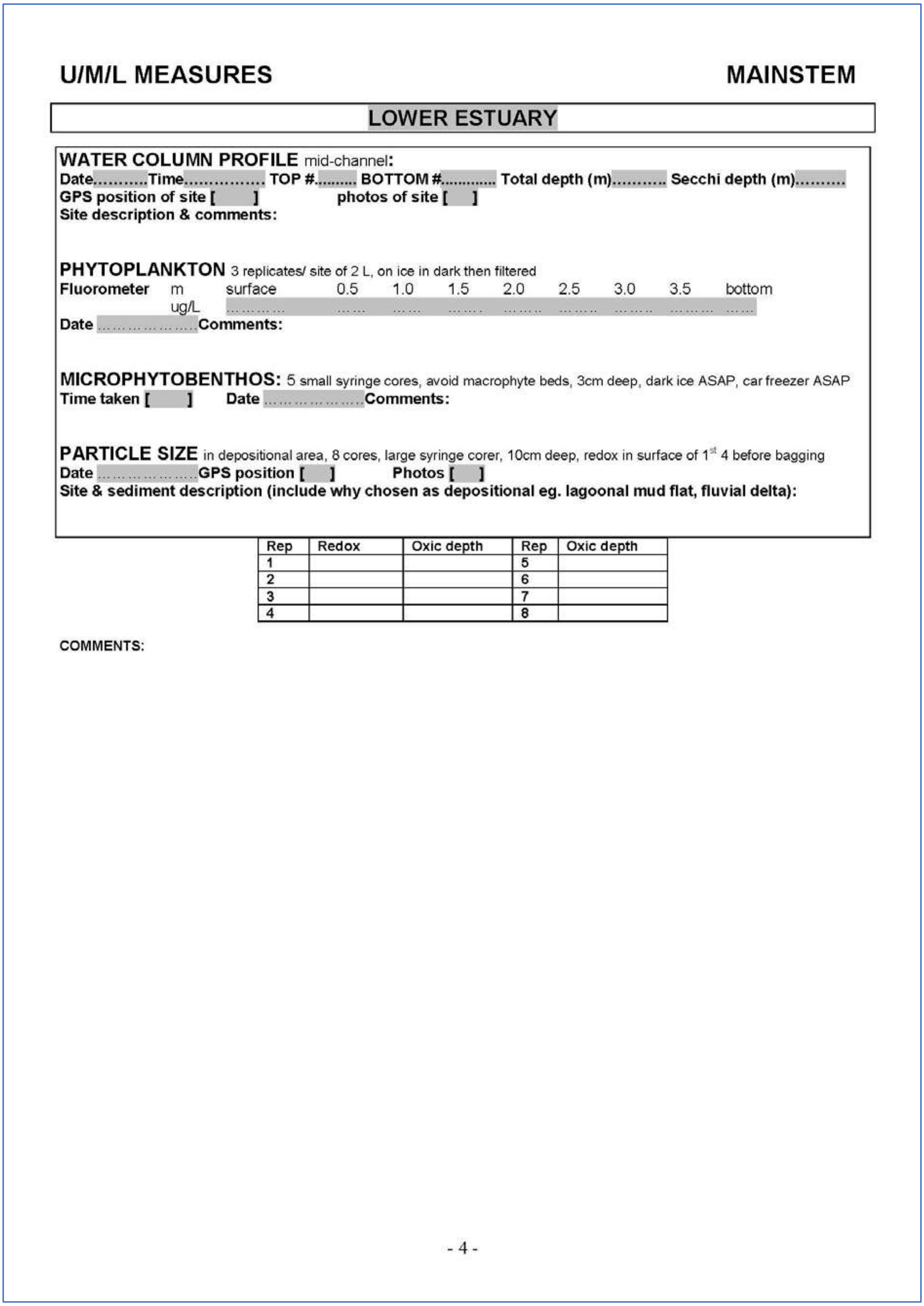
- 3 -



U/M/L MEASURES **MAINSTEM**

LOWER ESTUARY

WATER COLUMN PROFILE mid-channel**:**
Date……….Time……………. TOP #……… BOTTOM #………… Total depth (m)………. Secchi depth (m)………
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

PHYTOPLANKTON 3 replicates/ site of 2 L, on ice in dark then filtered

Fluorometer	m	surface	0.5	1.0	1.5	2.0	2.5	3.0	3.5	bottom
	ug/L	………	……	……	…….	…….	…….	…….	…….	……

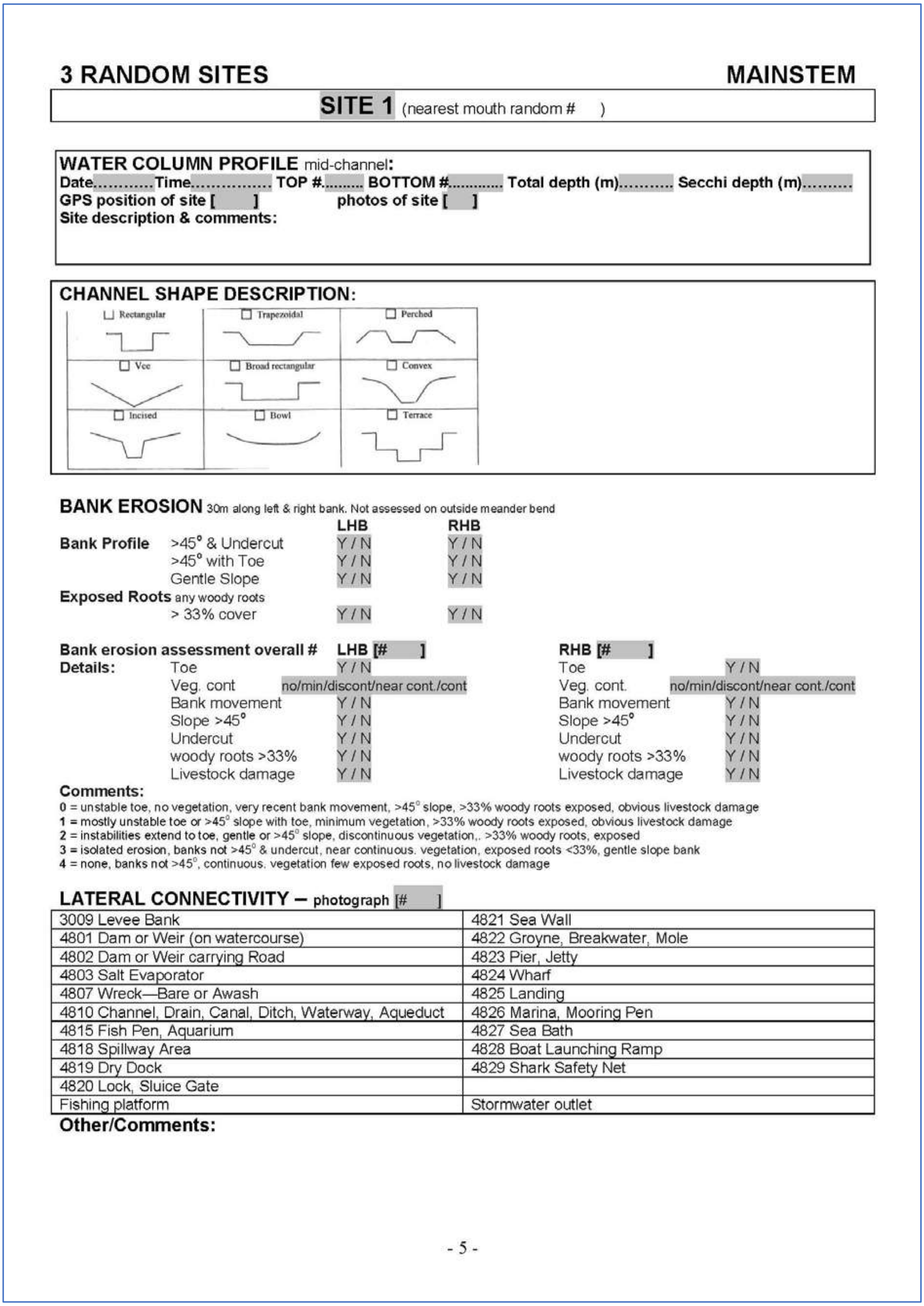
Date ……………….Comments:

MICROPHYTOBENTHOS: 5 small syringe cores, avoid macrophyte beds, 3cm deep, dark ice ASAP, car freezer ASAP
Time taken [ ] **Date ……………….Comments:**

PARTICLE SIZE in depositional area, 8 cores, large syringe corer, 10cm deep, redox in surface of 1st 4 before bagging
Date ……………….GPS position [ ] **Photos [ ]**
Site & sediment description (include why chosen as depositional eg. lagoonal mud flat, fluvial delta):

Rep	Redox	Oxic depth	Rep	Oxic depth
1			5	
2			6	
3			7	
4			8	

COMMENTS:



3 RANDOM SITES — MAINSTEM

SITE 1 (nearest mouth random #)

WATER COLUMN PROFILE mid-channel**:**
Date............**Time**................ **TOP #**......... **BOTTOM #**............ **Total depth (m)**........... **Secchi depth (m)**..........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

CHANNEL SHAPE DESCRIPTION:

☐ Rectangular	☐ Trapezoidal	☐ Perched
☐ Vee	☐ Broad rectangular	☐ Convex
☐ Incised	☐ Bowl	☐ Terrace

BANK EROSION 30m along left & right bank. Not assessed on outside meander bend

		LHB	RHB
Bank Profile	>45° & Undercut	Y / N	Y / N
	>45° with Toe	Y / N	Y / N
	Gentle Slope	Y / N	Y / N
Exposed Roots any woody roots			
	> 33% cover	Y / N	Y / N

Bank erosion assessment overall #		**LHB [#]**		**RHB [#]**
Details:	Toe	Y / N	Toe	Y / N
	Veg. cont	no/min/discont/near cont./cont	Veg. cont.	no/min/discont/near cont./cont
	Bank movement	Y / N	Bank movement	Y / N
	Slope >45°	Y / N	Slope >45°	Y / N
	Undercut	Y / N	Undercut	Y / N
	woody roots >33%	Y / N	woody roots >33%	Y / N
	Livestock damage	Y / N	Livestock damage	Y / N

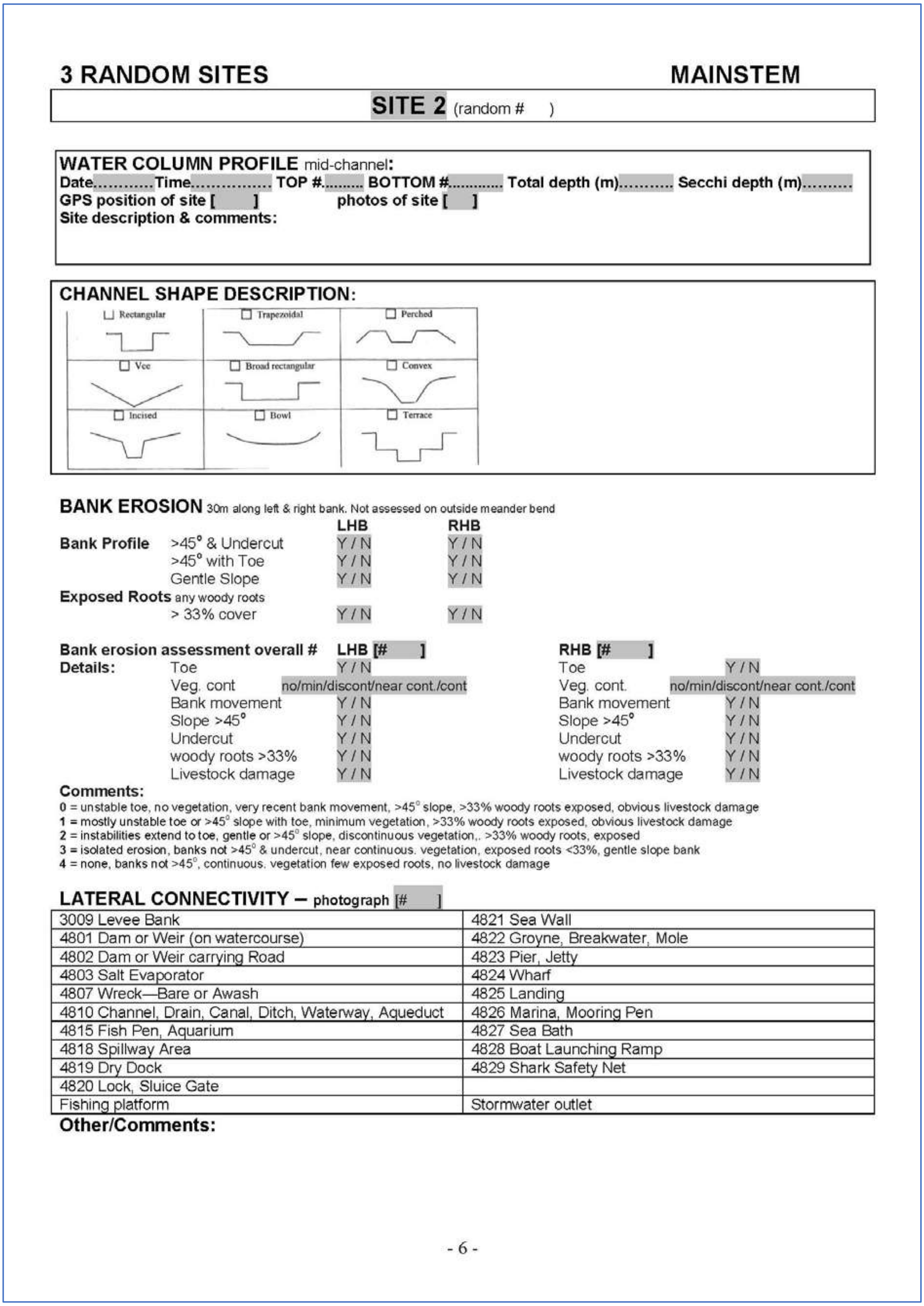
Comments:
0 = unstable toe, no vegetation, very recent bank movement, >45° slope, >33% woody roots exposed, obvious livestock damage
1 = mostly unstable toe or >45° slope with toe, minimum vegetation, >33% woody roots exposed, obvious livestock damage
2 = instabilities extend to toe, gentle or >45° slope, discontinuous vegetation,. >33% woody roots, exposed
3 = isolated erosion, banks not >45° & undercut, near continuous. vegetation, exposed roots <33%, gentle slope bank
4 = none, banks not >45°, continuous. vegetation few exposed roots, no livestock damage

LATERAL CONNECTIVITY – photograph [#]

3009 Levee Bank	4821 Sea Wall
4801 Dam or Weir (on watercourse)	4822 Groyne, Breakwater, Mole
4802 Dam or Weir carrying Road	4823 Pier, Jetty
4803 Salt Evaporator	4824 Wharf
4807 Wreck—Bare or Awash	4825 Landing
4810 Channel, Drain, Canal, Ditch, Waterway, Aqueduct	4826 Marina, Mooring Pen
4815 Fish Pen, Aquarium	4827 Sea Bath
4818 Spillway Area	4828 Boat Launching Ramp
4819 Dry Dock	4829 Shark Safety Net
4820 Lock, Sluice Gate	
Fishing platform	Stormwater outlet

Other/Comments:

- 5 -



3 RANDOM SITES **MAINSTEM**

SITE 2 (random #)

WATER COLUMN PROFILE mid-channel**:**
Date............**Time**................ **TOP #**......... **BOTTOM #**............ **Total depth (m)**........... **Secchi depth (m)**..........
GPS position of site [ ] **photos of site [ ]**
Site description & comments:

CHANNEL SHAPE DESCRIPTION:

☐ Rectangular	☐ Trapezoidal	☐ Perched
☐ Vee	☐ Broad rectangular	☐ Convex
☐ Incised	☐ Bowl	☐ Terrace

BANK EROSION 30m along left & right bank. Not assessed on outside meander bend

		LHB	**RHB**
Bank Profile	>45° & Undercut	Y / N	Y / N
	>45° with Toe	Y / N	Y / N
	Gentle Slope	Y / N	Y / N
Exposed Roots any woody roots			
	> 33% cover	Y / N	Y / N

Bank erosion assessment overall #		**LHB [#]**		**RHB [#]**
Details:	Toe	Y / N	Toe	Y / N
	Veg. cont	no/min/discont/near cont./cont	Veg. cont.	no/min/discont/near cont./cont
	Bank movement	Y / N	Bank movement	Y / N
	Slope >45°	Y / N	Slope >45°	Y / N
	Undercut	Y / N	Undercut	Y / N
	woody roots >33%	Y / N	woody roots >33%	Y / N
	Livestock damage	Y / N	Livestock damage	Y / N

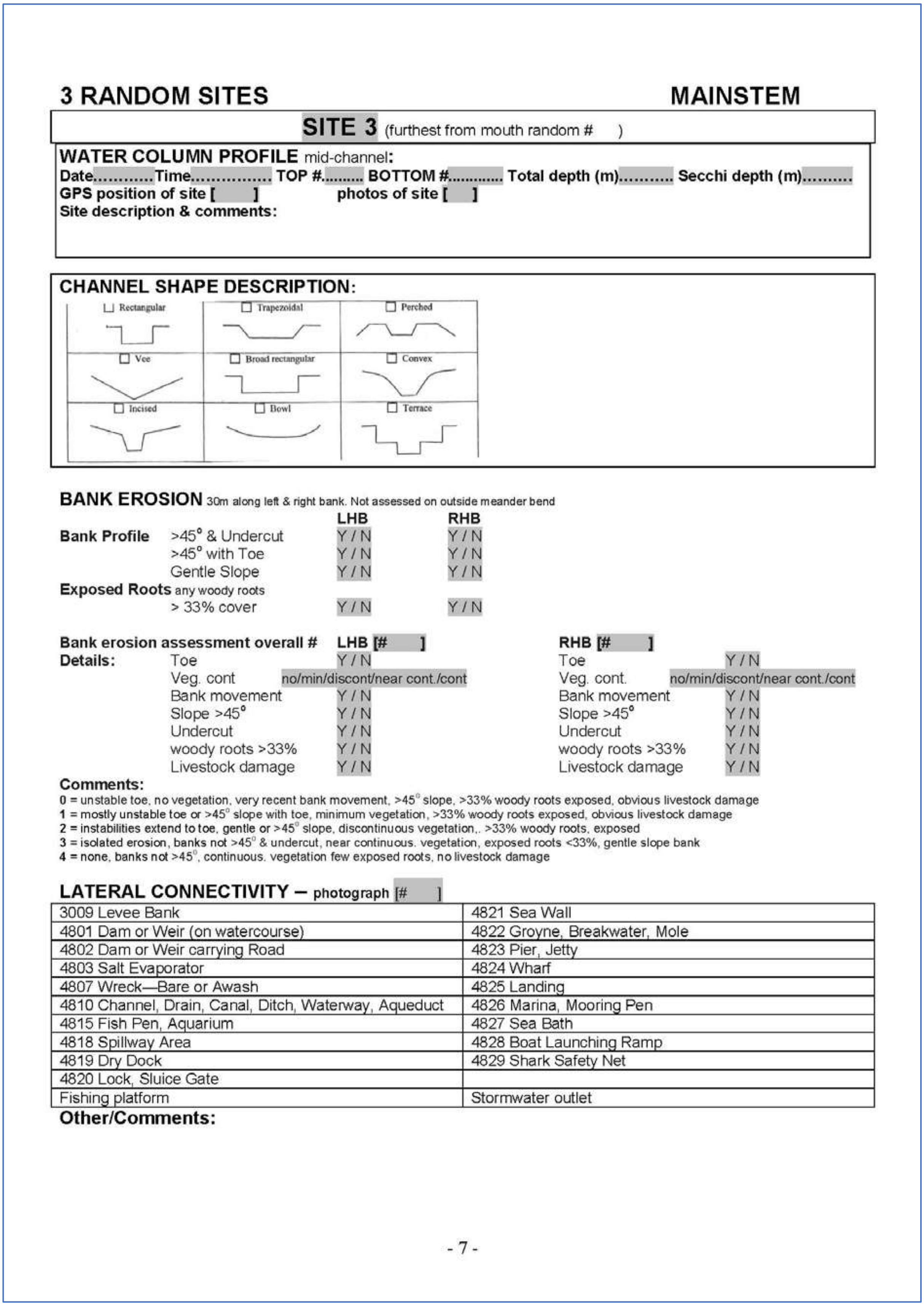
Comments:
0 = unstable toe, no vegetation, very recent bank movement, >45° slope, >33% woody roots exposed, obvious livestock damage
1 = mostly unstable toe or >45° slope with toe, minimum vegetation, >33% woody roots exposed, obvious livestock damage
2 = instabilities extend to toe, gentle or >45° slope, discontinuous vegetation,. >33% woody roots, exposed
3 = isolated erosion, banks not >45° & undercut, near continuous. vegetation, exposed roots <33%, gentle slope bank
4 = none, banks not >45°, continuous. vegetation few exposed roots, no livestock damage

LATERAL CONNECTIVITY – photograph [#]

3009 Levee Bank	4821 Sea Wall
4801 Dam or Weir (on watercourse)	4822 Groyne, Breakwater, Mole
4802 Dam or Weir carrying Road	4823 Pier, Jetty
4803 Salt Evaporator	4824 Wharf
4807 Wreck—Bare or Awash	4825 Landing
4810 Channel, Drain, Canal, Ditch, Waterway, Aqueduct	4826 Marina, Mooring Pen
4815 Fish Pen, Aquarium	4827 Sea Bath
4818 Spillway Area	4828 Boat Launching Ramp
4819 Dry Dock	4829 Shark Safety Net
4820 Lock, Sluice Gate	
Fishing platform	Stormwater outlet

Other/Comments:

- 6 -



3 RANDOM SITES **MAINSTEM**

SITE 3 (furthest from mouth random #)

WATER COLUMN PROFILE mid-channel**:**

Date............Time................ TOP #......... BOTTOM #............ Total depth (m)........... Secchi depth (m)..........

GPS position of site [ ] **photos of site [ ]**

Site description & comments:

CHANNEL SHAPE DESCRIPTION:

☐ Rectangular	☐ Trapezoidal	☐ Perched
☐ Vee	☐ Broad rectangular	☐ Convex
☐ Incised	☐ Bowl	☐ Terrace

BANK EROSION 30m along left & right bank. Not assessed on outside meander bend

		LHB	**RHB**
Bank Profile	>45° & Undercut	Y / N	Y / N
	>45° with Toe	Y / N	Y / N
	Gentle Slope	Y / N	Y / N
Exposed Roots any woody roots			
	> 33% cover	Y / N	Y / N

Bank erosion assessment overall #		**LHB [#]**		**RHB [#]**
Details:	Toe	Y / N	Toe	Y / N
	Veg. cont	no/min/discont/near cont./cont	Veg. cont.	no/min/discont/near cont./cont
	Bank movement	Y / N	Bank movement	Y / N
	Slope >45°	Y / N	Slope >45°	Y / N
	Undercut	Y / N	Undercut	Y / N
	woody roots >33%	Y / N	woody roots >33%	Y / N
	Livestock damage	Y / N	Livestock damage	Y / N

Comments:

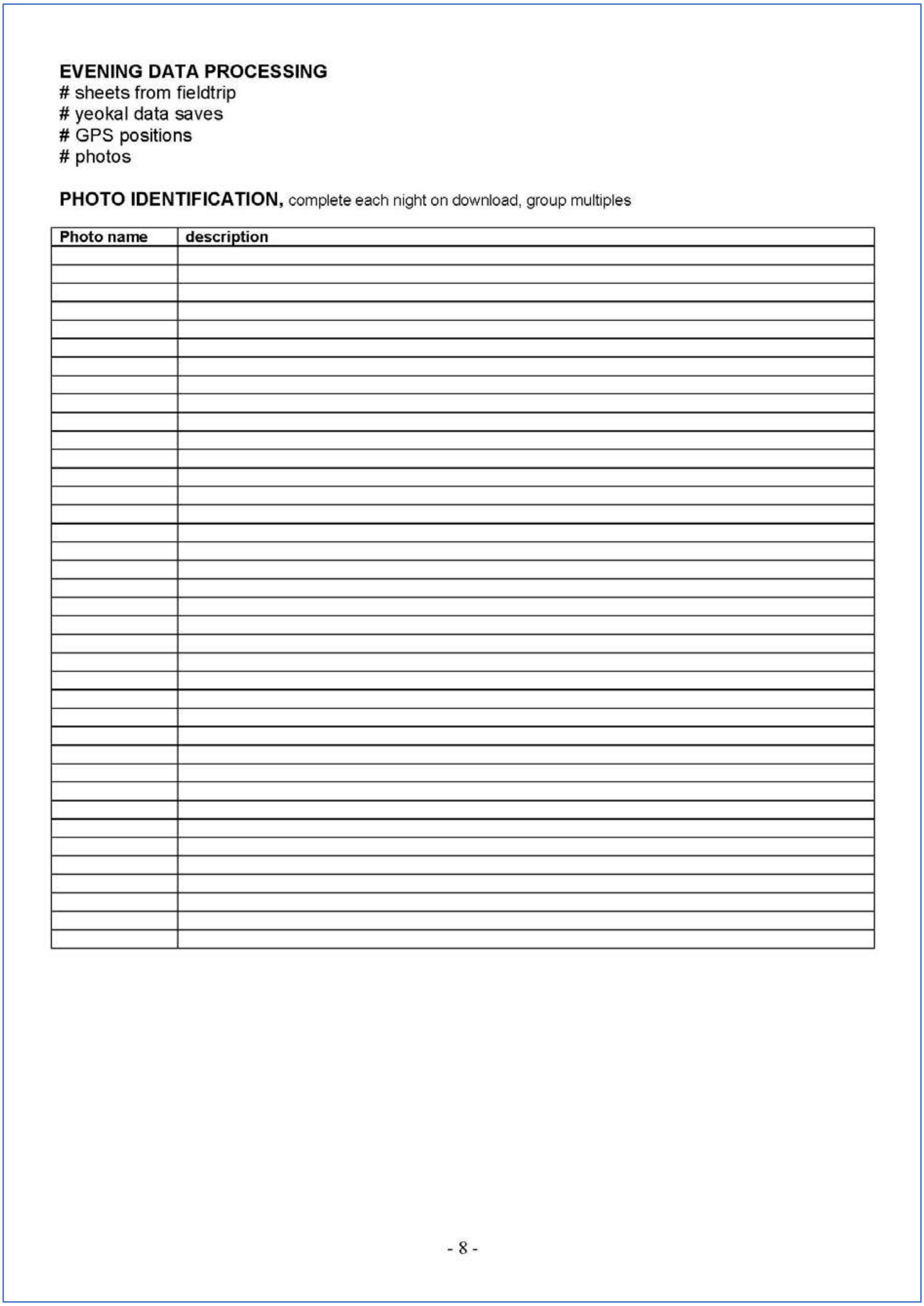
0 = unstable toe, no vegetation, very recent bank movement, >45° slope, >33% woody roots exposed, obvious livestock damage
1 = mostly unstable toe or >45° slope with toe, minimum vegetation, >33% woody roots exposed, obvious livestock damage
2 = instabilities extend to toe, gentle or >45° slope, discontinuous vegetation,. >33% woody roots, exposed
3 = isolated erosion, banks not >45° & undercut, near continuous. vegetation, exposed roots <33%, gentle slope bank
4 = none, banks not >45°, continuous. vegetation few exposed roots, no livestock damage

LATERAL CONNECTIVITY – photograph [#]

3009 Levee Bank	4821 Sea Wall
4801 Dam or Weir (on watercourse)	4822 Groyne, Breakwater, Mole
4802 Dam or Weir carrying Road	4823 Pier, Jetty
4803 Salt Evaporator	4824 Wharf
4807 Wreck—Bare or Awash	4825 Landing
4810 Channel, Drain, Canal, Ditch, Waterway, Aqueduct	4826 Marina, Mooring Pen
4815 Fish Pen, Aquarium	4827 Sea Bath
4818 Spillway Area	4828 Boat Launching Ramp
4819 Dry Dock	4829 Shark Safety Net
4820 Lock, Sluice Gate	
Fishing platform	Stormwater outlet

Other/Comments:

- 7 -



EVENING DATA PROCESSING

sheets from fieldtrip
yeokal data saves
GPS positions
photos

PHOTO IDENTIFICATION, complete each night on download, group multiples

Photo name	description

APPENDIX 6 COMPLETE LIST OF VICTORIAN ESTUARIES, SUBESTUARIES AND SECTIONS

Table 128. Victorian estuaries, subestuaries and sections.

Basin ID	Estuary	Subestuary	Section name	Section type	Section ID
38_00	Glenelg River	Glenelg River	Glenelg River Lagoon	Lagoon	001101
38_00	Glenelg River	Glenelg River	Mud Lagoon	Lagoon	001102
38_00	Glenelg River	Glenelg River	Glenelg River	Riverine	001103
37_00	Fawthrop Lagoon	Fawthrop Lagoon	Fawthrop Entrance Channel	Riverine	002101
37_00	Fawthrop Lagoon	Fawthrop Lagoon	Fawthrop Lagoon	Lagoon	002102
37_00	Surrey River	Surrey River	Surrey River	Riverine	003101
37_00	Fitzroy River	Fitzroy River	Fitzroy River Lagoon	Lagoon	004101
37_00	Fitzroy River	Fitzroy River	Fitzroy River	Riverine	004102
37_00	Lake Yambuk	Lake Yambuk	Lake Yambuk	Lagoon	005101
37_00	Lake Yambuk	Lake Yambuk	Eumeralla River	Riverine	005102
37_00	Lake Yambuk	Shaw River	Shaw River	Riverine	005203
37_00	Moyne River	Moyne River	Moyne River Entrance Channel	Riverine	006101
37_00	Moyne River	Moyne River	Belfast Lough	Lagoon	006102
37_00	Moyne River	Moyne River	Moyne River	Riverine	006103
36_00	Merri River	Merri River	Merri River	Riverine	007101
36_00	Merri River	Merri River	Saltwater Swamp	Lagoon	007102
36_00	Hopkins River	Hopkins River	Hopkins River Lagoon	Lagoon	008101
36_00	Hopkins River	Hopkins River	Hopkins River	Riverine	008102
35_00	Curdies Inlet	Curdies Inlet	Curdies Inlet	Lagoon	009101
35_00	Curdies Inlet	Curdies Inlet	Curdies River	Riverine	009102
35_00	Campbell Creek	Campbell Creek	Campbell Creek	Riverine	010101
35_00	Sherbrook River	Sherbrook River	Sherbrook River	Riverine	011101
35_00	Gellibrand River	Gellibrand River	Gellibrand River Lagoon	Lagoon	012101
35_00	Gellibrand River	Gellibrand River	Gellibrand River	Riverine	012102
35_00	Gellibrand River	LaTrobe Creek	LaTrobe Creek	Riverine	012203
35_00	Johanna River	Johanna River	Johanna River	Riverine	013101
35_00	Aire River	Aire River	Aire River Lagoon	Lagoon	014101
35_00	Aire River	Aire River	Aire River	Riverine	014102
35_00	Aire River	Ford River	Ford River	Riverine	014203
35_00	Aire River	Ford River	Lake Hordern	Lagoon	014204
35_00	Aire River	Lake Craven	Lake Craven	Lagoon	014305
35_00	Barham River	Barham River	Barham River Lagoon	Lagoon	015101
35_00	Barham River	Barham River	Barham River	Riverine	015102
35_00	Barham River	Barham Lagoon South	Barham Lagoon South	Lagoon	015203
35_00	Kennett River	Kennett River	Kennett River	Riverine	016101
35_00	Wye River	Wye River	Wye River	Riverine	017101
35_00	St George River	St George River	St George River	Riverine	018101
35_00	Erskine River	Erskine River	Erskine River	Riverine	019101

Basin ID	Estuary	Subestuary	Section name	Section type	Section ID
35_00	Painkalac Creek	Painkalac Creek	Painkalac Creek Lagoon (Aireys Inlet)	Lagoon	020101
35_00	Painkalac Creek	Painkalac Creek	Painkalac Creek	Riverine	020102
35_00	Anglesea River	Anglesea River	Anglesea River Lagoon	Lagoon	021101
35_00	Anglesea River	Anglesea River	Anglesea River	Riverine	021102
35_00	Anglesea River	Anglesea River	Coogoorah Park	Lagoon	021103
35_00	Spring Creek	Spring Creek	Spring Creek	Riverine	022101
35_00	Thompson Creek	Thompson Creek	Thompson Creek	Lagoon	023101
35_00	Thompson Creek	Thompson Creek	Thompson Creek	Riverine	023102
33_00	Barwon River	Barwon River	Barwon River Entrance Channel	Riverine	024101
33_00	Barwon River	Barwon River	Lake Connewarre	Lagoon	024102
33_00	Barwon River	Barwon River	Barwon River	Riverine	024103
32_00	Limeburners Lagoon	Limeburners Lagoon	Limeburners Lagoon	Lagoon	025101
32_00	Limeburners Lagoon	Limeburners Lagoon	Hovells Creek	Riverine	025102
32_00	Little River	Little River	Little River	Riverine	026101
31_00	Werribee River	Werribee River	Werribee River Lagoon	Lagoon	027101
31_00	Werribee River	Werribee River	Werribee River	Riverine	027102
31_00	Skeleton Creek	Skeleton Creek	Skeleton Creek	Riverine	028101
31_00	Laverton Creek	Laverton Creek	Laverton Creek	Riverine	029101
31_00	Kororoit Creek	Kororoit Creek	Kororoit Creek	Riverine	030101
29_30	Yarra River	Yarra River	Yarra Port Area	Lagoon	031101
29_30	Yarra River	Yarra River	Yarra River	Riverine	031102
29_30	Yarra River	Stony Creek	Stony Creek	Riverine	031203
29_30	Yarra River	Maribyrnong River	Maribyrnong River	Riverine	031304
29_30	Yarra River	Moonee Ponds Creek	Moonee Ponds Creek	Riverine	031405
29_00	Elwood Canal	Elwood Canal	Elwood Canal	Riverine	032101
28_00	Mordialloc Creek	Mordialloc Creek	Mordialloc Creek	Riverine	033101
28_00	Patterson River	Patterson River	Patterson River	Riverine	034101
28_00	Patterson River	Patterson River	Patterson Lakes Canal Estate	Lagoon	034102
28_00	Kananook Creek	Kananook Creek	Kananook Creek	Riverine	035101
28_00	Balcombe Creek	Balcombe Creek	Balcombe Creek Lagoon	Lagoon	036101
28_00	Balcombe Creek	Balcombe Creek	Balcombe Creek	Riverine	036102
28_00	Merricks Creek	Merricks Creek	Merricks Creek	Riverine	037101
28_00	Cardinia Creek	Cardinia Creek	Cardinia Creek	Riverine	038101
28_00	Cardinia Creek	Cardinia Catchment Drain	Cardinia Catchment Drain	Riverine	038202
28_00	Deep Creek	Deep Creek	Deep Creek	Riverine	039101
28_00	Deep Creek	Lower Gum Scrub Creek	Lower Gum Scrub Creek	Riverine	039202
28_00	Deep Creek	Toomuc Creek	Toomuc Creek	Riverine	039303

Basin ID	Estuary	Subestuary	Section name	Section type	Section ID
28_00	Deep Creek	Deep Creek Catchment Drain	Deep Creek Catchment Drain	Riverine	039404
28_00	Bunyip River	Bunyip River	Bunyip River	Riverine	040101
28_00	Bunyip River	McGregors Drain	McGregors Drain	Riverine	040202
28_00	Bunyip River	Ararat Creek	Ararat Creek	Riverine	040303
28_00	Bunyip River	North West Catchment Drain	North West Catchment Drain	Riverine	040404
28_00	Bunyip River	South East Catchment Drain	South East Catchment Drain	Riverine	040505
28_00	Yallock Creek	Yallock Creek	Yallock Creek	Riverine	041101
28_00	Yallock Drain	Yallock Drain	Yallock Drain	Riverine	042101
28_00	Lang Lang River	Lang Lang River	Lang Lang River	Riverine	043101
27_00	Bass River	Bass River	Bass River	Riverine	044101
99_00	Saltwater Creek	Saltwater Creek	Saltwater Creek	Riverine	045101
27_00	Bourne Creek	Bourne Creek	Bourne Creek	Riverine	046101
27_00	Powlett River	Powlett River	Powlett River Lagoon	Lagoon	047101
27_00	Powlett River	Powlett River	Powlett River	Riverine	047102
27_00	Powlett River	Bridge Creek	Bridge Creek	Riverine	047203
27_00	Wreck Creek	Wreck Creek	Wreck Creek	Riverine	048101
27_00	Anderson Inlet	Anderson Inlet	Anderson Inlet	Lagoon	049101
27_00	Anderson Inlet	Anderson Inlet	Tarwin River	Riverine	049102
27_00	Anderson Inlet	Screw Creek	Screw Creek	Riverine	049203
27_00	Anderson Inlet	Pound Creek	Pound Creek	Riverine	049304
27_00	Shallow Inlet	Shallow Inlet	Shallow Inlet	Lagoon	050101
27_00	Darby River	Darby River	Darby River	Riverine	051101
27_00	Tidal River	Tidal River	Tidal River	Riverine	052101
27_00	Growler Creek	Growler Creek	Growler Creek	Riverine	053101
27_00	Sealers Creek	Sealers Creek	Sealers Creek	Riverine	054101
27_00	Miranda Creek	Miranda Creek	Miranda Creek	Riverine	055101
27_00	Chinaman Creek	Chinaman Creek	Chinaman Creek	Riverine	056101
27_00	Old Hat Creek	Old Hat Creek	Old Hat Creek Lagoon	Lagoon	057101
27_00	Old Hat Creek	Old Hat Creek	Old Hat Creek	Riverine	057102
27_00	Old Hat Creek	Poor Fellow Me Creek	Poor Fellow Me Creek	Riverine	057203
27_00	Stockyard Creek	Stockyard Creek	Stockyard Creek	Riverine	058101
27_00	Bennison Creek	Bennison Creek	Bennison Creek	Riverine	059101
27_00	Franklin River	Franklin River	Franklin River	Lagoon	060101
27_00	Franklin River	Franklin River	Franklin River	Riverine	060102
27_00	Agnes River	Agnes River	Agnes River	Riverine	061101
27_00	Shady Creek	Shady Creek	Shady Creek	Riverine	062101
27_00	Nine Mile Creek	Nine Mile Creek	Nine Mile Creek	Riverine	063101
27_00	Albert River	Albert River	Albert River Lagoon	Lagoon	064101
27_00	Albert River	Albert River	Albert River	Riverine	064102
27_00	Albert River	Muddy Creek	Muddy Creek	Riverine	064203
27_00	Tarra River	Tarra River	Tarra River Lagoon	Lagoon	065101

Basin ID	Estuary	Subestuary	Section name	Section type	Section ID
27_00	Tarra River	Tarra River	Tarra River	Riverine	065102
27_00	Neils Creek	Neils Creek	Neils Creek	Riverine	066101
27_00	Bruthen Creek	Bruthen Creek	Bruthen Creek Lagoon	Lagoon	067101
27_00	Bruthen Creek	Bruthen Creek	Bruthen Creek	Riverine	067102
27_00	Jack Smith Lake	Jack Smith Lake	Jack Smith Lake	Lagoon	068101
27_00	Lake Denison	Lake Denison	Lake Denison	Lagoon	069101
27_00	Merriman Creek	Merriman Creek	Merriman Creek Lagoon	Lagoon	070101
27_00	Merriman Creek	Merriman Creek	Merriman Creek	Riverine	070102
26_00	LaTrobe River	LaTrobe River	LaTrobe River	Riverine	071101
26_00	LaTrobe River	Thomson River	Thomson River	Riverine	071202
25_00	Lake Wellington Main Drain	Lake Wellington Main Drain	Lake Wellington Main Drain	Riverine	072101
25_00	Avon River	Avon River	Avon River	Riverine	073101
25_00	Avon River	Perry River	Perry River	Riverine	073202
24_00	Tom Creek	Tom Creek	Tom Creek	Riverine	074101
24_00	Tom Roberts Creek	Tom Roberts Creek	Tom Roberts Creek	Riverine	075101
24_00	Newlands Arm	Newlands Arm	Newlands Arm	Lagoon	076101
24_00	Newlands Arm	Newlands Arm	Forge Creek	Riverine	076102
24_23	Mitchell/Nicholson	Mitchell River	Mitchell River	Riverine	077101
24_23	Mitchell/Nicholson	Jones Bay	Jones Bay	Lagoon	077202
24_23	Mitchell/Nicholson	Nicholson River	Nicholson River	Riverine	077303
23_00	Slaughterhouse Creek	Slaughterhouse Creek	Slaughterhouse Creek	Riverine	078101
23_00	Slaughterhouse Creek	Butcher Creek	Butcher Creek	Riverine	078202
23_00	Tambo River	Tambo River	Tambo River	Riverine	079101
23_00	Maringa Creek	Maringa Creek	Maringa Creek	Riverine	080101
23_00	Mississippi Creek	Mississippi Creek	North Arm	Lagoon	081101
23_00	Mississippi Creek	Mississippi Creek	Mississippi Creek	Riverine	081102
23_00	Lake Bunga	Lake Bunga	Lake Bunga	Lagoon	082101
23_00	Lake Tyers	Nowa Nowa Arm	Lake Tyers (Lower)	Lagoon	083101
23_00	Lake Tyers	Nowa Nowa Arm	Nowa Nowa Arm (Lower)	Lagoon	083102
23_00	Lake Tyers	Nowa Nowa Arm	Nowa Nowa Arm (Upper)	Riverine	083103
23_00	Lake Tyers	Toorloo Arm	Fishermans Arm	Lagoon	083204
23_00	Lake Tyers	Toorloo Arm	Toorloo Arm (Lower)	Lagoon	083205
23_00	Lake Tyers	Toorloo Arm	Toorloo Arm (Upper)	Riverine	083206
23_00	Lake Tyers	Toorloo Arm	Blackfellows Arm	Lagoon	083207
22_00	Snowy River	Snowy River	Snowy River Lagoon	Lagoon	084101
22_00	Snowy River	Snowy River	Frenchs Narrows	Lagoon	084102
22_00	Snowy River	Snowy River	Snowy River	Riverine	084103
22_00	Snowy River	Lake Corringle	Lake Corringle	Lagoon	084204
22_00	Snowy River	Brodribb River	Brodribb River	Riverine	084305
22_00	Snowy River	Brodribb River	Lake Curlip	Lagoon	084306
22_00	Snowy River	Brodribb River	Brodribb Diversion Channel	Riverine	084307

Basin ID	Estuary	Subestuary	Section name	Section type	Section ID
22_00	Snowy River	Cabbage Tree Creek	Cabbage Tree Creek (below lagoon)	Riverine	084408
22_00	Snowy River	Cabbage Tree Creek	Cabbage Tree Creek Lagoon	Lagoon	084409
22_00	Snowy River	Cabbage Tree Creek	Cabbage Tree Creek (above lagoon)	Riverine	084410
21_00	Yeerung River	Yeerung River	Yeerung River Lagoon	Lagoon	085101
21_00	Yeerung River	Yeerung River	Yeerung River	Riverine	085102
21_00	Sydenham Inlet	Sydenham Inlet	Sydenham Entrance Channel	Lagoon	086101
21_00	Sydenham Inlet	Sydenham Inlet	Sydenham Inlet	Lagoon	086102
21_00	Sydenham Inlet	Sydenham Inlet	Bemm River	Riverine	086103
21_00	Sydenham Inlet	Swan Lake	Swan Lake Channel	Riverine	086204
21_00	Sydenham Inlet	Swan Lake	Swan Lake	Lagoon	086205
21_00	Sydenham Inlet	Swan Lake	Mud Lake	Lagoon	086206
21_00	Tamboon Inlet	Tamboon Inlet	Tamboon Inlet	Lagoon	087101
21_00	Tamboon Inlet	Tamboon Inlet	Cann River	Riverine	087102
21_00	Tamboon Inlet	Tamboon Inlet	Lake Furnell	Lagoon	087103
21_00	Thurra River	Thurra River	Thurra River	Riverine	088101
21_00	Mueller River	Mueller River	Mueller River Lagoon	Lagoon	089101
21_00	Mueller River	Mueller River	Mueller River	Riverine	089102
21_00	Mueller River	Camp Creek	Camp Creek	Riverine	089203
21_00	Wingan Inlet	Wingan Inlet	Wingan Inlet	Lagoon	090101
21_00	Wingan Inlet	Wingan Inlet	Wingan River	Riverine	090102
21_00	Easby Creek	Easby Creek	Easby Creek	Riverine	091101
21_00	Red River	Red River	Red River	Riverine	092101
21_00	Benadore River	Benadore River	Benadore River Lagoon	Lagoon	093101
21_00	Benadore River	Benadore River	Benadore River	Riverine	093102
21_00	Seal Creek	Seal Creek	Seal Creek	Riverine	094101
21_00	Shipwreck Creek	Shipwreck Creek	Shipwreck Creek	Riverine	095101
21_00	Betka River	Betka River	Betka River Lagoon	Lagoon	096101
21_00	Betka River	Betka River	Betka River	Riverine	096102
21_00	Davis Creek	Davis Creek	Davis Creek	Riverine	097101
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Entrance Shoals	Lagoon	098101
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Bottom Lake	Lagoon	098102
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Top Lake	Lagoon	098103
21_00	Mallacoota Inlet	Mallacoota Inlet	Mallacoota Gypsy Point Reach	Riverine	098104
21_00	Mallacoota Inlet	Mallacoota Inlet	Wallagaraugh River	Riverine	098105
21_00	Mallacoota Inlet	Double Creek Arm	Double Creek Arm	Lagoon	098206
21_00	Mallacoota Inlet	Double Creek Arm	Double Creek	Riverine	098207
21_00	Mallacoota Inlet	Genoa River	Genoa River	Riverine	098308
21_00	Mallacoota Inlet	Maramingo Creek	Maramingo Creek	Riverine	098409
21_00	Mallacoota Inlet	Harrison Creek Arm	Harrison Creek Arm	Lagoon	098510

Basin ID	Estuary	Subestuary	Section name	Section type	Section ID
21_00	Mallacoota Inlet	Harrison Creek Arm	Harrison Creek	Riverine	098511
21_00	Mallacoota Inlet	Teal Creek	Teal Creek	Riverine	098612
21_00	Mallacoota Inlet	Dowell Creek	Dowell Creek	Riverine	098713
21_00	Wau Wauka Outlet	Wau Wauka Outlet	Wau Wauka Outlet	Riverine	099101
28_00	Watsons Creek	Watsons Creek	Watsons Creek	Riverine	998101
28_00	Warringine Creek	Warringine Creek	Warringine Creek	Riverine	999101

Appendix 7 Physical Form Scores for Estuaries (2, 3) and Subestuaries (3) by Section

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
38_00	001101	Glenelg River	Glenelg River Lagoon	3	M	1	L	5	H	5	H
38_00	001102	Glenelg River	Mud Lagoon	3	M	1	L	5	H	5	H
38_00	001103	Glenelg River	Glenelg River	3	M	1	L	5	H	5	H
37_00	002101	Fawthrop Lagoon	Fawthrop Entrance Channel	3	L	1	L	4	L	4	L
37_00	002102	Fawthrop Lagoon	Fawthrop Lagoon	3	L	1	L	4	L	4	L
37_00	003101	Surrey River	Surrey River	3	M	1	L	5	H	5	H
37_00	004101	Fitzroy River	Fitzroy River Lagoon	3	M	1	L	5	H	5	H
37_00	004102	Fitzroy River	Fitzroy River	3	M	1	L	5	H	5	H
37_00	005101	Lake Yambuk	Lake Yambuk	5	M	5	L	5	M	5	H
37_00	005102	Lake Yambuk	Eumeralla River	5	M	5	L	5	M	5	H
37_00	005203	Lake Yambuk	Shaw River	5	M	5	L	5	M		
37_00	006101	Moyne River	Moyne River Entrance Channel	5	M	5	L	5	H	5	H
37_00	006102	Moyne River	Belfast Lough	5	M	5	L	5	H	5	H
37_00	006103	Moyne River	Moyne River	5	M	5	L	5	H	5	H
36_00	007101	Merri River	Merri River	3	M	1	L	5	H	5	H
36_00	007102	Merri River	Saltwater Swamp	3	M	1	L	5	H	5	H
36_00	008101	Hopkins River	Hopkins River Lagoon	3	M	1	L	5	H	5	H
36_00	008102	Hopkins River	Hopkins River	3	M	1	L	5	H	5	H
35_00	009101	Curdies Inlet	Curdies Inlet	3	M	1	L	5	H	5	H
35_00	009102	Curdies Inlet	Curdies River	3	M	1	L	5	H	5	H

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
35_00	010101	Campbell Creek	Campbell Creek	4	M	2	L	5	H	5	H
35_00	011101	Sherbrook River	Sherbrook River	5	M			5	H	5	H
35_00	012101	Gellibrand River	Gellibrand River Lagoon	4	M	3	L	5	H	5	H
35_00	012102	Gellibrand River	Gellibrand River	4	M	3	L	5	H	5	H
35_00	012203	Gellibrand River	LaTrobe Creek	4	M	3	L	5	H	5	H
35_00	013101	Johanna River	Johanna River								
35_00	014101	Aire River	Aire River Lagoon	5	M	4	L	5	H	5	H
35_00	014102	Aire River	Aire River	5	M	4	L	5	H	5	H
35_00	014203	Aire River	Ford River	5	M	4	L	5	H	5	H
35_00	014204	Aire River	Lake Hordern	5	M	4	L	5	H	5	H
35_00	014305	Aire River	Lake Craven	5	M	4	L	5	H	5	H
35_00	015101	Barham River	Barham River Lagoon	5	M	4	L	5	H	5	H
35_00	015102	Barham River	Barham River	5	M	4	L	5	H	5	H
35_00	015203	Barham River	Barham Lagoon South	5	M	4	L	5	H	5	H
35_00	016101	Kennett River	Kennett River	5	M			5	H	5	H
35_00	017101	Wye River	Wye River	5	M			5	H	5	H
35_00	018101	St George River	St George River	5	M			5	H	5	H
35_00	019101	Erskine River	Erskine River	5	M			5	H	5	H
35_00	020101	Painkalac Creek	Painkalac Creek Lagoon (Aireys Inlet)	5	M			5	H	5	H
35_00	020102	Painkalac Creek	Painkalac Creek	5	M			5	H	5	H
35_00	021101	Anglesea River	Anglesea River Lagoon	5	M	4	L	5	H	5	H
35_00	021102	Anglesea River	Anglesea River	5	M	4	L	5	H	5	H

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
35_00	021103	Anglesea River	Coogoorah Park	5	M	4	L	5	H	5	H
35_00	022101	Spring Creek	Spring Creek	4	L			4	L	4	L
35_00	023101	Thompson Creek	Thompson Creek	2	L	1	L	2	L	2	L
35_00	023102	Thompson Creek	Thompson Creek	2	L	1	L	2	L	2	L
33_00	024101	Barwon River	Barwon River Entrance Channel	1	M	1	L	1	H	1	H
33_00	024102	Barwon River	Lake Connewarre	1	M	1	L	1	H	1	H
33_00	024103	Barwon River	Barwon River	1	M	1	L	1	H	1	H
32_00	025101	Limeburners Lagoon	Limeburners Lagoon	3	L	1	L	4	L	4	L
32_00	025102	Limeburners Lagoon	Hovells Creek	3	L	1	L	4	L	4	L
32_00	026101	Little River	Little River	3	M	1	L	5	H	5	H
31_00	027101	Werribee River	Werribee River Lagoon	4	M	3	L	4	H	4	M
31_00	027102	Werribee River	Werribee River	4	M	3	L	4	H	4	M
31_00	028101	Skeleton Creek	Skeleton Creek	2	L	2	L	2	L	2	L
31_00	029101	Laverton Creek	Laverton Creek	5	M			5	H	5	H
31_00	030101	Kororoit Creek	Kororoit Creek	4	M	2	L	5	H	5	H
29_30	031101	Yarra River	Yarra Port Area	4	M	2	L	5	M	5	H
29_30	031102	Yarra River	Yarra River	4	M	2	L	5	M	5	H
29_30	031203	Yarra River	Stony Creek	4	M	2	L	5	M	4	M
29_30	031304	Yarra River	Maribyrnong River	4	M	2	L	5	M	5	H
29_30	031405	Yarra River	Moonee Ponds Creek	4	M	2	L	5	M	3	L
29_00	032101	Elwood Canal	Elwood Canal	1	M			1	H	1	M
28_00	033101	Mordialloc Creek	Mordialloc Creek	1	L	1	L				
28_00	034101	Patterson River	Patterson River	1	M	1	L	1	H	1	M

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
28_00	034102	Patterson River	Patterson Lakes Canal Estate	1	M	1	L	1	H	1	M
28_00	035101	Kananook Creek	Kananook Creek								
28_00	036101	Balcombe Creek	Balcombe Creek Lagoon	3	M	1	L	5	H	5	H
28_00	036102	Balcombe Creek	Balcombe Creek	3	M	1	L	5	H	5	H
28_00	037101	Merricks Creek	Merricks Creek	5	M			5	H	5	H
28_00	038101	Cardinia Creek	Cardinia Creek	3	M	1	L	5	H	5	H
28_00	038202	Cardinia Creek	Cardinia Catchment Drain	3	M	1	L	5	H	5	H
28_00	039101	Deep Creek	Deep Creek	4	M	2	L	5	H	5	H
28_00	039202	Deep Creek	Lower Gum Scrub Creek	4	M	2	L	5	H	5	H
28_00	039303	Deep Creek	Toomuc Creek	4	M	2	L	5	H	5	H
28_00	039404	Deep Creek	Deep Creek Catchment Drain	4	M	2	L	5	H	5	H
28_00	040101	Bunyip River	Bunyip River	4	M	2	L	5	H	4	M
28_00	040202	Bunyip River	McGregors Drain	4	M	2	L	5	H	5	H
28_00	040303	Bunyip River	Ararat Creek	4	M	2	L	5	H	5	H
28_00	040404	Bunyip River	North West Catchment Drain	4	M	2	L	5	H	5	H
28_00	040505	Bunyip River	South East Catchment Drain	4	M	2	L	5	H	5	H
28_00	041101	Yallock Creek	Yallock Creek								
28_00	042101	Yallock Drain	Yallock Drain	3	M			3	H	3	M

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
28_00	043101	Lang Lang River	Lang Lang River	4	M	2	L	5	H	5	H
27_00	044101	Bass River	Bass River	4	M	2	L	5	H	5	H
99_00	045101	Saltwater Creek	Saltwater Creek								
27_00	046101	Bourne Creek	Bourne Creek								
27_00	047101	Powlett River	Powlett River Lagoon	4	M	2	L	5	H	5	H
27_00	047102	Powlett River	Powlett River	4	M	2	L	5	H	5	H
27_00	047203	Powlett River	Bridge Creek	4	M	2	L	5	H	5	H
27_00	048101	Wreck Creek	Wreck Creek								
27_00	049101	Anderson Inlet	Anderson Inlet	4	L	3	L	4	L	4	L
27_00	049102	Anderson Inlet	Tarwin River	4	L	3	L	4	L	4	L
27_00	049203	Anderson Inlet	Screw Creek	4	L	3	L	4	L	5	H
27_00	049304	Anderson Inlet	Pound Creek	4	L	3	L	4	L		
27_00	050101	Shallow Inlet	Shallow Inlet								
27_00	051101	Darby River	Darby River	5	M			5	H	5	H
27_00	052101	Tidal River	Tidal River	3	M			3	H	3	H
27_00	053101	Growler Creek	Growler Creek								
27_00	054101	Sealers Creek	Sealers Creek								
27_00	055101	Miranda Creek	Miranda Creek	5	M			5	H	5	H
27_00	056101	Chinaman Creek	Chinaman Creek					5	H	5	H
27_00	057101	Old Hat Creek	Old Hat Creek Lagoon								
27_00	057102	Old Hat Creek	Old Hat Creek								
27_00	057203	Old Hat Creek	Poor Fellow Me Creek								
27_00	058101	Stockyard Creek	Stockyard Creek								
27_00	059101	Bennison Creek	Bennison Creek	5	M			5	H	5	H
27_00	060101	Franklin River	Franklin River	5	M	4	L	5	H	5	H

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
27_00	060102	Franklin River	Franklin River	5	M	4	L	5	H	5	H
27_00	061101	Agnes River	Agnes River	4	L	4	L				
27_00	062101	Shady Creek	Shady Creek								
27_00	063101	Nine Mile Creek	Nine Mile Creek								
27_00	064101	Albert River	Albert River Lagoon	4	L	4	L				
27_00	064102	Albert River	Albert River	4	L	4	L				
27_00	064203	Albert River	Muddy Creek	4	L	4	L				
27_00	065101	Tarra River	Tarra River Lagoon	4	L	4	L				
27_00	065102	Tarra River	Tarra River	4	L	4	L				
27_00	066101	Neils Creek	Neils Creek								
27_00	067101	Bruthen Creek	Bruthen Creek Lagoon	2	L	2	L				
27_00	067102	Bruthen Creek	Bruthen Creek	2	L	2	L				
27_00	068101	Jack Smith Lake	Jack Smith Lake	5	L	5	L				
27_00	069101	Lake Denison	Lake Denison								
27_00	070101	Merriman Creek	Merriman Creek Lagoon	4	M	2	L	5	H	5	M
27_00	070102	Merriman Creek	Merriman Creek	4	M	2	L	5	H	5	M
26_00	071101	LaTrobe River	LaTrobe River	4	M	3	L	5	H	5	H
26_00	071202	LaTrobe River	Thomson River	4	M	3	L	5	H	5	H
25_00	072101	Lake Wellington Main Drain	Lake Wellington Main Drain	5	L	5	L				
25_00	073101	Avon River	Avon River	3	M	2	L	3	H	3	H
25_00	073202	Avon River	Perry River	3	M	2	L	3	H	5	H
24_00	074101	Tom Creek	Tom Creek	1	L	1	L				
24_00	075101	Tom Roberts Creek	Tom Roberts Creek								

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
24_00	076101	Newlands Arm	Newlands Arm	3	L			3	L	3	L
24_00	076102	Newlands Arm	Forge Creek	3	L			3	L	3	L
24_23	077101	Mitchell/Nicholson	Mitchell River	4	L	3	L	4	L	3	L
24_23	077202	Mitchell/Nicholson	Jones Bay	4	L	3	L	4	L	3	L
24_23	077303	Mitchell/Nicholson	Nicholson River	4	L	3	L	4	L	5	H
23_00	078101	Slaughterhouse Creek	Slaughterhouse Creek								
23_00	078202	Slaughterhouse Creek	Butcher Creek								
23_00	079101	Tambo River	Tambo River	3	L	2	L	4	L	4	L
23_00	080101	Maringa Creek	Maringa Creek								
23_00	081101	Mississippi Creek	North Arm	5	L	5	L				
23_00	081102	Mississippi Creek	Mississippi Creek	5	L	5	L				
23_00	082101	Lake Bunga	Lake Bunga	5	M			5	H	5	H
23_00	083101	Lake Tyers	Lake Tyers (Lower)	5	M	5	L	5	H	5	H
23_00	083102	Lake Tyers	Nowa Nowa Arm (Lower)	5	M	5	L	5	H	5	H
23_00	083103	Lake Tyers	Nowa Nowa Arm (Upper)	5	M	5	L	5	H	5	H
23_00	083204	Lake Tyers	Fishermans Arm	5	M	5	L	5	H	5	H
23_00	083205	Lake Tyers	Toorloo Arm (Lower)	5	M	5	L	5	H	5	H
23_00	083206	Lake Tyers	Toorloo Arm (Upper)	5	M	5	L	5	H	5	H
23_00	083207	Lake Tyers	Blackfellows Arm	5	M	5	L	5	H	5	H
22_00	084101	Snowy River	Snowy River Lagoon	4	M	2	L	5	H	5	H
22_00	084102	Snowy River	Frenchs Narrows	4	M	2	L	5	H	5	H
22_00	084103	Snowy River	Snowy River	4	M	2	L	5	H	5	H
22_00	084204	Snowy River	Lake Corringle	4	M	2	L	5	H	5	H

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
22_00	084305	Snowy River	Brodribb River	4	M	2	L	5	H	5	H
22_00	084306	Snowy River	Lake Curlip	4	M	2	L	5	H	5	H
22_00	084307	Snowy River	Brodribb Diversion Channel	4	M	2	L	5	H	5	H
22_00	084408	Snowy River	Cabbage Tree Creek (below lagoon)	4	M	2	L	5	H		
22_00	084409	Snowy River	Cabbage Tree Creek Lagoon	4	M	2	L	5	H		
22_00	084410	Snowy River	Cabbage Tree Creek (above lagoon)	4	M	2	L	5	H		
21_00	085101	Yeerung River	Yeerung River Lagoon	5	M	5	L	5	M	5	H
21_00	085102	Yeerung River	Yeerung River	5	M	5	L	5	M	5	H
21_00	086101	Sydenham Inlet	Sydenham Entrance Channel	4	M	3	L	5	M	5	H
21_00	086102	Sydenham Inlet	Sydenham Inlet	4	M	3	L	5	M	5	H
21_00	086103	Sydenham Inlet	Bemm River	4	M	3	L	5	M	5	H
21_00	086204	Sydenham Inlet	Swan Lake Channel	4	M	3	L	5	M		
21_00	086205	Sydenham Inlet	Swan Lake	4	M	3	L	5	M		
21_00	086206	Sydenham Inlet	Mud Lake	4	M	3	L	5	M		
21_00	087101	Tamboon Inlet	Tamboon Inlet	4	M	3	L	4	H	4	L
21_00	087102	Tamboon Inlet	Cann River	4	M	3	L	4	H	4	L
21_00	087103	Tamboon Inlet	Lake Furnell	4	M	3	L	4	H	4	L
21_00	088101	Thurra River	Thurra River	3	L	3	L				
21_00	089101	Mueller River	Mueller River Lagoon	5	L	5	L	5	L		
21_00	089102	Mueller River	Mueller River	5	L	5	L	5	L		

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
21_00	089203	Mueller River	Camp Creek	5	L	5	L	5	L	5	H
21_00	090101	Wingan Inlet	Wingan Inlet	5	M	5	L	5	H	5	H
21_00	090102	Wingan Inlet	Wingan River	5	M	5	L	5	H	5	H
21_00	091101	Easby Creek	Easby Creek	5	M			5	H	5	H
21_00	092101	Red River	Red River								
21_00	093101	Benadore River	Benadore River Lagoon								
21_00	093102	Benadore River	Benadore River								
21_00	094101	Seal Creek	Seal Creek								
21_00	095101	Shipwreck Creek	Shipwreck Creek	5	M			5	H	5	H
21_00	096101	Betka River	Betka River Lagoon	5	L	5	L				
21_00	096102	Betka River	Betka River	5	L	5	L				
21_00	097101	Davis Creek	Davis Creek	5	M			5	H	5	H
21_00	098101	Mallacoota Inlet	Mallacoota Entrance Shoals	3	L	1	L	5	L	5	H
21_00	098102	Mallacoota Inlet	Mallacoota Bottom Lake	3	L	1	L	5	L	5	H
21_00	098103	Mallacoota Inlet	Mallacoota Top Lake	3	L	1	L	5	L	5	H
21_00	098104	Mallacoota Inlet	Mallacoota Gypsy Point Reach	3	L	1	L	5	L	5	H
21_00	098105	Mallacoota Inlet	Wallagaraugh River	3	L	1	L	5	L	5	H
21_00	098206	Mallacoota Inlet	Double Creek Arm	3	L	1	L	5	L	5	H
21_00	098207	Mallacoota Inlet	Double Creek	3	L	1	L	5	L	5	H
21_00	098308	Mallacoota Inlet	Genoa River	3	L	1	L	5	L	4	L
21_00	098409	Mallacoota Inlet	Maramingo Creek	3	L	1	L	5	L		

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	2: Sed. load score	2: conf.	3: Upstr. barrier Est. score	3: Est. conf.	3: Sub. Est. score	3: Subest. conf.
21_00	098510	Mallacoota Inlet	Harrison Creek Arm	3	L	1	L	5	L	5	H
21_00	098511	Mallacoota Inlet	Harrison Creek	3	L	1	L	5	L	5	H
21_00	098612	Mallacoota Inlet	Teal Creek	3	L	1	L	5	L	5	H
21_00	098713	Mallacoota Inlet	Dowell Creek	3	L	1	L	5	L	5	H
21_00	099101	Wau Wauka Outlet	Wau Wauka Outlet								
28_00	998101	Watsons Creek	Watsons Creek	5	M			5	H	5	H
28_00	999101	Warringine Creek	Warringine Creek	5	M			5	H	5	H

APPENDIX 8 HYDROLOGY SCORES FOR ESTUARIES (5,6A, 6B) AND SECTIONS (6A)

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	5a Int. or 5b Perm.	5: Mar. exch.	5: conf.	6a: ISC or 6b: Dams	6: Flow Est. score	6: conf.	6a: Flow Sect. score
38_00	001101	Glenelg River	Glenelg River Lagoon	2	H	5a	1	M	6a	2	H	2
38_00	001102	Glenelg River	Mud Lagoon	2	H	5a	1	M	6a	2	H	2
38_00	001103	Glenelg River	Glenelg River	2	H	5a	1	M	6a	2	H	2
37_00	002101	Fawthrop Lagoon	Fawthrop Entrance Channel	2	M	5b	1	H	6a	2	L	2
37_00	002102	Fawthrop Lagoon	Fawthrop Lagoon	2	M	5b	1	H	6a	2	L	2
37_00	003101	Surrey River	Surrey River	4	M	5a	5	M	6a	3	M	3
37_00	004101	Fitzroy River	Fitzroy River Lagoon	2	H	5a	1	M	6a	3	H	3
37_00	004102	Fitzroy River	Fitzroy River	2	H	5a	1	M	6a	3	H	3
37_00	005101	Lake Yambuk	Lake Yambuk	2	M	5a	1	M	6a	3	M	3
37_00	005102	Lake Yambuk	Eumeralla River	2	M	5a	1	M	6a	3	M	3
37_00	005203	Lake Yambuk	Shaw River	2	M	5a	1	M	6a	3	M	4
37_00	006101	Moyne River	Moyne River Entrance Channel	2	H	5b	1	H	6a	3	M	3
37_00	006102	Moyne River	Belfast Lough	2	H	5b	1	H	6a	3	M	3
37_00	006103	Moyne River	Moyne River	2	H	5b	1	H	6a	3	M	3
36_00	007101	Merri River	Merri River*	2	H	*	2	H	6a	1	H	1
36_00	007102	Merri River	Saltwater Swamp*	2	H	*	2	H	6a	1	H	1
36_00	008101	Hopkins River	Hopkins River Lagoon	1	H	5a	1	H	6a	1	H	1
36_00	008102	Hopkins River	Hopkins River	1	H	5a	1	H	6a	1	H	1
35_00	009101	Curdies Inlet	Curdies Inlet	1	M	5a			6a	1	H	1
35_00	009102	Curdies Inlet	Curdies River	1	M	5a			6a	1	H	1
35_00	010101	Campbell Creek	Campbell Creek	4	L	5a			6a	4	L	4
35_00	011101	Sherbrook River	Sherbrook River	4	H	5a	5	H	6b	3	M	

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	5a Int. or 5b Perm.	5: Mar. exch.	5: conf.	6a: ISC or 6b: Dams	6: Flow Est. score	6: conf.	6a: Flow Sect. score
35_00	012101	Gellibrand River	Gellibrand River Lagoon	2	H	5a	1	M	6a	2	H	2
35_00	012102	Gellibrand River	Gellibrand River	2	H	5a	1	M	6a	2	H	2
35_00	012203	Gellibrand River	LaTrobe Creek	2	H	5a	1	M	6a	2	H	
35_00	013101	Johanna River	Johanna River	4	H	5a	5	H	6b	3	M	
35_00	014101	Aire River	Aire River Lagoon	4	L	5a			6a	4	M	4
35_00	014102	Aire River	Aire River	4	L	5a			6a	4	M	4
35_00	014203	Aire River	Ford River	4	L	5a			6a	4	M	5
35_00	014204	Aire River	Lake Hordern	4	L	5a			6a	4	M	5
35_00	014305	Aire River	Lake Craven	4	L	5a			6a	4	M	
35_00	015101	Barham River	Barham River Lagoon	4	M	5a	5	L	6a	2	M	2
35_00	015102	Barham River	Barham River	4	M	5a	5	L	6a	2	M	2
35_00	015203	Barham River	Barham Lagoon South	4	M	5a	5	L	6a	2	M	
35_00	016101	Kennett River	Kennett River	5	L	5a	5	L	6a	4	L	4
35_00	017101	Wye River	Wye River	5	L	5a			6a	5	L	5
35_00	018101	St George River	St George River	4	H	5a	5	M	6a	2	H	2
35_00	019101	Erskine River	Erskine River	3	L	5a	1	L	6a	5	L	5
35_00	020101	Painkalac Creek	Painkalac Creek Lagoon (Aireys Inlet)	1	M	5a	1	M	6a	1	M	1
35_00	020102	Painkalac Creek	Painkalac Creek	1	M	5a	1	M	6a	1	M	1
35_00	021101	Anglesea River	Anglesea River Lagoon	3	L	5a	1	L	6a	4	L	4
35_00	021102	Anglesea River	Anglesea River	3	L	5a	1	L	6a	4	L	4
35_00	021103	Anglesea River	Coogoorah Park	3	L	5a	1	L	6a	4	L	4
35_00	022101	Spring Creek	Spring Creek	2	L	5a			6a	2	L	2
35_00	023101	Thompson Creek	Thompson Creek	4	M	5a	5	L	6a	3	M	3
35_00	023102	Thompson Creek	Thompson Creek	4	M	5a	5	L	6a	3	M	3
33_00	024101	Barwon River	Barwon River Entrance Channel	3	H	5b	5	H	6a	1	H	1

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	5a Int. or 5b Perm.	5: Mar. exch.	5: conf.	6a: ISC or 6b: Dams	6: Flow Est. score	6: conf.	6a: Flow Sect. score
33_00	024102	Barwon River	Lake Connewarre	3	H	5b	5	H	6a	1	H	1
33_00	024103	Barwon River	Barwon River	3	H	5b	5	H	6a	1	H	1
32_00	025101	Limeburners Lagoon	Limeburners Lagoon	3	M	5b	5	H	6a	1	L	1
32_00	025102	Limeburners Lagoon	Hovells Creek	3	M	5b	5	H	6a	1	L	1
32_00	026101	Little River	Little River	2	H	5b	3	H	6a	1	M	1
31_00	027101	Werribee River	Werribee River Lagoon	1	H	5b	1	H	6a	1	M	1
31_00	027102	Werribee River	Werribee River	1	H	5b	1	H	6a	1	M	1
31_00	028101	Skeleton Creek	Skeleton Creek	5	M	5a	5	H	6a	4	L	4
31_00	029101	Laverton Creek	Laverton Creek	3	M	5b	3	M	6b	3	M	
31_00	030101	Kororoit Creek	Kororoit Creek	5	H	5b	5	H	6a	4	H	4
29_30	031101	Yarra River	Yarra Port Area	1	M	5b	1	H	6a	1	L	
29_30	031102	Yarra River	Yarra River	1	M	5b	1	H	6a	1	L	
29_30	031203	Yarra River	Stony Creek	1	M	5b	1	H	6a	1	L	
29_30	031304	Yarra River	Maribyrnong River	1	M	5b	1	H	6a	1	L	1
29_30	031405	Yarra River	Moonee Ponds Creek	1	M	5b	1	H	6a	1	L	
29_00	032101	Elwood Canal	Elwood Canal	3	H	5b	3	H	6b	3	M	
28_00	033101	Mordialloc Creek	Mordialloc Creek	1	H	5b	1	H	6b	1	M	
28_00	034101	Patterson River	Patterson River	2	H	5b	1	H	6b	3	M	
28_00	034102	Patterson River	Patterson Lakes Canal Estate	2	H	5b	1	H	6b	3	M	
28_00	035101	Kananook Creek	Kananook Creek	2	H	5b	1	H	6b	3	M	
28_00	036101	Balcombe Creek	Balcombe Creek Lagoon	1	L	5a			6a	1	L	1
28_00	036102	Balcombe Creek	Balcombe Creek	1	L	5a			6a	1	L	1
28_00	037101	Merricks Creek	Merricks Creek	1	L	5a			6b	1	M	
28_00	038101	Cardinia Creek	Cardinia Creek	3	H	5b	3	H	6a	2	M	2

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28_00	038202	Cardinia Creek	Cardinia Catchment Drain	3	H	5b	3	H	6a	2	M	
28_00	039101	Deep Creek	Deep Creek	3	M	5b	3	H	6a	2	L	
28_00	039202	Deep Creek	Lower Gum Scrub Creek	3	M	5b	3	H	6a	2	L	
28_00	039303	Deep Creek	Toomuc Creek	3	M	5b	3	H	6a	2	L	2
28_00	039404	Deep Creek	Deep Creek Catchment Drain	3	M	5b	3	H	6a	2	L	
28_00	040101	Bunyip River	Bunyip River	2	M	5b	3	H	6a	1	L	1
28_00	040202	Bunyip River	McGregors Drain	2	M	5b	3	H	6a	1	L	
28_00	040303	Bunyip River	Ararat Creek	2	M	5b	3	H	6a	1	L	
28_00	040404	Bunyip River	North West Catchment Drain	2	M	5b	3	H	6a	1	L	
28_00	040505	Bunyip River	South East Catchment Drain	2	M	5b	3	H	6a	1	L	
28_00	041101	Yallock Creek	Yallock Creek	3	H	5b	5	H	6b	1	M	
28_00	042101	Yallock Drain	Yallock Drain	3	H	5b	3	H	6b	3	M	
28_00	043101	Lang Lang River	Lang Lang River	3	H	5b	3	M	6a	2	H	2
27_00	044101	Bass River	Bass River	4	H	5b	5	H	6a	2	H	2
99_00	045101	Saltwater Creek	Saltwater Creek	4	H	5a	5	H	6b	3	M	
27_00	046101	Bourne Creek	Bourne Creek	3	L	5a			6b	3	M	
27_00	047101	Powlett River	Powlett River Lagoon	3	L	5a			6a	3	L	3
27_00	047102	Powlett River	Powlett River	3	L	5a			6a	3	L	3
27_00	047203	Powlett River	Bridge Creek	3	L	5a			6a	3	L	
27_00	048101	Wreck Creek	Wreck Creek	1	L	5a			6b	1	M	
27_00	049101	Anderson Inlet	Anderson Inlet	4	H	5b	5	H	6a	2	M	2
27_00	049102	Anderson Inlet	Tarwin River	4	H	5b	5	H	6a	2	M	2
27_00	049203	Anderson Inlet	Screw Creek	4	H	5b	5	H	6a	2	M	1

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	5a Int. or 5b Perm.	5: Mar. exch.	5: conf.	6a: ISC or 6b: Dams	6: Flow Est. score	6: conf.	6a: Flow Sect. score
27_00	049304	Anderson Inlet	Pound Creek	4	H	5b	5	H	6a	2	M	
27_00	050101	Shallow Inlet	Shallow Inlet	4	H	5b	5	H	6b	3	M	
27_00	051101	Darby River	Darby River	5	H	5a	5	H	6b	5	M	
27_00	052101	Tidal River	Tidal River	5	M	5a	5	H	6a	5	L	5
27_00	053101	Growler Creek	Growler Creek	5	H	5a	5	H	6b	5	M	
27_00	054101	Sealers Creek	Sealers Creek	5	M	5b	5	M	6b	5	M	
27_00	055101	Miranda Creek	Miranda Creek	5	H	5a	5	H	6b	5	M	
27_00	056101	Chinaman Creek	Chinaman Creek	5	H	5b	5	H	6b	5	M	
27_00	057101	Old Hat Creek	Old Hat Creek Lagoon	4	H	5b	5	H	6b	3	M	
27_00	057102	Old Hat Creek	Old Hat Creek	4	H	5b	5	H	6b	3	M	
27_00	057203	Old Hat Creek	Poor Fellow Me Creek	4	H	5b	5	H	6b	3	M	
27_00	058101	Stockyard Creek	Stockyard Creek	4	H	5b	5	H	6b	3	M	
27_00	059101	Bennison Creek	Bennison Creek	4	M	5b	5	H	6a	2	L	2
27_00	060101	Franklin River	Franklin River	4	H	5b	5	H	6a	3	M	3
27_00	060102	Franklin River	Franklin River	4	H	5b	5	H	6a	3	M	3
27_00	061101	Agnes River	Agnes River	4	H	5b	5	M	6a	2	H	2
27_00	062101	Shady Creek	Shady Creek	4	M	5b	5	M	6b	3	M	
27_00	063101	Nine Mile Creek	Nine Mile Creek	4	M	5b	5	M	6a	3	L	3
27_00	064101	Albert River	Albert River Lagoon	4	M	5b	5	M	6a	3	L	3
27_00	064102	Albert River	Albert River	4	M	5b	5	M	6a	3	L	3
27_00	064203	Albert River	Muddy Creek	4	M	5b	5	M	6a	3	L	
27_00	065101	Tarra River	Tarra River Lagoon	4	H	5b	5	H	6a	2	M	2
27_00	065102	Tarra River	Tarra River	4	H	5b	5	H	6a	2	M	2
27_00	066101	Neils Creek	Neils Creek	5	M	5b	5	M	6b	5	M	
27_00	067101	Bruthen Creek	Bruthen Creek Lagoon	4	H	5b	5	H	6b	3	M	
27_00	067102	Bruthen Creek	Bruthen Creek	4	H	5b	5	H	6b	3	M	
27_00	068101	Jack Smith Lake	Jack Smith Lake	4	H	5a	5	H	6b	3	M	

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27_00	069101	Lake Denison	Lake Denison	4	H	5a	5	H	6b	3	M	
27_00	070101	Merriman Creek	Merriman Creek Lagoon	1	M	5a			6a	1	H	1
27_00	070102	Merriman Creek	Merriman Creek	1	M	5a			6a	1	H	1
26_00	071101	LaTrobe River	LaTrobe River	1	H	5b	1	H	6a	1	H	1
26_00	071202	LaTrobe River	Thomson River	1	H	5b	1	H	6a	1	H	1
25_00	072101	Lake Wellington Main Drain	Lake Wellington Main Drain	3	M	5b	3	M	6b	3	M	
25_00	073101	Avon River	Avon River	2	M	5b	1	H	6a	3	L	3
25_00	073202	Avon River	Perry River	2	M	5b	1	H	6a	3	L	2
24_00	074101	Tom Creek	Tom Creek	4	M	5b	3	M	6a	4	L	4
24_00	075101	Tom Roberts Creek	Tom Roberts Creek	4	H	5a	5	H	6b	3	M	
24_00	076101	Newlands Arm	Newlands Arm	4	M	5b	3	M	6a	4	L	4
24_00	076102	Newlands Arm	Forge Creek	4	M	5b	3	M	6a	4	L	4
24_23	077101	Mitchell/Nicholson	Mitchell River	2	H	5b	1	H	6a	3	M	2
24_23	077202	Mitchell/Nicholson	Jones Bay	2	H	5b	1	H	6a	3	M	
24_23	077303	Mitchell/Nicholson	Nicholson River	2	H	5b	1	H	6a	3	M	5
23_00	078101	Slaughterhouse Creek	Slaughterhouse Creek	3	M	5a	3	M	6b	3	M	
23_00	078202	Slaughterhouse Creek	Butcher Creek	3	M	5a	3	M	6b	3	M	
23_00	079101	Tambo River	Tambo River	3	H	5b	1	H	6a	4	H	4
23_00	080101	Maringa Creek	Maringa Creek	3	M	5b	3	M	6b	3	M	
23_00	081101	Mississippi Creek	North Arm	2	H	5b	1	H	6b	3	M	
23_00	081102	Mississippi Creek	Mississippi Creek	2	H	5b	1	H	6b	3	M	
23_00	082101	Lake Bunga	Lake Bunga	4	H	5a	5	H	6b	3	M	
23_00	083101	Lake Tyers	Lake Tyers (Lower)	4	L	5a			6a	4	L	4

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23_00	083102	Lake Tyers	Nowa Nowa Arm (Lower)	4	L	5a			6a	4	L	4
23_00	083103	Lake Tyers	Nowa Nowa Arm (Upper)	4	L	5a			6a	4	L	4
23_00	083204	Lake Tyers	Fishermans Arm	4	L	5a			6a	4	L	4
23_00	083205	Lake Tyers	Toorloo Arm (Lower)	4	L	5a			6a	4	L	4
23_00	083206	Lake Tyers	Toorloo Arm (Upper)	4	L	5a			6a	4	L	4
23_00	083207	Lake Tyers	Blackfellows Arm	4	L	5a			6a	4	L	4
22_00	084101	Snowy River	Snowy River Lagoon	1	L	5a			6a	1	M	1
22_00	084102	Snowy River	Frenchs Narrows	1	L	5a			6a	1	M	1
22_00	084103	Snowy River	Snowy River	1	L	5a			6a	1	M	1
22_00	084204	Snowy River	Lake Corringle	1	L	5a			6a	1	M	
22_00	084305	Snowy River	Brodribb River	1	L	5a			6a	1	M	4
22_00	084306	Snowy River	Lake Curlip	1	L	5a			6a	1	M	4
22_00	084307	Snowy River	Brodribb Diversion Channel	1	L	5a			6a	1	M	4
22_00	084408	Snowy River	Cabbage Tree Creek (below lagoon)	1	L	5a			6a	1	M	4
22_00	084409	Snowy River	Cabbage Tree Creek Lagoon	1	L	5a			6a	1	M	4
22_00	084410	Snowy River	Cabbage Tree Creek (above lagoon)	1	L	5a			6a	1	M	4
21_00	085101	Yeerung River	Yeerung River Lagoon	5	M	5a	5	H	6a	5	L	5
21_00	085102	Yeerung River	Yeerung River	5	M	5a	5	H	6a	5	L	5
21_00	086101	Sydenham Inlet	Sydenham Entrance Channel	5	L	5a			6a	5	M	5
21_00	086102	Sydenham Inlet	Sydenham Inlet	5	L	5a			6a	5	M	5
21_00	086103	Sydenham Inlet	Bemm River	5	L	5a			6a	5	M	5
21_00	086204	Sydenham Inlet	Swan Lake Channel	5	L	5a			6a	5	M	

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21_00	086205	Sydenham Inlet	Swan Lake	5	L	5a			6a	5	M	
21_00	086206	Sydenham Inlet	Mud Lake	5	L	5a			6a	5	M	
21_00	087101	Tamboon Inlet	Tamboon Inlet	5	M	5a	5	H	6a	5	L	5
21_00	087102	Tamboon Inlet	Cann River	5	M	5a	5	H	6a	5	L	5
21_00	087103	Tamboon Inlet	Lake Furnell	5	M	5a	5	H	6a	5	L	5
21_00	088101	Thurra River	Thurra River	4	L	5a			6a	4	L	4
21_00	089101	Mueller River	Mueller River Lagoon	5	H	5a	5	H	6b	5	M	
21_00	089102	Mueller River	Mueller River	5	H	5a	5	H	6b	5	M	
21_00	089203	Mueller River	Camp Creek	5	H	5a	5	H	6b	5	M	
21_00	090101	Wingan Inlet	Wingan Inlet	5	H	5b	5	H	6a	5	H	5
21_00	090102	Wingan Inlet	Wingan River	5	H	5b	5	H	6a	5	H	5
21_00	091101	Easby Creek	Easby Creek	5	H	5a	5	H	6b	5	M	
21_00	092101	Red River	Red River	5	H	5a	5	H	6b	5	M	
21_00	093101	Benadore River	Benadore River Lagoon	5	H	5a	5	H	6b	5	M	
21_00	093102	Benadore River	Benadore River	5	H	5a	5	H	6b	5	M	
21_00	094101	Seal Creek	Seal Creek	5	H	5a	5	H	6b	5	M	
21_00	095101	Shipwreck Creek	Shipwreck Creek	5	H	5a	5	H	6b	5	M	
21_00	096101	Betka River	Betka River Lagoon	5	H	5a	5	H	6a	4	M	4
21_00	096102	Betka River	Betka River	5	H	5a	5	H	6a	4	M	4
21_00	097101	Davis Creek	Davis Creek	4	H	5a	5	H	6b	3	M	
21_00	098101	Mallacoota Inlet	Mallacoota Entrance Shoals	4	L	5a			6a	4	M	5
21_00	098102	Mallacoota Inlet	Mallacoota Bottom Lake	4	L	5a			6a	4	M	5
21_00	098103	Mallacoota Inlet	Mallacoota Top Lake	4	L	5a			6a	4	M	5
21_00	098104	Mallacoota Inlet	Mallacoota Gypsy Point Reach	4	L	5a			6a	4	M	5
21_00	098105	Mallacoota Inlet	Wallagaraugh River	4	L	5a			6a	4	M	5

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	5a Int. or 5b Perm.	5: Mar. exch.	5: conf.	6a: ISC or 6b: Dams	6: Flow Est. score	6: conf.	6a: Flow Sect. score
21_00	098206	Mallacoota Inlet	Double Creek Arm	4	L	5a			6a	4	M	
21_00	098207	Mallacoota Inlet	Double Creek	4	L	5a			6a	4	M	
21_00	098308	Mallacoota Inlet	Genoa River	4	L	5a			6a	4	M	4
21_00	098409	Mallacoota Inlet	Maramingo Creek	4	L	5a			6a	4	M	
21_00	098510	Mallacoota Inlet	Harrison Creek Arm	4	L	5a			6a	4	M	
21_00	098511	Mallacoota Inlet	Harrison Creek	4	L	5a			6a	4	M	
21_00	098612	Mallacoota Inlet	Teal Creek	4	L	5a			6a	4	M	
21_00	098713	Mallacoota Inlet	Dowell Creek	4	L	5a			6a	4	M	
21_00	099101	Wau Wauka Outlet	Wau Wauka Outlet	5	H	5a	5	H	6b	5	M	
28_00	998101	Watsons Creek	Watsons Creek	3	H	5b	5	H	6b	1	M	
28_00	999101	Warringine Creek	Warringine Creek	3	H	5b	5	H	6b	1	M	

* - Merri River estuary has two entrances. Scores are for whole estuary, an average of Saltwater Swamp (1, Intermittent) and Merri River (3, Permanent) sections.

APPENDIX 9 WATER QUALITY SCORES FOR ESTUARIES (8, 9) AND SECTIONS (8, 9)

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
38_00	001101	Glenelg River	Glenelg River Lagoon	4	M	4	4	M	4	3	M	3
38_00	001102	Glenelg River	Mud Lagoon	4	M	3	4	M	1	3	M	4
38_00	001103	Glenelg River	Glenelg River	4	M	4	4	M	4	3	M	3
37_00	002101	Fawthrop Lagoon	Fawthrop Entrance Channel									
37_00	002102	Fawthrop Lagoon	Fawthrop Lagoon									
37_00	003101	Surrey River	Surrey River	4	H	4	4	H	4	3	H	3
37_00	004101	Fitzroy River	Fitzroy River Lagoon	5	H	5	5	H	5	4	H	4
37_00	004102	Fitzroy River	Fitzroy River	5	H	5	5	H	5	4	H	4
37_00	005101	Lake Yambuk	Lake Yambuk	4	M	4	4	M	4	3	M	4
37_00	005102	Lake Yambuk	Eumeralla River	4	M	4	4	M	4	3	M	3
37_00	005203	Lake Yambuk	Shaw River	4	M		4	M		3	M	
37_00	006101	Moyne River	Moyne River Entrance Channel									
37_00	006102	Moyne River	Belfast Lough									
37_00	006103	Moyne River	Moyne River									
36_00	007101	Merri River	Merri River	4	H	4	4	H	4	3	H	3
36_00	007102	Merri River	Saltwater Swamp	4	H	4	4	H	4	3	H	3
36_00	008101	Hopkins River	Hopkins River Lagoon	4	H	4	4	H	4	3	H	3
36_00	008102	Hopkins River	Hopkins River	4	H	4	4	H	4	3	H	3
35_00	009101	Curdies Inlet	Curdies Inlet	4	L	4	4	L	4	3	L	3
35_00	009102	Curdies Inlet	Curdies River	4	L	3	4	L	3	3	L	2
35_00	010101	Campbell Creek	Campbell Creek	2	L	2	1	L	1	2	L	2
35_00	011101	Sherbrook River	Sherbrook River									
35_00	012101	Gellibrand River	Gellibrand River Lagoon	3	M	4	3	M	4	3	M	4

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
35_00	012102	Gellibrand River	Gellibrand River	3	M	3	3	M	3	3	M	3
35_00	012203	Gellibrand River	LaTrobe Creek	3	M	4	3	M	4	3	M	4
35_00	013101	Johanna River	Johanna River									
35_00	014101	Aire River	Aire River Lagoon	3	L	4	3	L	4	3	L	3
35_00	014102	Aire River	Aire River	3	L	4	3	L	4	3	L	3
35_00	014203	Aire River	Ford River	3	L		3	L		3	L	
35_00	014204	Aire River	Lake Hordern	3	L	2	3	L	1	3	L	2
35_00	014305	Aire River	Lake Craven	3	L	3	3	L	3	3	L	3
35_00	015101	Barham River	Barham River Lagoon	4	L	4	4	L	4	3	L	3
35_00	015102	Barham River	Barham River	4	L	4	4	L	4	3	L	3
35_00	015203	Barham River	Barham Lagoon South	4	L	2	4	L	3	3	L	1
35_00	016101	Kennett River	Kennett River	4	L	4	4	L	4	4	L	4
35_00	017101	Wye River	Wye River	3	L	3	3	L	3	3	L	3
35_00	018101	St George River	St George River	3	L	3	3	L	3	3	L	3
35_00	019101	Erskine River	Erskine River	3	L	3	3	L	3	2	L	2
35_00	020101	Painkalac Creek	Painkalac Creek Lagoon (Aireys Inlet)	4	M	3	4	M	3	3	M	3
35_00	020102	Painkalac Creek	Painkalac Creek	4	M	4	4	M	4	3	M	3
35_00	021101	Anglesea River	Anglesea River Lagoon	4	M	4	4	M	4	3	M	3
35_00	021102	Anglesea River	Anglesea River	4	M	4	4	M	4	3	M	3
35_00	021103	Anglesea River	Coogoorah Park	4	M	4	4	M	4	3	M	3
35_00	022101	Spring Creek	Spring Creek	3	L	3	3	L	3	3	L	3
35_00	023101	Thompson Creek	Thompson Creek	4	L		4	L		3	L	
35_00	023102	Thompson Creek	Thompson Creek	4	L	4	4	L	4	3	L	3
33_00	024101	Barwon River	Barwon River Entrance Channel									

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
33_00	024102	Barwon River	Lake Connewarre									
33_00	024103	Barwon River	Barwon River									
32_00	025101	Limeburners Lagoon	Limeburners Lagoon	4	L	4	4	L	4	3	L	3
32_00	025102	Limeburners Lagoon	Hovells Creek	4	L	4	4	L	4	3	L	3
32_00	026101	Little River	Little River	3	L	3	4	L	4	1	L	1
31_00	027101	Werribee River	Werribee River Lagoon	3	L		3	L		2	L	
31_00	027102	Werribee River	Werribee River	3	L	3	3	L	3	2	L	2
31_00	028101	Skeleton Creek	Skeleton Creek									
31_00	029101	Laverton Creek	Laverton Creek									
31_00	030101	Kororoit Creek	Kororoit Creek	3	M	3	3	M	3	3	M	3
29_30	031101	Yarra River	Yarra Port Area	3	M	3	3	M	2	3	M	4
29_30	031102	Yarra River	Yarra River	3	M	3	3	M	3	3	M	3
29_30	031203	Yarra River	Stony Creek	3	M	3	3	M	4	3	M	2
29_30	031304	Yarra River	Maribyrnong River	3	M	3	3	M	3	3	M	2
29_30	031405	Yarra River	Moonee Ponds Creek	3	M	4	3	M	4	3	M	4
29_00	032101	Elwood Canal	Elwood Canal									
28_00	033101	Mordialloc Creek	Mordialloc Creek	2	M	2	3	M	3	1	M	1
28_00	034101	Patterson River	Patterson River									
28_00	034102	Patterson River	Patterson Lakes Canal Estate									
28_00	035101	Kananook Creek	Kananook Creek	3	M	3	3	M	3	2	M	2
28_00	036101	Balcombe Creek	Balcombe Creek Lagoon	4	L	3	4	L	3	3	L	2
28_00	036102	Balcombe Creek	Balcombe Creek	4	L	4	4	L	4	3	L	4
28_00	037101	Merricks Creek	Merricks Creek	3	M	3	3	M	3	2	M	2

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
28_00	038101	Cardinia Creek	Cardinia Creek	3	L	3	1	L	1	4	L	4
28_00	038202	Cardinia Creek	Cardinia Catchment Drain	3	L		1	L		4	L	
28_00	039101	Deep Creek	Deep Creek									
28_00	039202	Deep Creek	Lower Gum Scrub Creek									
28_00	039303	Deep Creek	Toomuc Creek									
28_00	039404	Deep Creek	Deep Creek Catchment Drain									
28_00	040101	Bunyip River	Bunyip River	4	L	4	4	L	4			
28_00	040202	Bunyip River	McGregors Drain	4	L		4	L				
28_00	040303	Bunyip River	Ararat Creek	4	L		4	L				
28_00	040404	Bunyip River	North West Catchment Drain	4	L		4	L				
28_00	040505	Bunyip River	South East Catchment Drain	4	L		4	L				
28_00	041101	Yallock Creek	Yallock Creek									
28_00	042101	Yallock Drain	Yallock Drain	2	M	2	2	M	2	2	M	2
28_00	043101	Lang Lang River	Lang Lang River									
27_00	044101	Bass River	Bass River	1	L	1	1	L	1	1	L	1
99_00	045101	Saltwater Creek	Saltwater Creek									
27_00	046101	Bourne Creek	Bourne Creek									
27_00	047101	Powlett River	Powlett River Lagoon	4	L	4	4	L	4	4	L	4
27_00	047102	Powlett River	Powlett River	4	L	4	4	L	4	4	L	4
27_00	047203	Powlett River	Bridge Creek	4	L		4	L		4	L	
27_00	048101	Wreck Creek	Wreck Creek									
27_00	049101	Anderson Inlet	Anderson Inlet	3	L	4	2	L	4	3	L	4
27_00	049102	Anderson Inlet	Tarwin River	3	L	3	2	L	1	3	L	4

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
27_00	049203	Anderson Inlet	Screw Creek	3	L	2	2	L	2	3	L	2
27_00	049304	Anderson Inlet	Pound Creek	3	L		2	L		3	L	
27_00	050101	Shallow Inlet	Shallow Inlet									
27_00	051101	Darby River	Darby River									
27_00	052101	Tidal River	Tidal River	4	L	4	4	L	4	3	L	3
27_00	053101	Growler Creek	Growler Creek									
27_00	054101	Sealers Creek	Sealers Creek									
27_00	055101	Miranda Creek	Miranda Creek	3	L	3	2	L	2	3	L	3
27_00	056101	Chinaman Creek	Chinaman Creek	3	L	3	4	L	4	2	L	2
27_00	057101	Old Hat Creek	Old Hat Creek Lagoon									
27_00	057102	Old Hat Creek	Old Hat Creek									
27_00	057203	Old Hat Creek	Poor Fellow Me Creek									
27_00	058101	Stockyard Creek	Stockyard Creek									
27_00	059101	Bennison Creek	Bennison Creek	2	L	2	2	L	2			
27_00	060101	Franklin River	Franklin River	4	L	4	4	L	4	4	L	4
27_00	060102	Franklin River	Franklin River	4	L	4	4	L	3	4	L	4
27_00	061101	Agnes River	Agnes River									
27_00	062101	Shady Creek	Shady Creek									
27_00	063101	Nine Mile Creek	Nine Mile Creek									
27_00	064101	Albert River	Albert River Lagoon									
27_00	064102	Albert River	Albert River									
27_00	064203	Albert River	Muddy Creek									
27_00	065101	Tarra River	Tarra River Lagoon	4	L	4	4	L	3	4	L	4
27_00	065102	Tarra River	Tarra River	4	L	4	4	L	4	4	L	4
27_00	066101	Neils Creek	Neils Creek									
27_00	067101	Bruthen Creek	Bruthen Creek Lagoon									
27_00	067102	Bruthen Creek	Bruthen Creek									

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
27_00	068101	Jack Smith Lake	Jack Smith Lake									
27_00	069101	Lake Denison	Lake Denison									
27_00	070101	Merriman Creek	Merriman Creek Lagoon	4	L	4	4	L	4			
27_00	070102	Merriman Creek	Merriman Creek	4	L	4	4	L	4			
26_00	071101	LaTrobe River	LaTrobe River									
26_00	071202	LaTrobe River	Thomson River									
25_00	072101	Lake Wellington Main Drain	Lake Wellington Main Drain									
25_00	073101	Avon River	Avon River	4	L	4	4	L	3	4	L	4
25_00	073202	Avon River	Perry River	4	L	4	4	L	4	4	L	
24_00	074101	Tom Creek	Tom Creek									
24_00	075101	Tom Roberts Creek	Tom Roberts Creek									
24_00	076101	Newlands Arm	Newlands Arm									
24_00	076102	Newlands Arm	Forge Creek									
24_23	077101	Mitchell/Nicholson	Mitchell River	3	L	3	3	L	3	2	L	3
24_23	077202	Mitchell/Nicholson	Jones Bay	3	L	3	3	L	4	2	L	2
24_23	077303	Mitchell/Nicholson	Nicholson River	3	L	3	3	L	4	2	L	2
23_00	078101	Slaughterhouse Creek	Slaughterhouse Creek									
23_00	078202	Slaughterhouse Creek	Butcher Creek									
23_00	079101	Tambo River	Tambo River									
23_00	080101	Maringa Creek	Maringa Creek									
23_00	081101	Mississippi Creek	North Arm									
23_00	081102	Mississippi Creek	Mississippi Creek									
23_00	082101	Lake Bunga	Lake Bunga	4	L	4	4	L	4	3	L	3

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
23_00	083101	Lake Tyers	Lake Tyers (Lower)	4	L	4	4	L	4	3	L	4
23_00	083102	Lake Tyers	Nowa Nowa Arm (Lower)	4	L	4	4	L	4	3	L	3
23_00	083103	Lake Tyers	Nowa Nowa Arm (Upper)	4	L	4	4	L	4	3	L	4
23_00	083204	Lake Tyers	Fishermans Arm	4	L		4	L		3	L	
23_00	083205	Lake Tyers	Toorloo Arm (Lower)	4	L	4	4	L	4	3	L	3
23_00	083206	Lake Tyers	Toorloo Arm (Upper)	4	L	4	4	L	4	3	L	3
23_00	083207	Lake Tyers	Blackfellows Arm	4	L	4	4	L	4	3	L	3
22_00	084101	Snowy River	Snowy River Lagoon	4	L	4	4	L		3	L	4
22_00	084102	Snowy River	Frenchs Narrows	4	L	1	4	L		3	L	1
22_00	084103	Snowy River	Snowy River	4	L	3	4	L		3	L	3
22_00	084204	Snowy River	Lake Corringle	4	L	3	4	L	4	3	L	1
22_00	084305	Snowy River	Brodribb River	4	L	4	4	L	4	3	L	3
22_00	084306	Snowy River	Lake Curlip	4	L	3	4	L	4	3	L	1
22_00	084307	Snowy River	Brodribb Diversion Channel	4	L	4	4	L	4	3	L	3
22_00	084408	Snowy River	Cabbage Tree Creek (below lagoon)	4	L	4	4	L	4	3	L	4
22_00	084409	Snowy River	Cabbage Tree Creek Lagoon	4	L	4	4	L	4	3	L	4
22_00	084410	Snowy River	Cabbage Tree Creek (above lagoon)	4	L	3	4	L	4	3	L	2
21_00	085101	Yeerung River	Yeerung River Lagoon	4	L	4	4	L	4	3	L	4
21_00	085102	Yeerung River	Yeerung River	4	L	3	4	L	3	3	L	3
21_00	086101	Sydenham Inlet	Sydenham Entrance Channel	4	L	4	4	L	4	3	L	4

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
21_00	086102	Sydenham Inlet	Sydenham Inlet	4	L	4	4	L	4	3	L	3
21_00	086103	Sydenham Inlet	Bemm River	4	L	3	4	L	4	3	L	2
21_00	086204	Sydenham Inlet	Swan Lake Channel	4	L	4	4	L	4	3	L	3
21_00	086205	Sydenham Inlet	Swan Lake	4	L	4	4	L	4	3	L	3
21_00	086206	Sydenham Inlet	Mud Lake	4	L		4	L		3	L	
21_00	087101	Tamboon Inlet	Tamboon Inlet									
21_00	087102	Tamboon Inlet	Cann River									
21_00	087103	Tamboon Inlet	Lake Furnell									
21_00	088101	Thurra River	Thurra River									
21_00	089101	Mueller River	Mueller River Lagoon	4	L	4	4	L	4	3	L	3
21_00	089102	Mueller River	Mueller River	4	L	3	4	L	3	3	L	3
21_00	089203	Mueller River	Camp Creek	4	L	4	4	L	4	3	L	3
21_00	090101	Wingan Inlet	Wingan Inlet	4	L	4	4	L	4	3	L	3
21_00	090102	Wingan Inlet	Wingan River	4	L	4	4	L	4	3	L	3
21_00	091101	Easby Creek	Easby Creek									
21_00	092101	Red River	Red River									
21_00	093101	Benadore River	Benadore River Lagoon									
21_00	093102	Benadore River	Benadore River									
21_00	094101	Seal Creek	Seal Creek									
21_00	095101	Shipwreck Creek	Shipwreck Creek	3	L	3	3	L	3	3	L	3
21_00	096101	Betka River	Betka River Lagoon									
21_00	096102	Betka River	Betka River									
21_00	097101	Davis Creek	Davis Creek	4	L	4	3	L	3	4	L	4
21_00	098101	Mallacoota Inlet	Mallacoota Entrance Shoals	4	L	3	4	L	3			
21_00	098102	Mallacoota Inlet	Mallacoota Bottom Lake	4	L		4	L				

Basin ID	Section ID	Estuary	Section name	Theme score	Theme conf.	Sect Theme score	8.: Water clarity	8: conf.	8: Sect. score	9.: Dissolved Oxygen	9: conf.	9: Sect. score
21_00	098103	Mallacoota Inlet	Mallacoota Top Lake	4	L	4	4	L	4			
21_00	098104	Mallacoota Inlet	Mallacoota Gypsy Point Reach	4	L	4	4	L	4			
21_00	098105	Mallacoota Inlet	Wallagaraugh River	4	L	4	4	L	4			
21_00	098206	Mallacoota Inlet	Double Creek Arm	4	L		4	L				
21_00	098207	Mallacoota Inlet	Double Creek	4	L		4	L				
21_00	098308	Mallacoota Inlet	Genoa River	4	L	4	4	L	4			
21_00	098409	Mallacoota Inlet	Maramingo Creek	4	L	4	4	L	4			
21_00	098510	Mallacoota Inlet	Harrison Creek Arm	4	L	4	4	L	4			
21_00	098511	Mallacoota Inlet	Harrison Creek	4	L	3	4	L	3			
21_00	098612	Mallacoota Inlet	Teal Creek	4	L	4	4	L	4			
21_00	098713	Mallacoota Inlet	Dowell Creek	4	L	4	4	L	4			
21_00	099101	Wau Wauka Outlet	Wau Wauka Outlet									
28_00	998101	Watsons Creek	Watsons Creek	3	L	3	2	L	2	4	L	4
28_00	999101	Warringine Creek	Warringine Creek	3	L	3	2	L	2	3	L	3

APPENDIX 10 SEDIMENT SCORES FOR ESTUARIES (11) AND SECTIONS (11); PARTICLE SIZE RESULTS

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
38_00	001101	Glenelg River	Glenelg River Lagoon	4	M	4	4	L
38_00	001102	Glenelg River	Mud Lagoon	4	M			
38_00	001103	Glenelg River	Glenelg River	4	M	4	4	M
37_00	002101	Fawthrop Lagoon	Fawthrop Entrance Channel					
37_00	002102	Fawthrop Lagoon	Fawthrop Lagoon					
37_00	003101	Surrey River	Surrey River					
37_00	004101	Fitzroy River	Fitzroy River Lagoon	4	M			
37_00	004102	Fitzroy River	Fitzroy River	4	M	4	4	H
37_00	005101	Lake Yambuk	Lake Yambuk	2	M	2	2	L
37_00	005102	Lake Yambuk	Eumeralla River	2	M	3	3	H
37_00	005203	Lake Yambuk	Shaw River	2	M			
37_00	006101	Moyne River	Moyne River Entrance Channel					
37_00	006102	Moyne River	Belfast Lough					
37_00	006103	Moyne River	Moyne River					
36_00	007101	Merri River	Merri River	3	L			
36_00	007102	Merri River	Saltwater Swamp	3	L	3	3	L
36_00	008101	Hopkins River	Hopkins River Lagoon	4	M	4	4	M
36_00	008102	Hopkins River	Hopkins River	4	M	4	4	M
35_00	009101	Curdies Inlet	Curdies Inlet	4	M	4	4	L
35_00	009102	Curdies Inlet	Curdies River	4	M	4	4	M
35_00	010101	Campbell Creek	Campbell Creek	3	H	3	3	H
35_00	011101	Sherbrook River	Sherbrook River					
35_00	012101	Gellibrand River	Gellibrand River Lagoon	3	M	3	3	M
35_00	012102	Gellibrand River	Gellibrand River	3	M	3	3	M

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
35_00	012203	Gellibrand River	LaTrobe Creek	3	M	4	4	H
35_00	013101	Johanna River	Johanna River					
35_00	014101	Aire River	Aire River Lagoon	4	M	3	3	M
35_00	014102	Aire River	Aire River	4	M	4	4	H
35_00	014203	Aire River	Ford River	4	M			
35_00	014204	Aire River	Lake Hordern	4	M	4	4	M
35_00	014305	Aire River	Lake Craven	4	M	4	4	L
35_00	015101	Barham River	Barham River Lagoon	2	M	3	3	M
35_00	015102	Barham River	Barham River	2	M	1	1	M
35_00	015203	Barham River	Barham Lagoon South	2	M	4	4	M
35_00	016101	Kennett River	Kennett River	2	H	2	2	H
35_00	017101	Wye River	Wye River	2	H	2	2	H
35_00	018101	St George River	St George River					
35_00	019101	Erskine River	Erskine River	3	H	3	3	H
35_00	020101	Painkalac Creek	Painkalac Creek Lagoon (Aireys Inlet)	2	M	4	4	M
35_00	020102	Painkalac Creek	Painkalac Creek	2	M	2	2	M
35_00	021101	Anglesea River	Anglesea River Lagoon	3	M	4	4	M
35_00	021102	Anglesea River	Anglesea River	3	M	2	2	H
35_00	021103	Anglesea River	Coogoorah Park	3	M	3	3	M
35_00	022101	Spring Creek	Spring Creek					
35_00	023101	Thompson Creek	Thompson Creek	3	M	4	4	L
35_00	023102	Thompson Creek	Thompson Creek	3	M	2	2	H
33_00	024101	Barwon River	Barwon River Entrance Channel					
33_00	024102	Barwon River	Lake Connewarre					
33_00	024103	Barwon River	Barwon River					
32_00	025101	Limeburners Lagoon	Limeburners Lagoon	4	M	4	4	L
32_00	025102	Limeburners Lagoon	Hovells Creek	4	M	4	4	H

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
32_00	026101	Little River	Little River	4	H	4	4	H
31_00	027101	Werribee River	Werribee River Lagoon	2	H	3	3	L
31_00	027102	Werribee River	Werribee River	2	H	2	2	H
31_00	028101	Skeleton Creek	Skeleton Creek					
31_00	029101	Laverton Creek	Laverton Creek					
31_00	030101	Kororoit Creek	Kororoit Creek	3	H	3	3	H
29_30	031101	Yarra River	Yarra Port Area	3	L	4	4	L
29_30	031102	Yarra River	Yarra River	3	L	3	3	M
29_30	031203	Yarra River	Stony Creek	3	L	3	3	H
29_30	031304	Yarra River	Maribyrnong River	3	L	3	3	L
29_30	031405	Yarra River	Moonee Ponds Creek	3	L	4	4	L
29_00	032101	Elwood Canal	Elwood Canal					
28_00	033101	Mordialloc Creek	Mordialloc Creek					
28_00	034101	Patterson River	Patterson River					
28_00	034102	Patterson River	Patterson Lakes Canal Estate					
28_00	035101	Kananook Creek	Kananook Creek					
28_00	036101	Balcombe Creek	Balcombe Creek Lagoon					
28_00	036102	Balcombe Creek	Balcombe Creek					
28_00	037101	Merricks Creek	Merricks Creek	3	H	3	3	H
28_00	038101	Cardinia Creek	Cardinia Creek	3	M	3	3	H
28_00	038202	Cardinia Creek	Cardinia Catchment Drain	3	M			
28_00	039101	Deep Creek	Deep Creek					
28_00	039202	Deep Creek	Lower Gum Scrub Creek					
28_00	039303	Deep Creek	Toomuc Creek					
28_00	039404	Deep Creek	Deep Creek Catchment Drain					
28_00	040101	Bunyip River	Bunyip River	3	L	3	3	H
28_00	040202	Bunyip River	McGregors Drain	3	L			

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
28_00	040303	Bunyip River	Ararat Creek	3	L			
28_00	040404	Bunyip River	North West Catchment Drain	3	L			
28_00	040505	Bunyip River	South East Catchment Drain	3	L			
28_00	041101	Yallock Creek	Yallock Creek					
28_00	042101	Yallock Drain	Yallock Drain					
28_00	043101	Lang Lang River	Lang Lang River					
27_00	044101	Bass River	Bass River	3	M	3	3	M
99_00	045101	Saltwater Creek	Saltwater Creek					
27_00	046101	Bourne Creek	Bourne Creek					
27_00	047101	Powlett River	Powlett River Lagoon	2	H	1	1	M
27_00	047102	Powlett River	Powlett River	2	H	2	2	H
27_00	047203	Powlett River	Bridge Creek	2	H	2	2	H
27_00	048101	Wreck Creek	Wreck Creek					
27_00	049101	Anderson Inlet	Anderson Inlet	3	L	3	3	L
27_00	049102	Anderson Inlet	Tarwin River	3	L	3	3	M
27_00	049203	Anderson Inlet	Screw Creek	3	L	3	3	H
27_00	049304	Anderson Inlet	Pound Creek	3	L			
27_00	050101	Shallow Inlet	Shallow Inlet					
27_00	051101	Darby River	Darby River					
27_00	052101	Tidal River	Tidal River	4	H	4	4	H
27_00	053101	Growler Creek	Growler Creek					
27_00	054101	Sealers Creek	Sealers Creek					
27_00	055101	Miranda Creek	Miranda Creek	3	H	3	3	H
27_00	056101	Chinaman Creek	Chinaman Creek	4	H	4	4	H
27_00	057101	Old Hat Creek	Old Hat Creek Lagoon					
27_00	057102	Old Hat Creek	Old Hat Creek					
27_00	057203	Old Hat Creek	Poor Fellow Me Creek					

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
27_00	058101	Stockyard Creek	Stockyard Creek					
27_00	059101	Bennison Creek	Bennison Creek	4	H	4	4	H
27_00	060101	Franklin River	Franklin River	3	M	4	4	L
27_00	060102	Franklin River	Franklin River	3	M	3	3	H
27_00	061101	Agnes River	Agnes River					
27_00	062101	Shady Creek	Shady Creek					
27_00	063101	Nine Mile Creek	Nine Mile Creek					
27_00	064101	Albert River	Albert River Lagoon					
27_00	064102	Albert River	Albert River					
27_00	064203	Albert River	Muddy Creek					
27_00	065101	Tarra River	Tarra River Lagoon	4	M	4	4	L
27_00	065102	Tarra River	Tarra River	4	M	4	4	M
27_00	066101	Neils Creek	Neils Creek					
27_00	067101	Bruthen Creek	Bruthen Creek Lagoon					
27_00	067102	Bruthen Creek	Bruthen Creek					
27_00	068101	Jack Smith Lake	Jack Smith Lake					
27_00	069101	Lake Denison	Lake Denison					
27_00	070101	Merriman Creek	Merriman Creek Lagoon	3	M	4	4	M
27_00	070102	Merriman Creek	Merriman Creek	3	M	2	2	H
26_00	071101	LaTrobe River	LaTrobe River					
26_00	071202	LaTrobe River	Thomson River					
25_00	072101	Lake Wellington Main Drain	Lake Wellington Main Drain					
25_00	073101	Avon River	Avon River	3	M	3	3	M
25_00	073202	Avon River	Perry River	3	M	4	4	H
24_00	074101	Tom Creek	Tom Creek					
24_00	075101	Tom Roberts Creek	Tom Roberts Creek					
24_00	076101	Newlands Arm	Newlands Arm					

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
24_00	076102	Newlands Arm	Forge Creek					
24_23	077101	Mitchell/Nicholson	Mitchell River	4	M	4	4	M
24_23	077202	Mitchell/Nicholson	Jones Bay	4	M			
24_23	077303	Mitchell/Nicholson	Nicholson River	4	M	4	4	M
23_00	078101	Slaughterhouse Creek	Slaughterhouse Creek					
23_00	078202	Slaughterhouse Creek	Butcher Creek					
23_00	079101	Tambo River	Tambo River					
23_00	080101	Maringa Creek	Maringa Creek					
23_00	081101	Mississippi Creek	North Arm					
23_00	081102	Mississippi Creek	Mississippi Creek					
23_00	082101	Lake Bunga	Lake Bunga	4	L	4	4	L
23_00	083101	Lake Tyers	Lake Tyers (Lower)	3	M	3	3	L
23_00	083102	Lake Tyers	Nowa Nowa Arm (Lower)	3	M	3	3	L
23_00	083103	Lake Tyers	Nowa Nowa Arm (Upper)	3	M	3	3	M
23_00	083204	Lake Tyers	Fishermans Arm	3	M	4	4	L
23_00	083205	Lake Tyers	Toorloo Arm (Lower)	3	M	4	4	L
23_00	083206	Lake Tyers	Toorloo Arm (Upper)	3	M	4	4	H
23_00	083207	Lake Tyers	Blackfellows Arm	3	M	4	4	L
22_00	084101	Snowy River	Snowy River Lagoon	3	L	3	3	L
22_00	084102	Snowy River	Frenchs Narrows	3	L			
22_00	084103	Snowy River	Snowy River	3	L	3	3	L
22_00	084204	Snowy River	Lake Corringle	3	L			
22_00	084305	Snowy River	Brodribb River	3	L	4	4	M
22_00	084306	Snowy River	Lake Curlip	3	L			
22_00	084307	Snowy River	Brodribb Diversion Channel	3	L	4	4	H
22_00	084408	Snowy River	Cabbage Tree Creek (below lagoon)	3	L	4	4	M
22_00	084409	Snowy River	Cabbage Tree Creek Lagoon	3	L	4	4	M

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
22_00	084410	Snowy River	Cabbage Tree Creek (above lagoon)	3	L	4	4	H
21_00	085101	Yeerung River	Yeerung River Lagoon	2	M	2	2	M
21_00	085102	Yeerung River	Yeerung River	2	M	3	3	H
21_00	086101	Sydenham Inlet	Sydenham Entrance Channel	3	M			
21_00	086102	Sydenham Inlet	Sydenham Inlet	3	M	4	4	L
21_00	086103	Sydenham Inlet	Bemm River	3	M	2	2	H
21_00	086204	Sydenham Inlet	Swan Lake Channel	3	M	3	3	H
21_00	086205	Sydenham Inlet	Swan Lake	3	M	4	4	L
21_00	086206	Sydenham Inlet	Mud Lake	3	M			
21_00	087101	Tamboon Inlet	Tamboon Inlet					
21_00	087102	Tamboon Inlet	Cann River					
21_00	087103	Tamboon Inlet	Lake Furnell					
21_00	088101	Thurra River	Thurra River					
21_00	089101	Mueller River	Mueller River Lagoon	3	M	3	3	L
21_00	089102	Mueller River	Mueller River	3	M	4	4	H
21_00	089203	Mueller River	Camp Creek	3	M	3	3	H
21_00	090101	Wingan Inlet	Wingan Inlet	4	M	4	4	L
21_00	090102	Wingan Inlet	Wingan River	4	M	4	4	H
21_00	091101	Easby Creek	Easby Creek					
21_00	092101	Red River	Red River					
21_00	093101	Benadore River	Benadore River Lagoon					
21_00	093102	Benadore River	Benadore River					
21_00	094101	Seal Creek	Seal Creek					
21_00	095101	Shipwreck Creek	Shipwreck Creek	4	H	4	4	H
21_00	096101	Betka River	Betka River Lagoon					
21_00	096102	Betka River	Betka River					
21_00	097101	Davis Creek	Davis Creek	4	H	4	4	H

Basin ID	Section ID	Estuary	Section name	Theme score (estuary)	Theme conf.	Section score	11: Bank Erosion	11: conf.
21_00	098101	Mallacoota Inlet	Mallacoota Entrance Shoals	3	L	4	4	L
21_00	098102	Mallacoota Inlet	Mallacoota Bottom Lake	3	L	4	4	L
21_00	098103	Mallacoota Inlet	Mallacoota Top Lake	3	L	3	3	L
21_00	098104	Mallacoota Inlet	Mallacoota Gypsy Point Reach	3	L	4	4	M
21_00	098105	Mallacoota Inlet	Wallagaraugh River	3	L	4	4	M
21_00	098206	Mallacoota Inlet	Double Creek Arm	3	L			
21_00	098207	Mallacoota Inlet	Double Creek	3	L			
21_00	098308	Mallacoota Inlet	Genoa River	3	L	2	2	M
21_00	098409	Mallacoota Inlet	Maramingo Creek	3	L	4	4	H
21_00	098510	Mallacoota Inlet	Harrison Creek Arm	3	L	4	4	L
21_00	098511	Mallacoota Inlet	Harrison Creek	3	L	3	3	H
21_00	098612	Mallacoota Inlet	Teal Creek	3	L	2	2	H
21_00	098713	Mallacoota Inlet	Dowell Creek	3	L	3	3	H
21_00	099101	Wau Wauka Outlet	Wau Wauka Outlet					
28_00	998101	Watsons Creek	Watsons Creek	4	H	4	4	H
28_00	999101	Warringine Creek	Warringine Creek	4	H	4	4	H

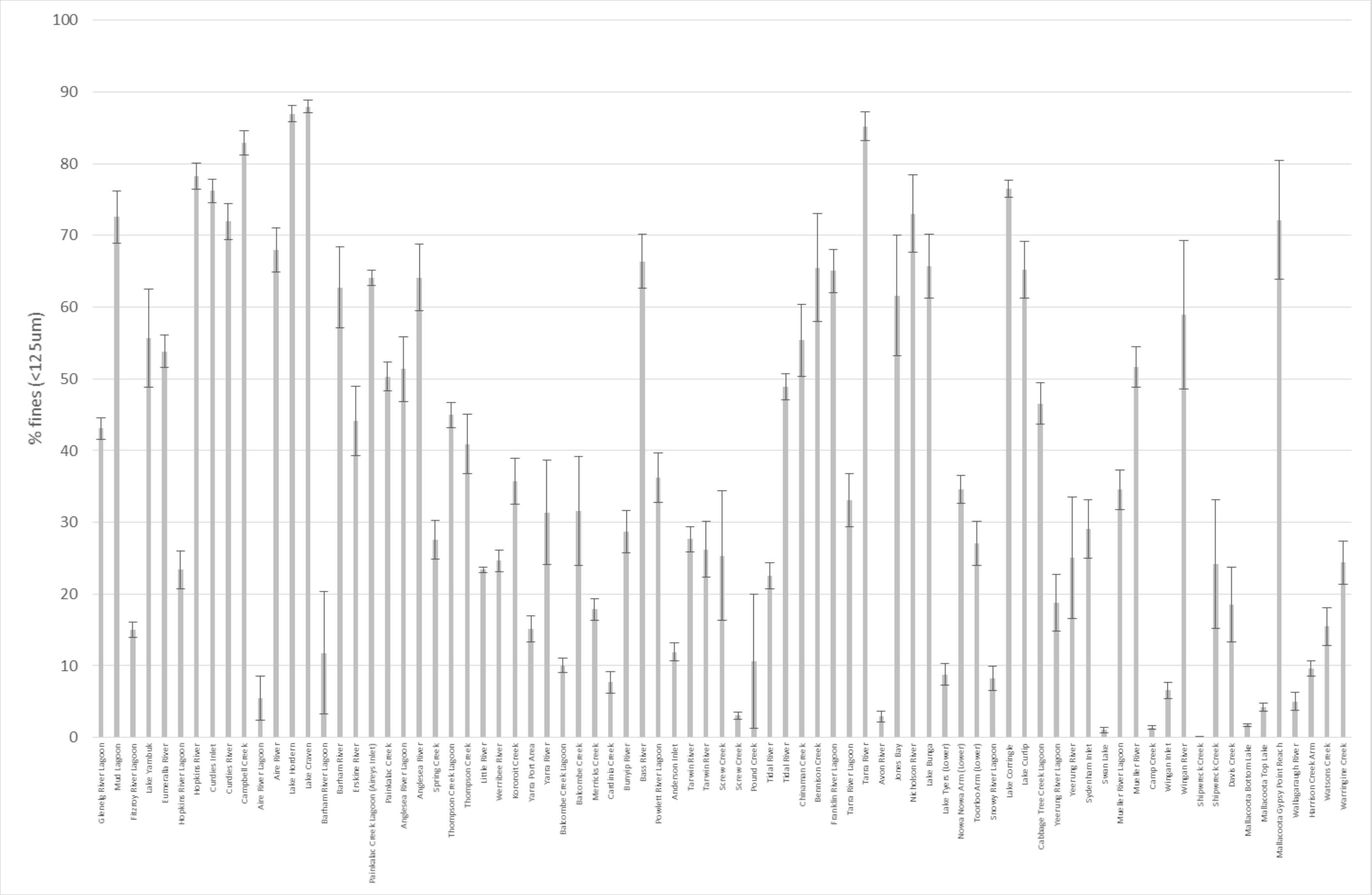

Figure 82. Mean percentage (+/- se) of sediment with particle size <125um in depositional areas by estuary section.

APPENDIX 11 FLORA SCORES FOR ESTUARIES (13A, 16) AND SECTIONS (13A, 16)

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
38_00	001101	Glenelg River	Glenelg River Lagoon	3	L	3			3	L
38_00	001102	Glenelg River	Mud Lagoon	3	L	3			3	L
38_00	001103	Glenelg River	Glenelg River	3	L	3			3	L
37_00	002101	Fawthrop Lagoon	Fawthrop Entrance Channel							
37_00	002102	Fawthrop Lagoon	Fawthrop Lagoon							
37_00	003101	Surrey River	Surrey River							
37_00	004101	Fitzroy River	Fitzroy River Lagoon	3	L	3			3	L
37_00	004102	Fitzroy River	Fitzroy River	3	L	3			3	L
37_00	005101	Lake Yambuk	Lake Yambuk	1	L	1			1	L
37_00	005102	Lake Yambuk	Eumeralla River	1	L	1			1	L
37_00	005203	Lake Yambuk	Shaw River							
37_00	006101	Moyne River	Moyne River Entrance Channel							
37_00	006102	Moyne River	Belfast Lough							
37_00	006103	Moyne River	Moyne River							
36_00	007101	Merri River	Merri River	1	L	1			1	L
36_00	007102	Merri River	Saltwater Swamp	1	L	1			1	L
36_00	008101	Hopkins River	Hopkins River Lagoon	5	L	5			5	L
36_00	008102	Hopkins River	Hopkins River	5	L	5			5	L
35_00	009101	Curdies Inlet	Curdies Inlet	2	L	2			2	L
35_00	009102	Curdies Inlet	Curdies River	2	L	2			2	L

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
35_00	010101	Campbell Creek	Campbell Creek	4	L	4			4	L
35_00	011101	Sherbrook River	Sherbrook River							
35_00	012101	Gellibrand River	Gellibrand River Lagoon							
35_00	012102	Gellibrand River	Gellibrand River							
35_00	012203	Gellibrand River	LaTrobe Creek	3	L	3			3	L
35_00	013101	Johanna River	Johanna River							
35_00	014101	Aire River	Aire River Lagoon	3	L	5			5	L
35_00	014102	Aire River	Aire River	3	L	5			5	L
35_00	014203	Aire River	Ford River	3	L	1			1	L
35_00	014204	Aire River	Lake Hordern	3	L	1			1	L
35_00	014305	Aire River	Lake Craven							
35_00	015101	Barham River	Barham River Lagoon	5	L	5			5	L
35_00	015102	Barham River	Barham River							
35_00	015203	Barham River	Barham Lagoon South							
35_00	016101	Kennett River	Kennett River	4	L	4			4	L
35_00	017101	Wye River	Wye River	5	L	5			5	L
35_00	018101	St George River	St George River	5	L	5			5	L
35_00	019101	Erskine River	Erskine River	5	L	5			5	L
35_00	020101	Painkalac Creek	Painkalac Creek Lagoon (Aireys Inlet)	5	L	5	5	L	5	L
35_00	020102	Painkalac Creek	Painkalac Creek	5	L	5	5	L	5	L
35_00	021101	Anglesea River	Anglesea River Lagoon	4	L	4	3	L	5	L
35_00	021102	Anglesea River	Anglesea River	4	L	4	3	L	5	L

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
35_00	021103	Anglesea River	Coogoorah Park	5	L	5			5	L
35_00	022101	Spring Creek	Spring Creek	5	L	5			5	L
35_00	023101	Thompson Creek	Thompson Creek	1	L	1			1	L
35_00	023102	Thompson Creek	Thompson Creek	1	L	1			1	L
33_00	024101	Barwon River	Barwon River Entrance Channel							
33_00	024102	Barwon River	Lake Connewarre							
33_00	024103	Barwon River	Barwon River							
32_00	025101	Limeburners Lagoon	Limeburners Lagoon	3	L	3			3	L
32_00	025102	Limeburners Lagoon	Hovells Creek	3	L	3			3	L
32_00	026101	Little River	Little River							
31_00	027101	Werribee River	Werribee River Lagoon	2	L	2			2	L
31_00	027102	Werribee River	Werribee River	2	L	2			2	L
31_00	028101	Skeleton Creek	Skeleton Creek							
31_00	029101	Laverton Creek	Laverton Creek							
31_00	030101	Kororoit Creek	Kororoit Creek							
29_30	031101	Yarra River	Yarra Port Area	3	L	3			3	L
29_30	031102	Yarra River	Yarra River	3	L	3			3	L
29_30	031203	Yarra River	Stony Creek	3	L	3			3	L
29_30	031304	Yarra River	Maribyrnong River	3	L	2			2	L
29_30	031405	Yarra River	Moonee Ponds Creek	3	L	3			3	L
29_00	032101	Elwood Canal	Elwood Canal							
28_00	033101	Mordialloc Creek	Mordialloc Creek							

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
28_00	034101	Patterson River	Patterson River							
28_00	034102	Patterson River	Patterson Lakes Canal Estate							
28_00	035101	Kananook Creek	Kananook Creek							
28_00	036101	Balcombe Creek	Balcombe Creek Lagoon							
28_00	036102	Balcombe Creek	Balcombe Creek							
28_00	037101	Merricks Creek	Merricks Creek	2	L	2			2	L
28_00	038101	Cardinia Creek	Cardinia Creek	5	L	5			5	L
28_00	038202	Cardinia Creek	Cardinia Catchment Drain							
28_00	039101	Deep Creek	Deep Creek							
28_00	039202	Deep Creek	Lower Gum Scrub Creek							
28_00	039303	Deep Creek	Toomuc Creek							
28_00	039404	Deep Creek	Deep Creek Catchment Drain							
28_00	040101	Bunyip River	Bunyip River							
28_00	040202	Bunyip River	McGregors Drain							
28_00	040303	Bunyip River	Ararat Creek							
28_00	040404	Bunyip River	North West Catchment Drain							
28_00	040505	Bunyip River	South East Catchment Drain							
28_00	041101	Yallock Creek	Yallock Creek							
28_00	042101	Yallock Drain	Yallock Drain							

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
28_00	043101	Lang Lang River	Lang Lang River							
27_00	044101	Bass River	Bass River							
99_00	045101	Saltwater Creek	Saltwater Creek							
27_00	046101	Bourne Creek	Bourne Creek							
27_00	047101	Powlett River	Powlett River Lagoon	3	L	3			3	L
27_00	047102	Powlett River	Powlett River	3	L	3			3	L
27_00	047203	Powlett River	Bridge Creek							
27_00	048101	Wreck Creek	Wreck Creek							
27_00	049101	Anderson Inlet*	Anderson Inlet	2	L	3			5	L
27_00	049102	Anderson Inlet*	Tarwin River	2	L	3			5	L
27_00	049203	Anderson Inlet*	Screw Creek	2	L	2			3	L
27_00	049304	Anderson Inlet*	Pound Creek	2		1				
27_00	050101	Shallow Inlet	Shallow Inlet							
27_00	051101	Darby River	Darby River							
27_00	052101	Tidal River	Tidal River	5	L	5			5	L
27_00	053101	Growler Creek	Growler Creek							
27_00	054101	Sealers Creek	Sealers Creek							
27_00	055101	Miranda Creek	Miranda Creek	4	L	4			4	L
27_00	056101	Chinaman Creek	Chinaman Creek	3	L	3			3	L
27_00	057101	Old Hat Creek	Old Hat Creek Lagoon							
27_00	057102	Old Hat Creek	Old Hat Creek							
27_00	057203	Old Hat Creek	Poor Fellow Me Creek							
27_00	058101	Stockyard Creek	Stockyard Creek							
27_00	059101	Bennison Creek	Bennison Creek	3	L	3			3	L
27_00	060101	Franklin River	Franklin River	5	L	5			5	L
27_00	060102	Franklin River	Franklin River	5	L	5			5	L

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
27_00	061101	Agnes River	Agnes River							
27_00	062101	Shady Creek	Shady Creek							
27_00	063101	Nine Mile Creek	Nine Mile Creek							
27_00	064101	Albert River	Albert River Lagoon							
27_00	064102	Albert River	Albert River							
27_00	064203	Albert River	Muddy Creek							
27_00	065101	Tarra River	Tarra River Lagoon	4	L	4			4	L
27_00	065102	Tarra River	Tarra River	4	L	4			4	L
27_00	066101	Neils Creek	Neils Creek							
27_00	067101	Bruthen Creek	Bruthen Creek Lagoon							
27_00	067102	Bruthen Creek	Bruthen Creek							
27_00	068101	Jack Smith Lake	Jack Smith Lake							
27_00	069101	Lake Denison	Lake Denison							
27_00	070101	Merriman Creek	Merriman Creek Lagoon	3	L	3			3	L
27_00	070102	Merriman Creek	Merriman Creek	3	L	3			3	L
26_00	071101	LaTrobe River	LaTrobe River							
26_00	071202	LaTrobe River	Thomson River							
25_00	072101	Lake Wellington Main Drain	Lake Wellington Main Drain							
25_00	073101	Avon River	Avon River	1	L	1			1	L
25_00	073202	Avon River	Perry River	1	L	1			1	L
24_00	074101	Tom Creek	Tom Creek							
24_00	075101	Tom Roberts Creek	Tom Roberts Creek							

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
24_00	076101	Newlands Arm	Newlands Arm							
24_00	076102	Newlands Arm	Forge Creek							
24_23	077101	Mitchell/Nicholson	Mitchell River	3	L	3			3	L
24_23	077202	Mitchell/Nicholson	Jones Bay							
24_23	077303	Mitchell/Nicholson	Nicholson River							
23_00	078101	Slaughterhouse Creek	Slaughterhouse Creek							
23_00	078202	Slaughterhouse Creek	Butcher Creek							
23_00	079101	Tambo River	Tambo River							
23_00	080101	Maringa Creek	Maringa Creek							
23_00	081101	Mississippi Creek	North Arm							
23_00	081102	Mississippi Creek	Mississippi Creek							
23_00	082101	Lake Bunga	Lake Bunga	5	L	5			5	L
23_00	083101	Lake Tyers	Lake Tyers (Lower)	2	L	1			1	L
23_00	083102	Lake Tyers	Nowa Nowa Arm (Lower)	2	L	1			1	L
23_00	083103	Lake Tyers	Nowa Nowa Arm (Upper)	2	L	1			1	L
23_00	083204	Lake Tyers	Fishermans Arm	2	L	3			3	L
23_00	083205	Lake Tyers	Toorloo Arm (Lower)	2	L	3			3	L
23_00	083206	Lake Tyers	Toorloo Arm (Upper)	2	L	3			3	L
23_00	083207	Lake Tyers	Blackfellows Arm	2	L	3			3	L

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
22_00	084101	Snowy River	Snowy River Lagoon	1	L	2			2	L
22_00	084102	Snowy River	Frenchs Narrows	1	L	2			2	L
22_00	084103	Snowy River	Snowy River	1	L	2			2	L
22_00	084204	Snowy River	Lake Corringle	1	L	3			3	L
22_00	084305	Snowy River	Brodribb River	1	L	1			1	L
22_00	084306	Snowy River	Lake Curlip	1	L	1			1	L
22_00	084307	Snowy River	Brodribb Diversion Channel	1	L	1			1	L
22_00	084408	Snowy River	Cabbage Tree Creek (below lagoon)	1	L	1			1	L
22_00	084409	Snowy River	Cabbage Tree Creek Lagoon	1	L	1			1	L
22_00	084410	Snowy River	Cabbage Tree Creek (above lagoon)	1	L	1			1	L
21_00	085101	Yeerung River	Yeerung River Lagoon	1	L	1			1	L
21_00	085102	Yeerung River	Yeerung River	1	L	1			1	L
21_00	086101	Sydenham Inlet	Sydenham Entrance Channel	2	L	2			2	L
21_00	086102	Sydenham Inlet	Sydenham Inlet	2	L	2			2	L
21_00	086103	Sydenham Inlet	Bemm River	2	L	2			2	L
21_00	086204	Sydenham Inlet	Swan Lake Channel	2	L	2			2	L
21_00	086205	Sydenham Inlet	Swan Lake	2	L	2			2	L
21_00	086206	Sydenham Inlet	Mud Lake	2	L	2			2	L
21_00	087101	Tamboon Inlet	Tamboon Inlet							
21_00	087102	Tamboon Inlet	Cann River							

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
21_00	087103	Tamboon Inlet	Lake Furnell							
21_00	088101	Thurra River	Thurra River							
21_00	089101	Mueller River	Mueller River Lagoon	3	L	3			3	L
21_00	089102	Mueller River	Mueller River	3	L	3			3	L
21_00	089203	Mueller River	Camp Creek	3	L	3			5	L
21_00	090101	Wingan Inlet	Wingan Inlet	3	L	3	1	L	5	L
21_00	090102	Wingan Inlet	Wingan River	3	L	3	1	L	5	L
21_00	091101	Easby Creek	Easby Creek							
21_00	092101	Red River	Red River							
21_00	093101	Benadore River	Benadore River Lagoon							
21_00	093102	Benadore River	Benadore River							
21_00	094101	Seal Creek	Seal Creek							
21_00	095101	Shipwreck Creek	Shipwreck Creek	3	L	3			3	L
21_00	096101	Betka River	Betka River Lagoon							
21_00	096102	Betka River	Betka River							
21_00	097101	Davis Creek	Davis Creek	3	L	3			3	L
21_00	098101	Mallacoota Inlet	Mallacoota Entrance Shoals	3	L	2	1	L	3	L
21_00	098102	Mallacoota Inlet	Mallacoota Bottom Lake	3	L	3			3	L
21_00	098103	Mallacoota Inlet	Mallacoota Top Lake	3	L	3			3	L
21_00	098104	Mallacoota Inlet	Mallacoota Gypsy Point Reach	3	L	3			3	L
21_00	098105	Mallacoota Inlet	Wallagaraugh River	3	L	3			3	L
21_00	098206	Mallacoota Inlet	Double Creek Arm	3	L	5			5	L

Basin ID	Section ID	Estuary	Section name	Flora Theme & measure score	Flora. conf.	Sect Flora. score	13a Aquatic macrophyte extent	13a: conf.	16 Phytoplankton	16 conf.
21_00	098207	Mallacoota Inlet	Double Creek	3	L	5			5	L
21_00	098308	Mallacoota Inlet	Genoa River	3	L	5			5	L
21_00	098409	Mallacoota Inlet	Maramingo Creek	3	L	5			5	L
21_00	098510	Mallacoota Inlet	Harrison Creek Arm	3	L	2	1	L	3	L
21_00	098511	Mallacoota Inlet	Harrison Creek	3	L	3			3	L
21_00	098612	Mallacoota Inlet	Teal Creek	3	L	3	1	L	5	L
21_00	098713	Mallacoota Inlet	Dowell Creek	3	L	3	1	L	5	L
21_00	099101	Wau Wauka Outlet	Wau Wauka Outlet	3	L	3			5	L
28_00	998101	Watsons Creek	Watsons Creek	2	L	2			2	L
28_00	999101	Warringine Creek	Warringine Creek							

* fringing macrophyte (14) measure only calculated for the entire Anderson Inlet, with an IEC score of 1.