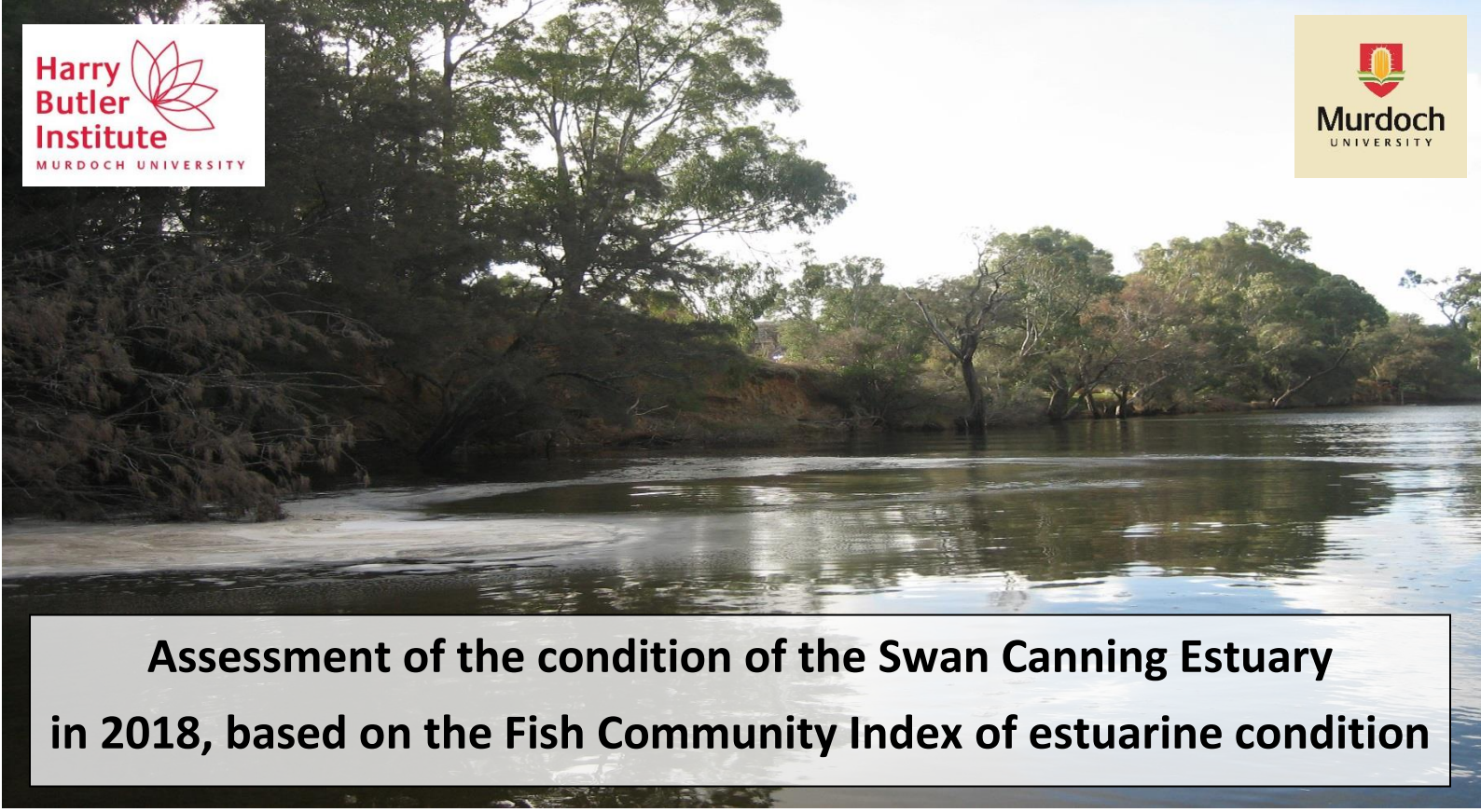

Assessment of the condition of the Swan Canning Estuary in 2018, based on the Fish Community Index of estuarine condition

July 2018

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Prepared for the Department of Biodiversity, Conservation and Attractions

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

The author has prepared this report in accordance with the scope of work and for the purpose required by the Department of Biodiversity, Conservation and Attractions. The methodology adopted and sources of information used by the author are outlined in this report. The author has made no independent verification of this information beyond the agreed scope of works, and assumes no responsibility for any inaccuracies or omissions. This report was prepared during June 2018, based on the information reviewed at the time of preparation. The author disclaims any responsibility for changes that may have occurred after this time. This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Executive summary

This report, commissioned by the Department of Biodiversity, Conservation and Attractions, describes the monitoring and evaluation of fish communities in the Swan Canning Riverpark during 2018 and applies the Fish Community Index (FCI) that was developed as a measure of the ecological condition of the Swan Canning Estuary. This index, versions of which were developed for both the shallow, nearshore waters of the estuary and also for its deeper, offshore waters, integrates information on various biological variables (metrics). Each of these metrics quantifies an aspect of the structure and/or function of estuarine fish communities, and together they respond to a range of stressors affecting the ecosystem.

Fish communities were sampled using different nets at six nearshore and six[1] offshore sites in each of four management zones of the estuary (Lower Swan Canning Estuary, LSCE; Canning Estuary, CE; Middle Swan Estuary, MSE; Upper Swan Estuary, USE) during summer and autumn of 2018. As many fish as possible were returned to the water alive after they had been identified and counted. The resulting data on the abundances of each fish species from each sample were used to calculate a Fish Community Index score (0–100). These index scores were then compared to established scoring thresholds to determine ecological condition grades (A–E) for each zone and for the estuary as a whole, based on the composition of the fish community.

Nearshore Fish Communities

The nearshore waters of the estuary as a whole were in good-fair condition (B/C) during 2018, consistent with the overall trend in condition since 2011.

The average nearshore FCI scores for each zone of the estuary show that all were in fair (C) or good (B) condition in summer and autumn, with the exception of the MSE, whose condition in autumn was poor (D). This decline in condition probably reflects the effects of a period of stratification and hypoxia in late May, which coincided with the sampling of fish in the MSE, and also the potential influence of algal blooms at this time.

Small-bodied, schooling species of hardyheads (Atherinidae) and gobies (Gobiidae) once again dominated catches from the nearshore waters of the estuary in 2018, comprising seven of the eight most abundant nearshore species overall. In particular, Wallace's hardyhead was again the most abundant species overall and in the CE, MSE and USE, reflecting the preference of this species for the fresh to brackish conditions that were present in these zones during the 2018 monitoring period. Other abundant species of goby and hardyhead included the Elongate hardyhead and Silverfish, which prefer more saline waters, the tropical Mugil's hardyhead in the CE, the Bluespot goby in the USE and Red-spot goby in the MSE. Perth herring were also abundant in the USE (20% of the total catch in that zone).

As in previous years, and as is typical for this and similar estuaries in south-western Australia, the total number of species recorded in the nearshore waters of each zone declined in an upstream direction, from 29 species in the LSCE to 15 species in the USE.

[1] An act of vandalism resulted in only five offshore sites being sampled in autumn of 2018. See note in text below.

Offshore fish communities

Overall, the offshore waters of the estuary were in fair-good (C/B) condition during 2018, reflecting the lack of any widespread or severe hypoxia (low dissolved oxygen) during this year's monitoring period. The offshore condition in 2018 represents an increase from the last two years, and particularly from 2017 – a year in which unusually high summer flows impacted the condition of the estuary.

Each of the Riverpark's individual management zones exhibited good (B) ecological condition during summer, with the exception of the CE, which was poor (D). During autumn, the offshore waters of the LSCE, CE and USE were in fair to good condition, whereas those of the MSE were poor (D). This likely reflects the low dissolved oxygen levels that developed in localised areas of this zone during late May, as the water column became stratified with fresher water overlying denser, saltier bottom-water. Blooms of potentially harmful species of algae (dinoflagellates) may also have contributed to the poor condition of the MSE in autumn.

As in the six previous years of monitoring, Perth herring was among the dominant species in offshore waters from all four zones, comprising 37–75% of the total catches. Tailor were also abundant in 2018, comprising 6–13.5% of the catches from the LSCE, CE and MSE. The Southern eagle ray was abundant in the LSCE and Yellowtail grunter in the USE. Also, Mulloway were unusually abundant in the catches during 2018, being caught in all four zones yet most prevalent in the USE.

Overall

In summary, and across the estuary as a whole, the ecological condition of nearshore waters in 2018 was assessed as good-fair (B/C) and that of the offshore waters as fair-good (C/B), based on their fish communities. These results indicate slightly better ecological condition of both nearshore and offshore waters during 2018 compared to 2017. This reflects the lack of any extensive or severe hypoxia during the 2018 monitoring period, in contrast to the widespread impacts of unusually high summer river flows on the estuary in 2017.

Assessment of the condition of the Swan Canning Estuary in 2018, based on the Fish Community Index of estuarine condition

Contents

1. Background

The Department of Biodiversity, Conservation and Attractions works with other government organizations, local government authorities, community groups and research institutions to reduce nutrient and organic loading to the Swan Canning Estuary and river system. This is a priority issue for the waterway that has impacts on water quality, ecological health and community benefit.

Environmental monitoring for the waterway includes water quality reporting in the estuary and catchment and reporting on ecological health. Reporting on changes in fish communities provides insight into the biotic integrity of the system and complements water quality reporting.

The Fish Community Index (FCI) was developed by Murdoch University, through a collaborative project (2007–2012) between the Swan River Trust, Department of Fisheries and Department of Water (Valesini et al. 2011, Hallett et al. 2012, Hallett and Valesini 2012, Hallett 2014), for assessing the ecological condition of the Swan Canning Estuary. The FCI has been subjected to extensive testing and validation over a period of several years (e.g. Hallett and Valesini 2012, Hallett 2014), and has been shown to be a sensitive and robust tool for quantifying ecological health responses to local-scale environmental perturbations and the subsequent recovery of the system following their removal (Hallett 2012, Hallett et al. 2012, 2016).

2. Rationale

Versions of the Fish Community Index were developed for the shallow, nearshore waters of the estuary and also for its deeper, offshore waters, as the composition of the fish communities living in these different environments tends to differ, as do the methods used to sample them. These indices integrate information on various biological variables ('metrics'; Table 1), each of which quantifies an aspect of the structure and/or function of estuarine fish communities. Together, the metrics respond to a wide array of stressors affecting the ecosystem. The FCI therefore provides a means to assess an important component of the ecology of the system and how it responds to, and thus reflects, changes in estuarine condition.

The responses of estuarine fish communities to increasing ecosystem stress and degradation (*i.e.* declining ecosystem health or condition) may be summarised in a conceptual model (Fig. 1). In response to increasing degradation of estuarine ecosystems, fish species with specific habitat, feeding or other environmental requirements will tend to become less abundant and diverse, whilst a few species with more general requirements become more abundant. This leads ultimately to an overall reduction in the number and diversity of fish species (Gibson et al. 2000; Whitfield and Elliott 2002; Villéger et al. 2010; Fonseca et al. 2013). So, in a degraded estuary with poor water, sediment and habitat quality, the abundance and diversity of specialist feeders (*e.g.* Garfish and Tailor), bottom-living ('benthic-associated') species (*e.g.* Cobbler and Flathead) and estuarine spawning species (*e.g.* Black bream, Perth herring and Yellow-tail grunter) will tend to decrease, as will the overall number and diversity of species. In contrast, generalist feeders (*e.g.* Banded toadfish or Blowfish) and detritivores (*e.g.* Sea mullet), which eat particles of decomposing organic material, will become more abundant and dominant (see left side of Fig. 1). The reverse will be observed in a relatively unspoiled system that is subjected to fewer human stressors (see right side of Fig. 1; noting that this conceptual diagram represents either end of a continuum of ecological condition from very poor to very good).

Each of the metrics that make up the FCI are scored from 0–10 according to the numbers and proportions of the various fish species present in samples collected from the estuary using either seine or gill nets. These metric scores are summed to generate a FCI score for the sample, which ranges

from 0–100. Grades (A–E) describing the condition of the estuary, and/or of particular zones, are then awarded based on the FCI scores (see section 4 for more details).

Table 1. Summary of the fish metrics comprising the nearshore and offshore Fish Community Indices developed for the Swan Canning Estuary (Hallett et al. 2012).

Metric	Predicted response to degradation	*Nearshore Index*	*Offshore Index*
Number of species (No.species)	Decrease	✓	✓
Shannon-Wiener diversity (Sh-div) [a]	Decrease		✓
Proportion of trophic specialists (Prop.trop.spec.) [b]	Decrease	✓	
Number of trophic specialist species (No.trop.spec.) [b]	Decrease	✓	✓
Number of trophic generalist species (No.trop.gen.) [c]	Increase	✓	✓
Proportion of detritivores (Prop.detr.) [d]	Increase	✓	✓
Proportion of benthic-associated individuals (Prop.benthic) [e]	Decrease	✓	✓
Number of benthic-associated species (No.benthic) [e]	Decrease	✓	
Proportion of estuarine spawning individuals (Prop.est.spawn)	Decrease	✓	✓
Number of estuarine spawning species (No.est.spawn)	Decrease	✓	
Proportion of *Pseudogobius olorum* (Prop. *P. olorum*) [f]	Increase	✓	
Total number of *Pseudogobius olorum* (Tot no. *P. olorum*) [f]	Increase	✓	

[a] A measure of the biodiversity of species
[b] Species with specialist feeding requirements (*e.g.* those that only eat small invertebrates)
[c] Species that are omnivorous or opportunistic feeders
[d] Species that eat detritus (decomposing organic material)
[e] Species that live on, or are closely associated with, the sea/river bed
[f] The Blue-spot or Swan River goby, a tolerant, omnivorous species that often inhabits silty habitats

3. Study objectives

This report describes the monitoring and evaluation of fish communities in the Swan Canning Riverpark during 2018 for the purposes of applying the Fish Community Index as a measure of ecological condition. The objectives of this study were to:

1. Undertake monitoring of fish communities in mid-summer and mid-autumn periods, following an established approach as detailed in Hallett and Valesini (2012), including six nearshore and six offshore sampling sites in each estuarine management zone.
2. Analyse the information collected so that the Fish Community Index is calculated for nearshore and offshore waters in each management zone and for the estuary overall. The information shall be presented as quantitative FCI scores (0–100), qualitative condition grades (A–E) and descriptions of the fish communities. Radar plots shall also be used to demonstrate the patterns of fish metric scores for each zone.
3. Provide a report that summarizes the approach and results and that could feed into a broader estuarine reporting framework.

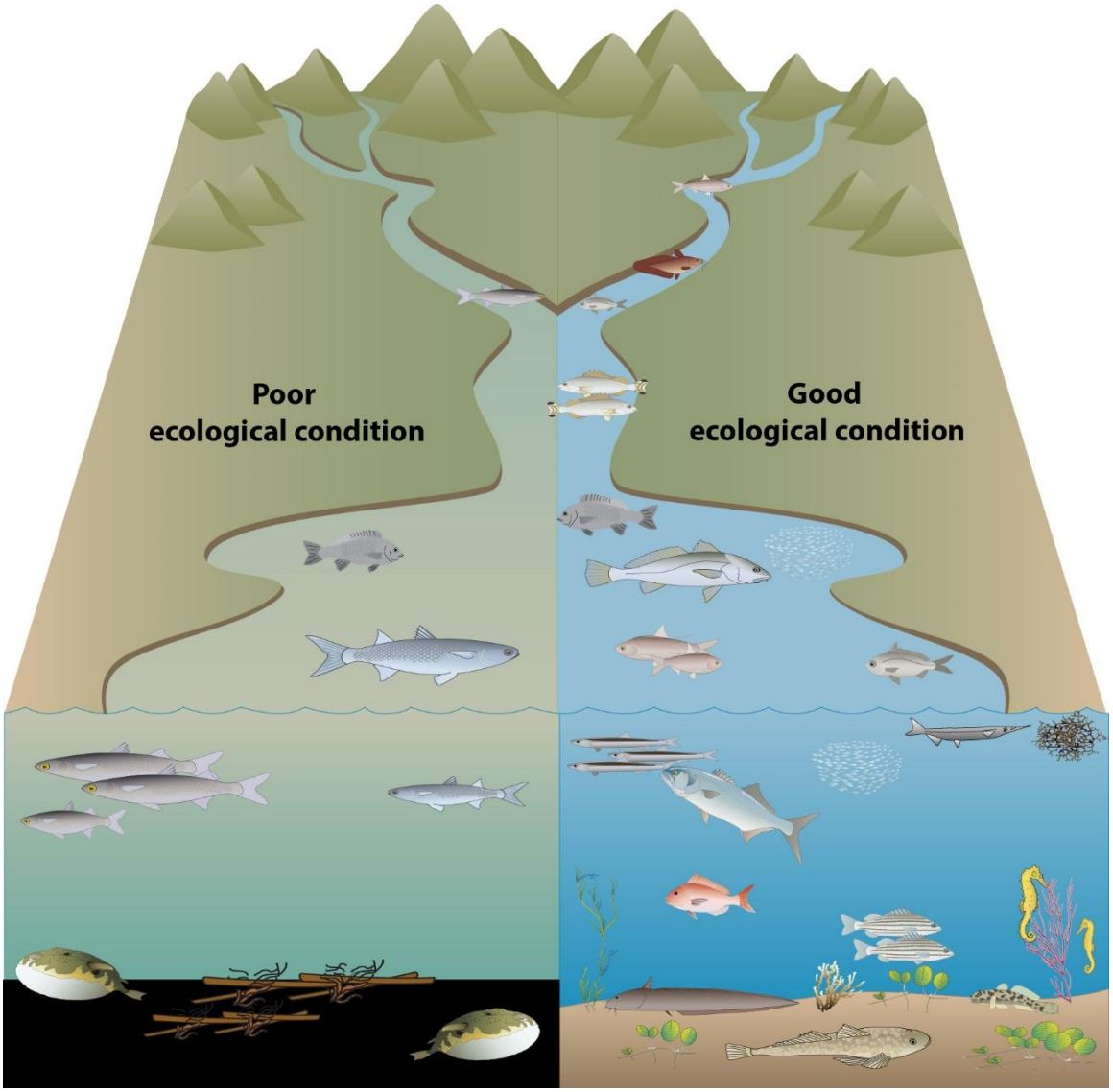


Figure 1. Conceptual diagram illustrating the predicted responses of the estuarine fish community to situations of poor and good ecological condition. (Images courtesy of the Integration and Application Network [ian.umces.edu/symbols/].)

4. Methods

Fish communities were sampled at six nearshore and six offshore sites in each of four management zones of the Swan Canning Estuary (LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary; Fig. 2) during both summer (22 January–6 March) and autumn (23 April–31 May) of 2018. Heavy rainfall and strong river flows during February interrupted summer sampling, which was completed on 6 March. Due to an act of vandalism, only five of the six offshore sites in the LSCE could be sampled successfully during autumn.

Nearshore waters were sampled using a 21.5 m seine net that was walked out from the beach to a maximum depth of approximately 1.5 m and deployed parallel to the shore, and then rapidly dragged towards and onto the shore (Fig. 3). Offshore waters were sampled using 160 m-long, sunken,

multimesh gill nets, each consisting of eight 20 m-long panels with stretched mesh sizes of 35, 51, 63, 76, 89, 102, 115 and 127 mm (Fig. 3). These were deployed (*i.e.* laid parallel to the bank at a depth of 2–8 m, depending on the site) from a boat immediately before sunset and retrieved after three hours.

Once a sample had been collected, any fish that could be identified immediately to species (*e.g.* larger species that are caught in relatively lower numbers) were identified, counted and returned to the water alive. All other fish caught in the nets were placed into zip-lock polythene bags, humanely killed in ice slurry and preserved on ice in eskies for subsequent identification and counting, except in cases where large catches (*e.g.* thousands) of small fish were obtained. In such instances, an appropriate sub-sample (*e.g.* one-half to one-eighth of the catch) was retained for identification and estimation of the numbers of each species, and the remaining fish were returned alive to the water to minimise the impact on fish populations. All retained fish were then frozen until their identification in the laboratory. See appendices (i and ii) for full details of the sampling locations and methods employed.

The abundances of each fish species in each sample were used to derive values for each of the relevant metrics comprising the nearshore and offshore indices (see Hallett et al. 2012, Hallett and Valesini 2012). Metric scores were then calculated from these metric values, and the metric scores in turn combined to form the FCI scores. The detailed methodology for how this is achieved is provided in Hallett and Valesini (2012), but can be summarised simply as follows:

1. Calculate metric values for each sample, after allocating each of its component fish species to their appropriate Habitat guild, Estuarine Use guild and Feeding Mode guild (Appendix iii).
2. Convert metric values to metric scores (0–10) via comparison with the relevant (zone- and season-specific) reference condition values for each metric.
3. Combine scores for the component metrics into a scaled FCI score (0–100) for each sample.
4. Compare the FCI score to the thresholds used to determine the condition grade for each sample (Table 2; Hallett 2014), noting that intermediate grades *e.g.* B/C (good-fair) or C/B (fair-good) are awarded if the index score lies within one point either side of a grade threshold.

The FCI scores and condition grades for nearshore and offshore samples collected during summer and autumn 2018 were then examined to assess the condition of the Swan Canning Estuary during this period and compared to previous years.

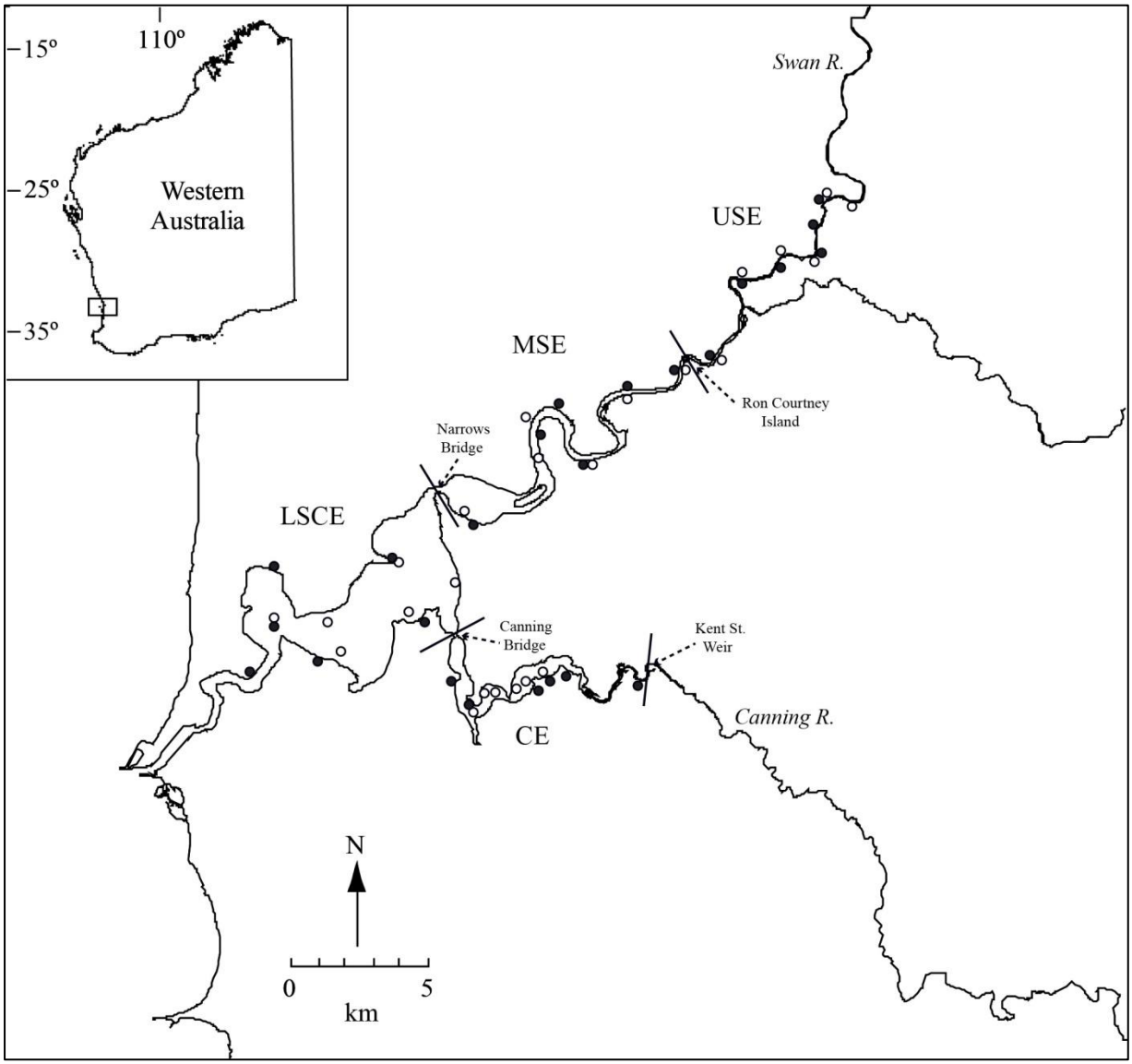


Figure 2. Locations of nearshore (black circles) and offshore (open circles) sampling sites for the Fish Community Index of estuarine condition. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

Table 2. Fish Community Index (FCI) scores comprising each of the five condition grades for both nearshore and offshore waters.

Condition grade	Nearshore FCI scores	Offshore FCI scores
A (very good)	>74.5	>70.7
B (good)	64.6-74.5	58.4-70.7
C (fair)	57.1-64.6	50.6-58.4
D (poor)	45.5-57.1	36.8-50.6
E (very poor)	<45.5	<36.8

Figure 3. Images of the beach seine netting (upper row) used to sample the fish community in shallower, nearshore waters and the multimesh gill netting (lower row) used to sample fish communities in deeper, offshore waters of the Swan Canning Estuary. (Images courtesy of Steeg Hoeksema, Jen Eliot and Kerry Trayler, DBCA).

5. Results and discussion

5.1 Context: water quality and environmental conditions during the 2018 monitoring period

Vertical contour plots of interpolated salinities and dissolved oxygen (DO) concentrations, measured at regular water quality monitoring sites along the length of the Swan Canning Estuary, illustrate the environmental conditions present throughout the system during the monitoring period (Appendix iv). The water column of the Swan Estuary was vertically well mixed in early January 2018, with brackish conditions in the MSE to USE and more marine conditions in the LSCE. Increasing river flows in mid-January created a highly stratified water column in the MSE during the latter part of January and the first week of February. This generated hypoxic conditions (<2 mg/L dissolved oxygen) in the bottom waters of the MSE and parts of the USE at this time. River flows subsequently declined and the salt wedge pushed back upstream during March and April, bringing conditions that remained well mixed and relatively well oxygenated into mid-May. Another flow event in late May then brought about marked stratification and re-established hypoxic conditions in parts of the MSE to USE in early June.

The river flows of mid-January also stratified the water column of the CE, with fresh conditions evident upstream from Riverton Bridge (Appendix iv). This stratification persisted in parts of the CE until the end of February, accompanied by areas of hypoxia. The subsequent decline in flow

established more marine conditions throughout the CE during March, April and into early May, by which time FCI sampling in this zone was completed.

5.2 Description of the fish community of the Swan Canning Estuary during 2018

Overall, the nearshore and offshore fish communities of the Swan Canning Estuary in 2018 were again broadly similar in species composition to those observed during equivalent monitoring conducted annually since 2012.

An estimated 28,331 fish, belonging to 36 species, were caught in seine net samples collected from the nearshore waters of the Swan Canning Estuary during summer and autumn 2018. As in previous years, and as is typical for this and similar estuaries in south-western Australia, the total number of species recorded in the nearshore waters of each zone declined in an upstream direction, from 29 species in the LSCE to 15 species in the USE (Table 3). More species were recorded from the nearshore waters of the LSCE, CE and USE in 2018 than during comparable monitoring in 2017. This reflects the effects of significant freshwater flows and thus lower salinities in the estuary during the 2017 monitoring period, which created less favourable conditions for a large number of the marine-associated species that inhabit this system.

The hardyheads (Atherinidae) and gobies (Gobiidae) once again dominated catches from the nearshore waters of the estuary in 2018, with seven of the eight most abundant nearshore species overall belonging to these families. In particular, Wallace's hardyhead (*Leptatherina wallacei*) was again the most abundant species overall and in the CE, MSE and USE (comprising 16–51% of all fish in these zones; Table 3). This reflects the preference of this species for fresh to brackish conditions (Potter et al. 2015), which were evident in these zones during the 2018 monitoring period. In contrast, the LSCE was dominated by two atherinids, *Atherinosoma elongata* and *L. presbyteroides,* which prefer more saline waters. Other abundant species belonging to the Gobiidae and Atherinidae included the tropical hardyhead *Craterocephalus mugiloides* in the CE, the Bluespot goby (*Pseudogobius olorum*) in the USE, Red-spot goby (*Favonigobius punctatus*) in the MSE, and Ogilby's hardyhead (*Atherinomorus vaigiensis*) in the MSE (Table 3). In addition, the Western striped grunter (*Pelates octolineatus*) was fairly abundant in the LSCE (5% of the total catch), as was the Perth herring (*Nematalosa vlaminghi*) in the USE (20%).

Samples collected from offshore waters in summer and autumn 2018 using gill nets returned 1,562 fish, comprising 17 species (Table 4). The total number of species recorded from each zone was relatively consistent (8–12), with the CE and MSE being the most speciose zones. As in the six previous years of monitoring, Perth herring (*Nematalosa vlaminghi*) was among the dominant species in offshore waters from all four zones, comprising 37–75% of the total catches (Table 4). Tailor (*Pomatomus saltatrix*) were also abundant in 2018, comprising 6–13.5% of the catches from the LSCE, CE and MSE. The Southern eagle ray (*Myliobatis tenuicaudata*) was abundant in the LSCE and Yellowtail grunter (*Amniataba caudavittata*) in the USE. Interestingly, Mulloway were unusually abundant in the catches during 2018, being caught in all four zones yet most abundant in the USE (4.2% of the catch).

Table 3. Compositions of the fish communities observed across the six nearshore sites sampled in each zone of the Swan Canning Estuary during summer and autumn of 2018. Data for the three most abundant species in the catches from each zone are emboldened for emphasis. LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary. * denotes introduced species

Species	**Common name**	**LSCE** (*n* = 12)		**CE** (*n* = 12)		**MSE** (*n* = 12)		**USE** (*n* = 12)	
		Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution
Leptatherina wallacei	Wallace's hardyhead	0.1	0.1	**307.8**	**31.0**	**27.2**	**15.6**	**308.8**	**51.4**
Craterocephalus mugiloides	Mugil's hardyhead	12.8	4.8	**378.6**	**38.2**	15.9	9.1	0.2	<0.1
Atherinosoma elongata	Elongate hardyhead	**163.2**	**60.7**	14.9	1.5	1.1	0.6	-	-
Leptatherina presbyteroides	Presbyter's hardyhead/ silverfish	**34.6**	**12.9**	**110.0**	**11.1**	0.4	0.2	-	-
Favonigobius punctatus	Red-spot goby	12.3	4.6	92.0	9.3	**20.4**	**11.7**	16.4	2.7
Nematalosa vlaminghi	Perth herring	-	-	2.3	0.2	10.6	6.0	**121.1**	**20.2**
Pseudogobius olorum	Blue-spot goby	4.8	1.8	20.5	2.1	13.4	7.7	**80.5**	**13.4**
Atherinomorus vaigensis	Ogilby's hardyhead	0.3	0.1	15.0	1.5	**51.1**	**29.3**	-	-
Gambusia holbrooki	Mosquito fish *	-	-	8.1	0.8	-	-	43.3	7.2
Acanthopagrus butcheri	Black bream	1.5	0.6	14.4	1.5	15.2	8.7	8.12	1.4
Pelates octolineatus	Western striped grunter	**14.2**	**5.3**	<0.1	<0.1	1.7	1.0	3.7	0.6
Gerres subfasciatus	Roach	0.7	0.2	4.0	0.4	2.0	1.2	10.3	1.7
Amniataba caudavittata	Yellowtail grunter	1.4	0.5	7.3	0.7	3.1	1.8	0.9	0.1
Favonigobius lateralis	Long-finned goby	7.0	2.6	2.4	0.2	0.4	0.2	-	-
Afurcagobius suppositus	Southwestern goby	-	-	1.7	0.2	4.2	2.4	4.0	0.7
Ostorhinchus rueppelli	Gobbleguts	5.2	2.0	<0.1	<0.1	3.4	1.9	0.2	<0.1
Torquigener pleurogramma	Blowfish/Banded toadfish	6.3	2.4	0.6	0.1	0.1	0.1	-	-
Aldrichetta forsteri	Yellow-eye mullet	1.3	0.5	3.2	0.3	1.0	0.6	-	-
Arenigobius bifrenatus	Bridled goby	-	-	3.2	0.3	1.8	1.0	0.4	0.1
Mugil cephalus	Sea mullet	<0.1	<0.1	2.2	0.2	0.3	0.2	2.4	0.4
Sillago burrus	Western trumpeter whiting	0.6	0.2	2.2	0.2	1.2	0.7	-	-
Geophagus brasiliensis	Pearl cichlid *	-	-	0.7	0.1	-	-	-	-

Species	Common name	**LSCE** (*n* = 12)		**CE** (*n* = 12)		**MSE** (*n* = 12)		**USE** (*n* = 12)	
		Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution
(continued)									
Haletta semifasciata	Blue weed whiting	0.6	0.2	-	-	-	-	-	-
Gymnapistes marmoratus	Devilfish	0.4	0.2	-	-	-	-	-	-
Sillago schomburgkii	Yellow-finned whiting	0.1	0.1	0.3	0.0	-	-	-	-
Sillaginodes punctata	King George whiting	0.1	0.1	<0.1	<0.1	-	-	-	-
Hyperlophus vittatus	Sandy sprat	0.1	0.1	<0.1	<0.1	-	-	-	-
Rhabdosargus sarba	Tarwhine	0.2	0.1	-	-	-	-	-	-
Parablennius postoculomaculatus	False Tasmanian blenny	0.1	0.1	-	-	-	-	-	-
Cnidoglanis macrocephalus	Estuary cobbler	0.1	0.1	-	-	-	-	-	-
Pugnaso curtirostris	Pugnosed pipefish	-	-	-	-	0.1	0.1	-	-
Platycephalus westraliae	Yellowtail flathead	0.1	0.1	-	-	-	-	-	-
Omobranchus germaini	Germain's blenny	-	-	-	-	-	-	<0.1	<0.1
Galaxias occidentalis	Western minnow	<0.1	<0.1	-	-	-	-	-	-
Siphonognathus radiatus	Long-rayed weed whiting	<0.1	<0.1	-	-	-	-	-	-
Ammotertis elongatus	Elongate flounder	<0.1	<0.1	-	-	-	-	-	-
Scobinichthys granulatus	Rough leatherjacket	0.4	0.2	-	-	-	-	-	-
		29 Species		**25 Species**		**21 Species**		**15 Species**	
		Average total fish density (fish/100m^2)	Total number of fish	Average total fish density (fish/100m^2)	Total number of fish	Average total fish density (fish/100m^2)	Total number of fish	Average total fish density (fish/100m^2)	Total number of fish
		269	**3,740**	**992**	**13,806**	**175**	**2,430**	**600**	**8,355**

Table 4. Compositions of the fish communities observed across the six[2] offshore sites sampled in each zone of the Swan Canning Estuary during summer and autumn of 2018. Data for the three most abundant species in the catches from each zone are emboldened for emphasis. LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary. * denotes introduced species

Species	**Common name**	**LSCE** (*n* = 11)		**CE** (*n* = 12)		**MSE** (*n* = 12)		**USE** (*n* = 12)	
		Average catch rate (fish/net set)	% contribution	Average catch rate (fish/net set)	% contribution	Average catch rate (fish/net set)	% contribution	Average catch rate (fish/net set)	% contribution
Nematalosa vlaminghi	Perth herring	**7.5**	**37.4**	**23.7**	**74.9**	**14.3**	**68.0**	**27.0**	**45.8**
Amniataba caudavittata	Yellowtail grunter	-	-	0.7	2.1	1.0	4.7	**25.4**	**43.1**
Pomatomus saltatrix	Tailor	**2.7**	**13.5**	**2.8**	**9.0**	**1.3**	**6.3**	-	-
Myliobatis tenuicaudatus	Southern eagle ray	**4.8**	**23.9**	-	-	-	-	-	-
Argyrosomus japonicus	Mulloway	0.4	1.8	0.5	1.6	0.6	2.8	**2.5**	**4.2**
Acanthopagrus butcheri	Black bream	-	-	0.4	1.3	0.6	2.8	2.4	4.1
Platycephalus westraliae	Yellowtail flathead	1.4	6.8	0.4	1.3	0.6	2.8	0.3	0.6
Gerres subfasciatus	Roach	0.8	4.1	1.0	3.2	0.3	1.6	-	-
Mugil cephalus	Sea mullet	-	-	0.1	0.3	**1.3**	**6.3**	0.7	1.1
Pelates octolineatus	Western striped grunter	0.7	3.6	**1.1**	**3.4**	0.1	0.4	-	-
Engraulis australis	Southern anchovy	-	-	-	-	0.6	2.8	0.5	0.8
Sillago burrus	Western trumpeter whiting	1.0	5.0	-	-	-	-	-	-
Sardinella lemuru	Scaly mackerel	-	-	0.7	2.1	-	-	-	-
Elops machnata	Giant herring	0.5	2.3	-	-	0.1	0.4	-	-
Carcharinas leucas	Bull shark	-	-	-	-	0.3	1.2	0.2	0.3
Cnidoglanis macrocephalus	Estuary cobbler	0.4	1.8	0.1	0.3	-	-	-	-
Rhabdosargus sarba	Tarwhine	-	-	0.2	0.5	-	-	-	-
		10 Species		**12 Species**		**12 Species**		**8 Species**	
		Average total catch rate (fish/net set)	Total number of fish	Average total catch rate (fish/net set)	Total number of fish	Average total catch rate (fish/net set)	Total number of fish	Average total catch rate (fish/net set)	Total number of fish
		19	**222**	**32**	**379**	**21**	**253**	**59**	**708**

[2] Note that only five of the six offshore sites in the LSCE could be sampled successfully during autumn.

5.3 Ecological condition in 2018

Nearshore waters

The ecological condition (based on fish communities) of the nearshore waters of the Riverpark was generally good (B) to fair (C) during the 2018 monitoring period (Fig. 4). The condition of all zones was good or fair during summer 2018 (mean FCI scores 59–68), with the average nearshore condition of the estuary overall being fair-good (C/B), indicated by a mean FCI score of 64. During autumn, the condition of the LSCE, CE and USE was good, whereas that of the MSE had declined to poor (D). This decline in condition probably reflects the effects of a period of stratification and hypoxia in late May, which coincided with the sampling of fish in the MSE.

The presence of dinoflagellate blooms in the MSE and USE during autumn may also have contributed to the poor condition of the MSE at this time. The MSE was sampled during the second week of May, which coincided with a bloom of *Prorocentrum minimum* in the MSE (~6,000 cells/mL at Maylands on 14th May), and again in late-May, which immediately followed a significant rainfall event. The resulting flows may have shifted the effects of a *Karlodinium veneficum* bloom (maximum 28,600 cells/mL at the Jane Brook confluence in USE on 21 May 2018) downstream. If this occurred, it may have exacerbated the stressors (i.e. low oxygen) that fish in the MSE were subjected to. Although, maximum *K. veneficum* densities were only 84 cells/mL in the MSE on 28 May 2018, the potentially toxic effects of a declining bloom cannot be entirely ruled out. No stressed or dead fish were observed at the time of sampling.

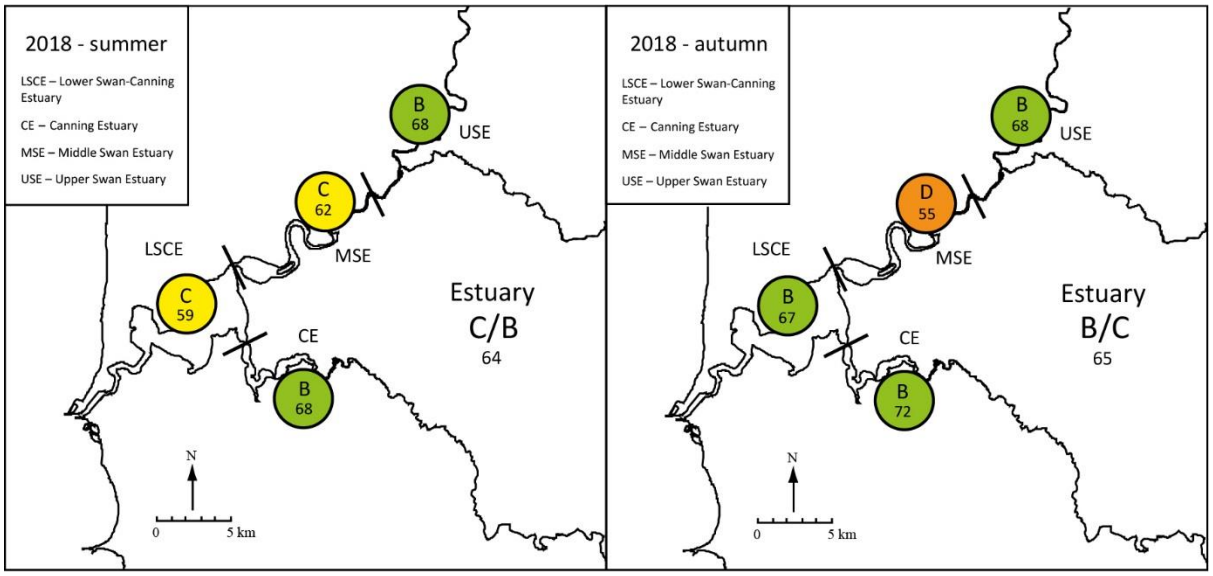
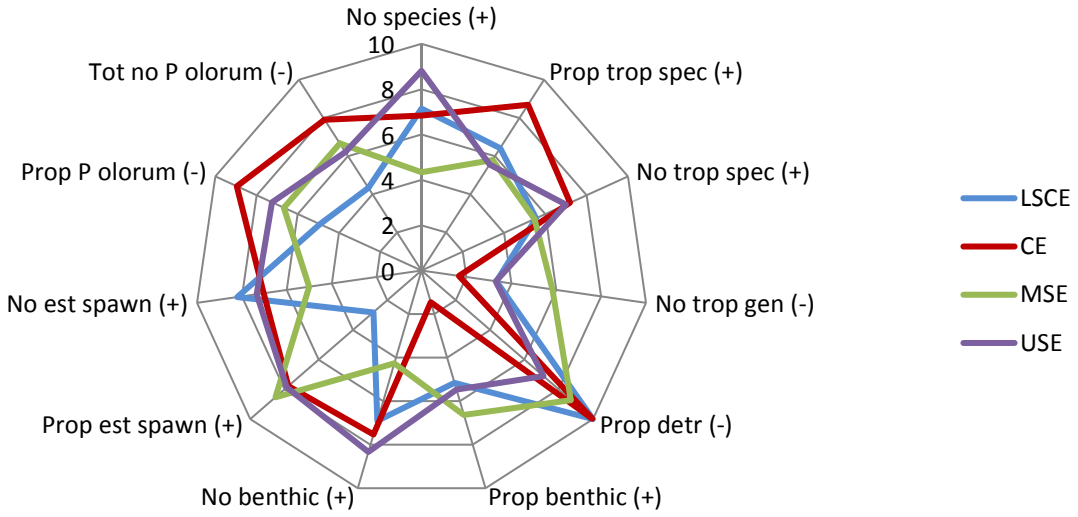


Figure 4. Average nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2018.

Radar plots of the nearshore metric scores for each zone in each season indicate that a small number of metrics drove the decrease in condition of the MSE from summer to autumn of 2018, shown by a contraction of the radar plot for this zone (compare Fig. 5a and b). The FCI scores for the

MSE in autumn indicated declines in the numbers of species, including those that spawn in the estuary, are specialist feeders and/or are bottom-dwelling.

(a) Summer 2018



(b) Autumn 2018

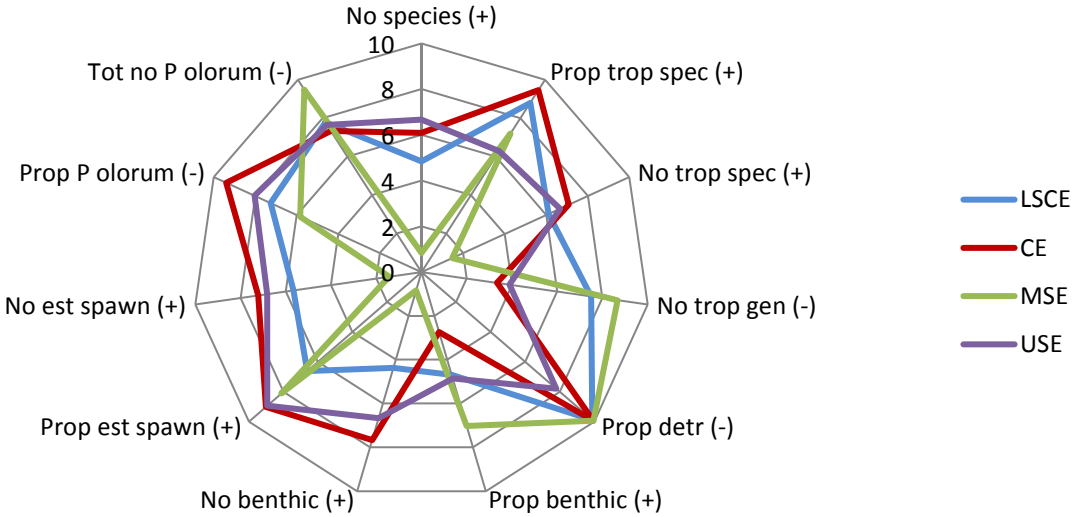


Figure 5. Average scores (0–10) for each component metric of the nearshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2018. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names and explanations).

Offshore waters

The ecological condition of the Riverpark's offshore waters was good (B) during summer of 2018, with the exception of the CE, which was poor (D) (Fig. 6). During autumn, the offshore waters of the LSCE, CE and USE were in fair to good condition, while those of the MSE were poor (D). This likely reflects the localised hypoxia that became established in the MSE during late May as the water column was stratified by freshwater flows (appendix iv), and the potential influence of dinoflagellate blooms as discussed above.

Radar plots of offshore metric scores for each zone in each season shed further light on the responses of the fish community to the environmental conditions throughout the Swan Estuary during 2018 (Fig. 7). In particular, the decline in offshore FCI scores in the MSE during autumn was driven by decreases in the number and diversity of species and the number of specialist feeders, and increases in the number of generalist feeders and the proportion of species that feed on decomposing organic material (*e.g.* Sea mullet, Perth herring). This is indicated by lower average scores for *Number of species*, *Shannon-Wiener diversity*, and *Proportion of trophic specialists* (all positive metrics) and for *Number of trophic generalists* and *Proportion of detritivores* (both negative metrics) during autumn (Fig. 7).

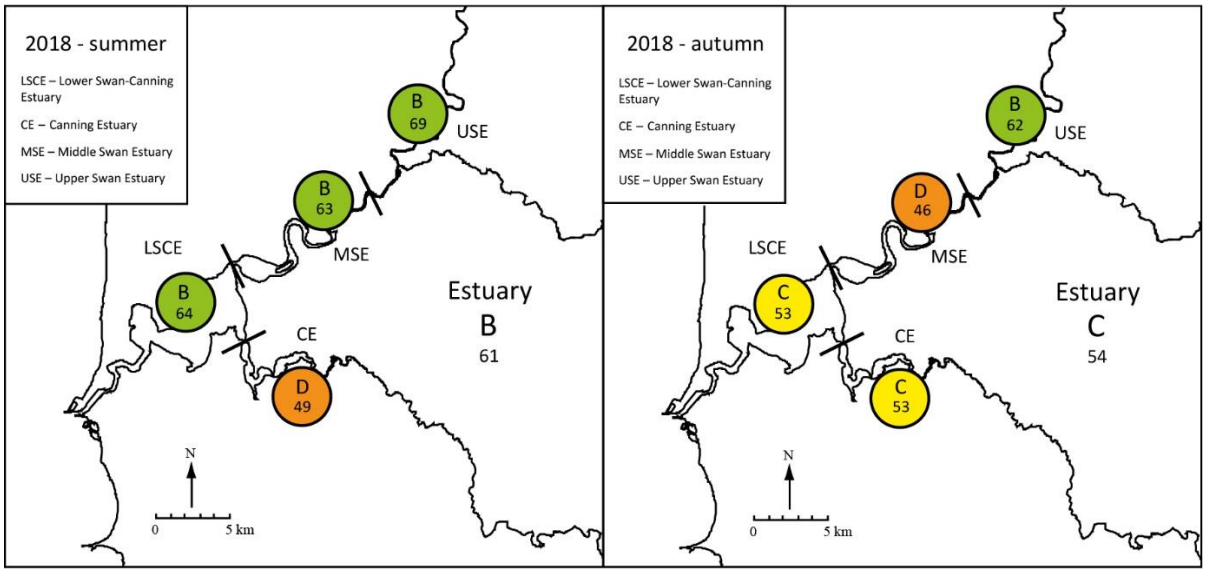


Figure 6. Average offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2018.

Longer term trends in ecological condition

Results indicate that the nearshore waters of the estuary as a whole were in good-fair condition (B/C) during 2018, consistent with the overall trend since 2011 (Fig. 8). Similarly, the mean offshore FCI score for the estuary as a whole indicated fair-good (C/B) offshore condition during 2018 (Fig. 9), reflecting the lack of any widespread or severe hypoxia during this year's monitoring period. The offshore condition in 2018 represents an increase from the last two years, and particularly from 2017. It is important to note that the condition of the estuary in 2017 was impacted markedly by unusually high river flows in summer of that year, which caused significant declines in salinities

throughout much of the system, followed by the development of highly stratified and low oxygen conditions that moved upstream during autumn (Hallett 2017).

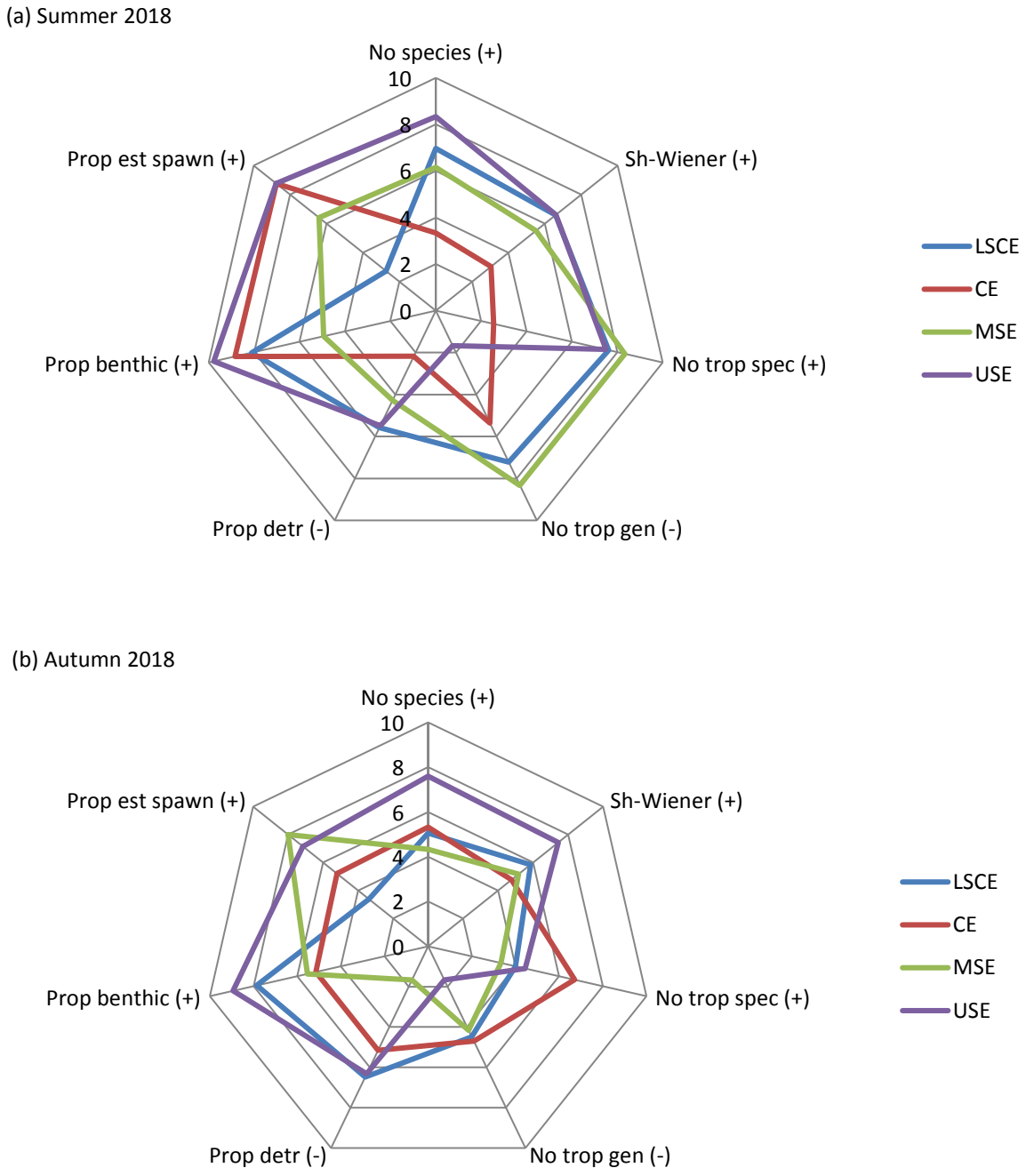


Figure 7. Average scores (0–10) for each component metric of the offshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2018. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names and explanations).

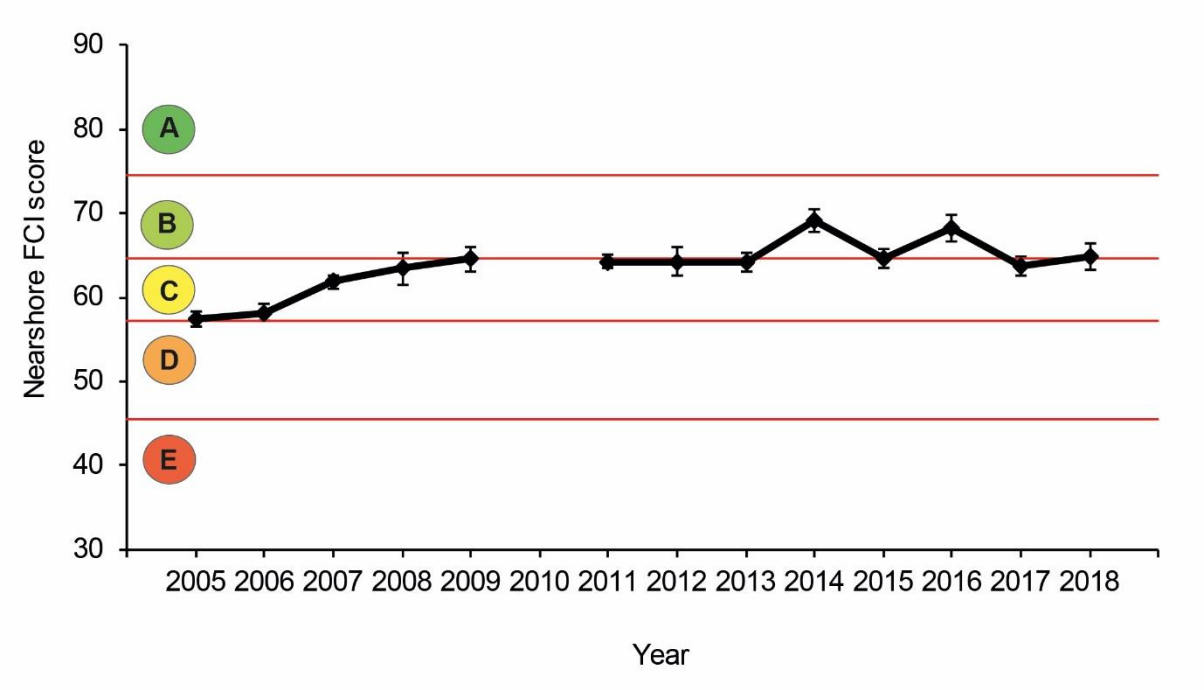


Figure 8. Trend plot of average (±SE) nearshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

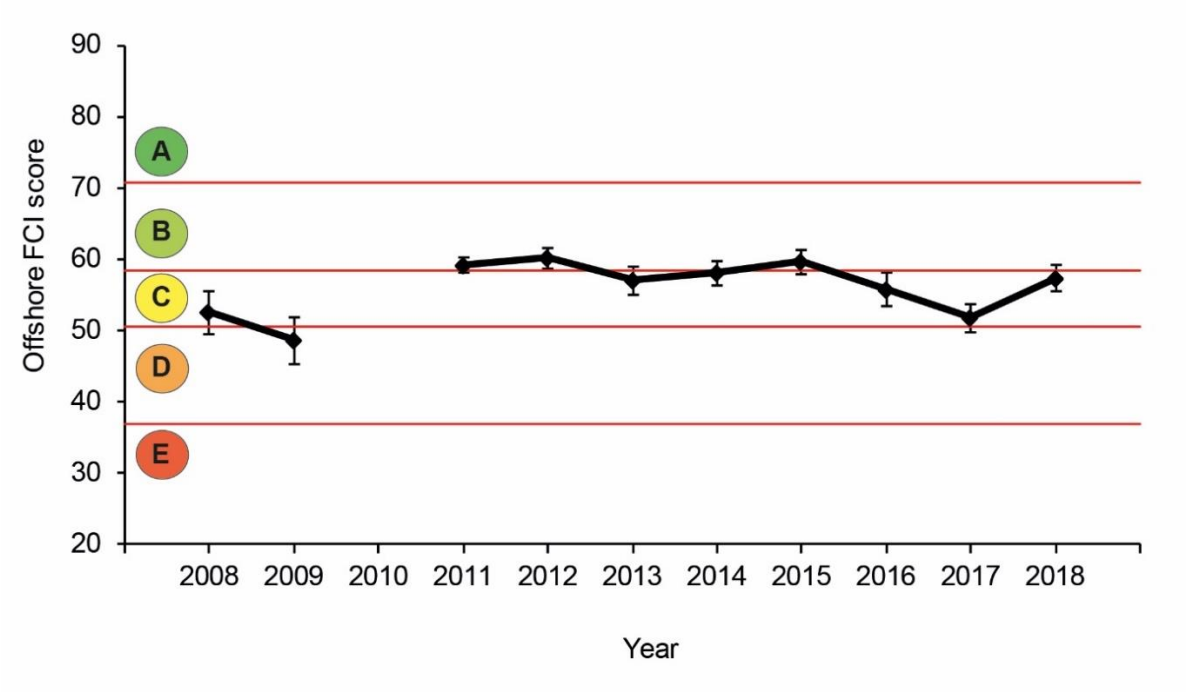


Figure 9. Trend plot of average (±SE) offshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor), for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

Summary

The Fish Community Index considers the fish community as a whole and provides a means to assess how the structure and function of these communities in shallow nearshore and deeper offshore waters respond to a wide array of stressors affecting the ecosystem. Note that the FCI does not provide information on the population dynamics or health of particular species (in comparison to *e.g.* Cottingham et al. 2014), nor does it provide information on the size or status of the fish stocks in the estuary.

Across the estuary as a whole, the ecological condition of nearshore waters in 2018 was assessed as good-fair (B/C) and that of the offshore waters as fair-good (C/B), based on their fish communities (Table 5). These results indicate slightly better ecological condition of both nearshore and offshore waters during 2018 compared to 2017. This reflects the lack of any widespread or severe hypoxia during the 2018 monitoring period, in contrast to the widespread impacts of unusually high summer river flows on the estuary in 2017.

Table 5. Fish Community Index scores and corresponding ecological condition grades for each zone of the estuary, and the estuary as a whole, during the 2018 monitoring period (mean of all summer and autumn of 2018). LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary.

	Nearshore		**Offshore**	
	Mean FCI score	*Condition*	*Mean FCI score*	*Condition*
LSCE	62.9	C	58.5	B/C
MSE	58.5	C	54.4	C
USE	67.5	B	65.5	B
CE	70.1	B	50.8	C/D
Estuary	64.8	B/C	57.4	C/B

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Appendix (i). Descriptions of (a) nearshore and (b) offshore Fish Community Index monitoring sites. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary

Zone	Site Code	Lat-Long (S, E)	Description
(a) – *Nearshore*			
LSCE	LSCE3	-32°01'29'', 115°46'27''	Shoreline in front of vegetation on eastern side of Point Roe, Mosman Pk
	LSCE4	-31°59'26'', 115°47'08''	Grassy shore in front of houses to east of Claremont Jetty
	LSCE5	-32°00'24'', 115°46'52''	North side of Point Walter sandbar
	LSCE6	-32°01'06'', 115°48'19''	Shore in front of bench on Attadale Reserve
	LSCE7	-32°00'11'', 115°50'29''	Sandy bay below Point Heathcote
	LSCE8	-31°59'11'', 115°49'40''	Eastern side of Pelican Point, immediately south of sailing club
CE	CE1	-32°01'28'', 115°51'16''	Sandy shore to south of Deepwater Point boat ramp
	CE2	-32°01'54'', 115°51'33''	Sandy beach immediately to north of Mount Henry Bridge
	CE5	-32°01'40'', 115°52'58''	Bay in Shelley Beach, adjacent to jetty
	CE6	-32°01'29'', 115°53'11''	Small clearing in vegetation off North Riverton Drive
	CE7	-32°01'18'', 115°53'43''	Sandy bay in front of bench, east of Wadjup Point
	CE8	-32°01'16'', 115°55'14''	Sandy beach immediately downstream of Kent Street Weir
MSE	MSE2	-31°58'12'', 115°51'07''	Sandy beach on South Perth foreshore, west of Mends St Jetty
	MSE4	-31°56'34'', 115°53'06''	Shoreline in front of Belmont racecourse, north of Windan Bridge
	MSE5	-31°56'13'', 115°53'23''	Beach to west of jetty in front of Maylands Yacht Club
	MSE6	-31°57'13'', 115°53'56''	Small beach upstream of Belmont Water Ski Area boat ramp
	MSE7	-31°55'53'', 115°55'10''	Beach in front of scout hut, east of Garratt Road Bridge
	MSE8	-31°55'37'', 115°56'18''	Vegetated shoreline, Claughton Reserve, upstream of boat ramp
USE	USE1	-31°55'20'', 115°57'03''	Small beach adjacent to jetty at Sandy Beach Reserve, Bassendean
	USE3	-31°53'43'', 115°57'32''	Sandy bay opposite Bennett Brook, at Fishmarket Reserve, Guildford
	USE4	-31°53'28'', 115°58'32''	Shoreline in front of Guildford Grammar stables, opposite Lilac Hill Park
	USE5	-31°53'13'', 115°59'29''	Small, rocky beach after bend in river at Ray Marshall Park
	USE6	-31°52'41'', 115°59'31''	Small beach with iron fence, in front of Caversham house
	USE7	-31°52'22'', 115°59'39''	Sandy shore on bend in river, below house on hill, upstream of powerlines
(b) – *Offshore*			
LSCE	LSCE1G	-32°00'24'', 115°46'56''	In deeper water *ca* 100 m off north side of Point Walter sandbar
	LSCE2G	-32°00'12'', 115°48'07''	Alongside seawall west of Armstrong Spit, Dalkeith
	LSCE3G	-32°01'00'', 115°48'44''	Parallel to shoreline, running westwards from Beacon 45, Attadale
	LSCE4G	-32°00'18'', 115°50'01''	In deep water of Waylen Bay, from *ca* 50 m east of Applecross jetty
	LSCE5G	-31°59'37'', 115°51'09''	Perpendicular to Como Jetty, running northwards
	LSCE6G	-31°59'12'', 115°49'42''	*Ca* 20 m from, and parallel to, sandy shore on east side of Pelican Point
CE	CE1G	-32°01'58'', 115°51'36''	Underneath Mount Henry Bridge, parallel to northern shoreline
	CE2G	-32°01'48'', 115°51'46''	Parallel to, and *ca* 20 m from, western shoreline of Aquinas Bay
	CE3G	-32°01'49'', 115°52'19''	To north of navigation markers, Aquinas Bay
	CE4G	-32°01'48'', 115°52'33''	Adjacent to Old Post Line (SW-ern end; Salter Point)
	CE5G	-32°01'36'', 115°52'52''	Adjacent to Old Post Line (NE-ern end; Prisoner Point)
	CE6G	-32°01'20'', 115°53'15''	Adjacent to Old Post Line, Shelley Water
MSE	MSE1G	-31°58'03'', 115°51'03''	From jetty at Point Belches towards Mends St Jetty, Perth Water
	MSE2G	-31°56'57'', 115°53'05''	Downstream of Windan Bridge, parallel to Burswood shoreline
	MSE3G	-31°56'22'', 115°53'05''	Downstream from port marker, parallel to Joel Terrace, Maylands
	MSE4G	-31°57'13'', 115°54'12''	Parallel to shore from former boat shed jetty, Cracknell Park, Belmont
	MSE5G	-31°55'57'', 115°55'12''	Parallel to southern shoreline, upstream of Garratt Road Bridge
	MSE6G	-31°55'23'', 115°56'25''	Parallel to eastern bank at Garvey Pk, from south of Ron Courtney Island
USE	USE1G	-31°55'19'', 115°57'09''	Parallel to tree-lined eastern bank, upstream of Sandy Beach Reserve
	USE2G	-31°53'42'', 115°57'40''	Along northern riverbank, running upstream from Bennett Brook
	USE3G	-31°53'16'', 115°58'42''	Along northern bank on bend in river, to north of Lilac Hill Park
	USE4G	-31°53'17'', 115°59'23''	Along southern bank, downstream from bend at Ray Marshall Pk
	USE5G	-31°52'13'', 115°59'40''	Running along northern bank, upstream from Sandalford winery jetty
	USE6G	-31°52'13'', 116°00'18''	Along southern shore adjacent to Midland Brickworks, from outflow pipe

Appendix (ii). Descriptions of sampling and processing procedures

Nearshore sampling methods

- On each sampling occasion, one replicate sample of the nearshore fish community is collected from each of the fixed, nearshore sampling sites.
- Sampling is not conducted during or within 3-5 days following any significant flow event.
- Nearshore fish samples are collected using a beach seine net that is 21.5 m long, comprises two 10 m-long wings (6 m of 9 mm mesh and 4 m of 3 mm mesh) and a 1.5 m-long bunt (3 mm mesh) and fishes to a depth of 1.5 m.
- This net is walked out from the beach to a maximum depth of approximately 1.5 m and deployed parallel to the shore, and is then rapidly dragged towards and onto the shore, so that it sweeps a roughly semicircular area of approximately 116 m^2.
- If a seine net deployment returns a catch of fewer than five fish, an additional sample is performed at the site (separated from the first sample by either 15 minutes or by 10-20 m distance). In the event that more than five fish are caught in the second sample, this second replicate is then used as the sample for that site and those fish from the first sample returned to the water alive. If, however, 0-5 fish are again caught, the original sample can be assumed to have been representative of the fish community present and be used as the sample for that site. The fish from the latter sample are then returned alive to the water. The above procedure thus helps to identify whether a collected sample is representative of the fish community present and enables instances of false negative catches to be identified and eliminated.
- Once an appropriate sample has been collected, any fish that may be readily identified to species (*e.g.* those larger species which are caught in relatively lower numbers) are counted and returned to the water alive.
- All other fish caught in the nets are placed into zip-lock polythene bags, euthanised in an ice slurry and preserved on ice in eskies in the field, except in cases where large catches (*e.g.* thousands) of small fish are obtained. In such cases, an appropriate sub-sample (*e.g.* one half to one eighth of the entire catch) is retained and the remaining fish are returned alive to the water. All retained fish are then bagged and frozen until their identification in the laboratory.

Offshore sampling methods

- On each sampling occasion, one replicate sample of the offshore fish community is collected from each of the fixed, offshore sampling sites.
- Sampling is not conducted within 3-5 days following any significant flow event.
- Offshore fish samples are collected using a sunken, multimesh gill net that consists of eight 20 m-long panels with stretched mesh sizes of 35, 51, 63, 76, 89, 102, 115 and 127 mm. These nets are deployed (*i.e.* laid parallel to the bank) from a boat immediately before sunset and retrieved after three hours.
- Given the time and labour associated with offshore sampling and the need to monitor the set nets for safety purposes, a maximum of three replicate net deployments is performed within a single zone in any one night. The three nets are deployed sequentially, and retrieved in the same order.
- During net retrieval (and, typically, when catch rates are sufficiently low to allow fish to be removed rapidly in the course of retrieval), any fishes that may be removed easily from the net are carefully removed, identified, counted, recorded and returned to the water alive as the net is pulled into the boat.

- All other fish caught in the nets are removed once the net has been retrieved. Retained fish are placed into zip-lock polythene bags in an ice slurry, preserved on ice in eskies in the field, and subsequently frozen until their identification in the laboratory.

Following their identification to the lowest possible taxon in the field or laboratory by fish specialists trained in fish taxonomy, all assigned scientific and common names are checked and standardised by referencing the Checklist of Australian Aquatic Biota (CAAB) database (Rees *et al.* on-line version), and the appropriate CAAB species code is allocated to each species. The abundance data for each species in each sample is entered into a database for record and subsequent computation of the biotic indices.

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Appendix (iii). List of species caught from the Swan Canning Estuary, and their functional guilds: D, Demersal; P, Pelagic; BP, Bentho-pelagic; SP, Small pelagic; SB, Small benthic; MS, Marine straggler; MM, Marine migrant; SA, Semi-anadromous; ES, Estuarine species; FM, Freshwater migrant; ZB, Zoobenthivore; PV, Piscivore; ZP, Zooplanktivore; DV, Detritivore; OV, Omnivore/Opportunist; HV, Herbivore.

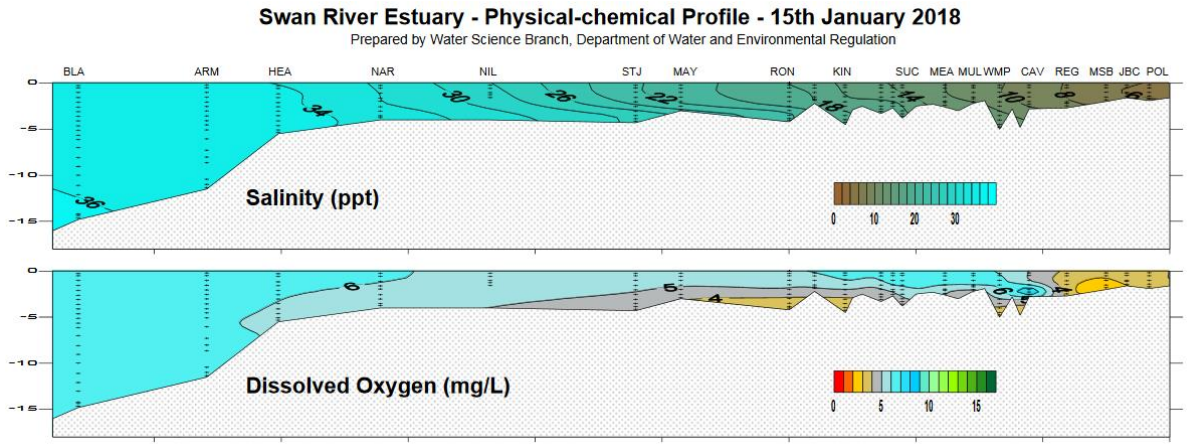
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Heterodontus portusjacksoni	Port Jackson shark	D	MS	ZB
Carcharinas leucas	Bull shark	P	MS	PV
Myliobatis tenuicaudatus	Southern Eagle ray	D	MS	ZB
Elops machnata	Giant herring	BP	MS	PV
Hyperlophus vittatus	Whitebait / sandy sprat	SP	MM	ZP
Spratelloides robustus	Blue sprat	SP	MM	ZP
Sardinops neopilchardus	Australian pilchard	P	MS	ZP
Sardinella lemuru	Scaly mackerel	P	MS	ZP
Nematalosa vlaminghi	Perth herring	BP	SA	DV
Engraulis australis	Southern anchovy	SP	ES	ZP
Galaxias occidentalis	Western minnow	SB	FM	ZB
Carassius auratus	Goldfish	BP	FM	OV
Cnidoglanis macrocephalus	Estuarine cobbler	D	MM	ZB
Tandanus bostocki	Freshwater cobbler	D	FM	ZB
Hyporhamphus melanochir	Southern Sea Garfish	P	ES	HV
Hyporhamphus regularis	Western River Garfish	P	FM	HV
Gambusia holbrooki	Mosquito fish	SP	FM	ZB
Atherinosoma elongata	Elongate hardyhead	SP	ES	ZB
Leptatherina presbyteroides	Presbyter's hardyhead	SP	MM	ZP
Atherinomorus vaigensis	Ogilby's hardyhead	SP	MM	ZB
Craterocephalus mugiloides	Mugil's hardyhead	SP	ES	ZB
Leptatherina wallacei	Wallace's hardyhead	SP	ES	ZP
Cleidopus gloriamaris	Knightfish / Pineapplefish	D	MS	ZB
Stigmatophora nigra	Wide-bodied pipefish	D	MS	ZB
Vanacampus phillipi	Port Phillip pipefish	D	MS	ZB
Phyllopteryx taeniolatus	Common seadragon	D	MS	ZB
Hippocampus angustus	Western spiny seahorse	D	MS	ZP
Stigmatopora argus	Spotted pipefish	D	MS	ZP
Urocampus carinirostris	Hairy pipefish	D	ES	ZP
Filicampus tigris	Tiger pipefish	D	MS	ZP
Pugnaso curtirostris	Pugnose pipefish	D	MS	ZP
Gymnapistes marmoratus	Devilfish	D	MS	ZB
Chelidonichthys kumu	Red gurnard	D	MS	ZB
Platycephalus laevigatus	Rock Flathead	D	MS	PV
Platycephalus westraliae	Yellowtail flathead	D	ES	PV
Leviprora inops	Long-head Flathead	D	MS	PV
Pegasus lancifer	Sculptured Seamoth	D	MS	ZB
Amniataba caudavittata	Yellow-tail trumpeter	BP	ES	OP
Pelates octolineatus	Western striped grunter	BP	MM	OV
Bidyanus bidyanus	Silver perch	BP	FM	OV
Pelsartia humeralis	Sea trumpeter	BP	MS	OV
Edelia vittata	Western pygmy perch	BP	FM	ZB
Ostorhinchus rueppellii	Gobbleguts	BP	ES	ZB
Siphamia cephalotes	Woods Siphonfish	BP	MS	ZB
Sillago bassensis	Southern school whiting	D	MS	ZB
Sillago burrus	Western trumpeter whiting	D	MM	ZB
Sillaginodes punctata	King George whiting	D	MM	ZB

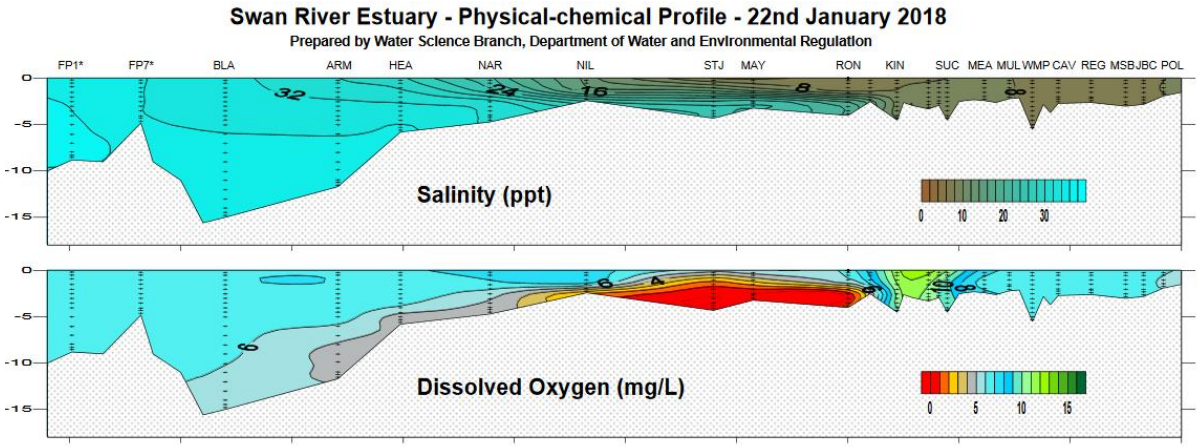
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Sillago schomburgkii	Yellow-finned whiting	D	MM	ZB
Sillago vittata	Western school whiting	D	MM	ZB
Pomatomus saltatrix	Tailor	P	MM	PV
Trachurus novaezelandiae	Yellowtail scad	P	MS	ZB
Scomeroides tol	Needleskin queenfish	P	MS	PV
Pseudocaranx dentex	Silver trevally	BP	MM	ZB
Pseudocaranx wrightii	Sand trevally	BP	MM	ZB
Arripis georgianus	Australian herring	P	MM	PV
Pentapodus vitta	Western butterfish	BP	MS	ZB
Gerres subfasciatus	Roach	BP	MM	ZB
Acanthopagrus butcheri	Southern black bream	BP	ES	OP
Rhabdosargus sarba	Tarwhine	BP	MM	ZB
Argyrosomus japonicus	Mulloway	BP	MM	PV
Pampeneus spilurus	Black-saddled goatfish	D	MS	ZB
Enoplosus armatus	Old wife	D	MS	ZB
Geophagus brasiliensis	Pearl cichlid	BP	FM	OV
Aldrichetta forsteri	Yellow-eye mullet	P	MM	OV
Mugil cephalus	Sea mullet	P	MM	DV
Sphyraena novaehollandiae	Snook	P	MS	PV
Sphyraena obtusata	Striped barracuda	P	MS	PV
Haletta semifasciata	Blue weed whiting	D	MS	OV
Siphonognathus radiatus	Long-rayed weed whiting	D	MS	OV
Neoodax baltatus	Little weed whiting	D	MS	OV
Odax acroptilus	Rainbow cale	D	MS	OV
Parapercis haackei	Wavy grubfish	D	MS	ZB
Lesueurina platycephala	Flathead sandfish	D	MS	ZB
Petroscirtes breviceps	Short-head sabre blenny	SB	MS	OV
Omobranchus germaini	Germain's blenny	SB	MS	ZB
Parablennius intermedius	Horned blenny	D	MS	ZB
Parablennius postoculomaculatus	False Tasmanian blenny	SB	MS	OV
Istiblennius meleagris	Peacock rockskipper	D	MS	HV
Cristiceps australis	Southern crested weedfish	D	MS	ZB
Pseudocalliurichthys goodladi	Longspine stinkfish	D	MS	ZB
Eocallionymus papilio	Painted stinkfish	D	MS	ZB
Nesogobius pulchellus	Sailfin goby	SB	MS	ZB
Favonigobius lateralis	Long-finned goby	SB	MM	ZB
Afurcagobius suppositus	Southwestern goby	SB	ES	ZB
Pseudogobius olorum	Blue-spot / Swan River goby	SB	ES	OV
Arenigobius bifrenatus	Bridled goby	SB	ES	ZB
Callogobius mucosus	Sculptured goby	SB	MS	ZB
Callogobius depressus	Flathead goby	SB	MS	ZB
Favonigobius punctatus	Red-spot goby	SB	ES	ZB
Tridentiger trigonocephalus	Trident goby	SB	MS	ZB
Pseudorhombus jenynsii	Small-toothed flounder	D	MM	ZB
Ammotretis rostratus	Longsnout flounder	D	MM	ZB
Ammotretis elongatus	Elongate flounder	D	MM	ZB
Cynoglossus broadhursti	Southern tongue sole	D	MS	ZB
Acanthaluteres brownii	Spiny-tailed Leatherjacket	D	MS	OV
Brachaluteres jacksonianus	Southern pygmy leatherjacket	D	MS	OV
Scobinichthys granulatus	Rough Leatherjacket	D	MS	OV

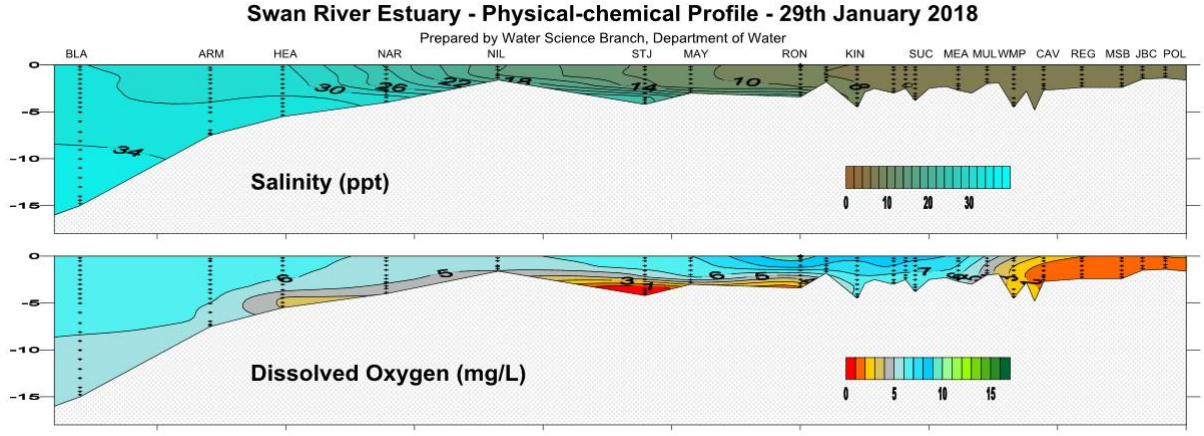
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Chaetodermis pencilligera	Tasselled leatherjacket	D	MS	OV
Meuschenia freycineti	Sixspine leatherjacket	D	MM	OV
Monacanthus chinensis	Fanbellied Leatherjacket	D	MM	OV
Eubalichthys mosaicus	Mosaic leatherjacket	D	MS	OV
Acanthaluteres vittiger	Toothbrush Leatherjacket	D	MS	OV
Acanthaluteres spilomelanurus	Bridled Leatherjacket	D	MM	OV
Torquigener pleurogramma	Blowfish / banded toadfish	BP	MM	OP
Contusus brevicaudus	Prickly toadfish	BP	MS	OP
Polyspina piosae	Orange-barred puffer	BP	MS	OP
Diodon nicthemenus	Globefish	D	MS	ZB
Scorpis aequipinnis	Sea sweep	P	MS	ZP
Neatypus obliquus	Footballer sweep	P	MS	ZP

Appendix (iv). A representative selection of vertical contour plots of salinity and dissolved oxygen concentrations (mg/L) measured at monitoring stations along the length of the Swan Canning Estuary on occasions throughout the summer to autumn period of fish community sampling. Prepared by the Department of Water and Environmental Regulation for the Department of Biodiversity, Conservation and Attractions (https://www.dpaw.wa.gov.au/management/swan-canning-riverpark/ecosystem-health-and-management/452-swan-river-vertical-plots/ and https://www.dpaw.wa.gov.au/management/swan-canning-riverpark/ecosystem-health-and-management/453-canning-river-vertical-plots/).

LSCE, MSE and USE zones in summer through autumn 2018.

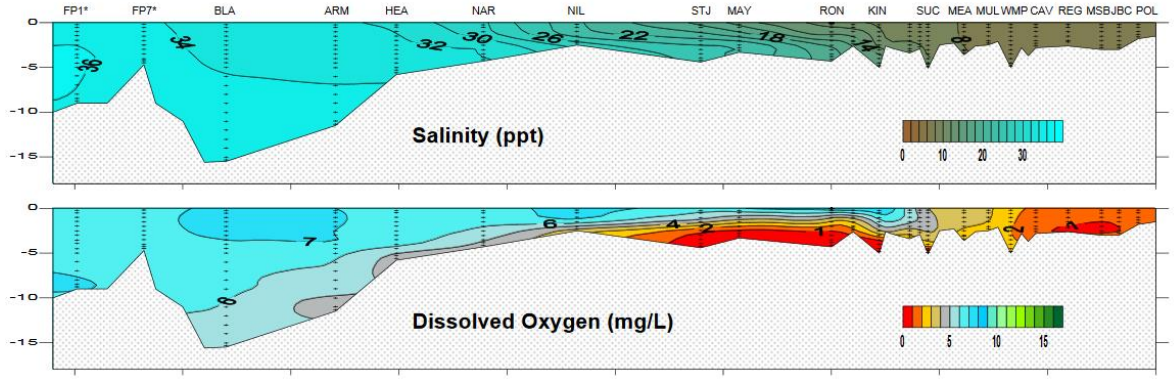






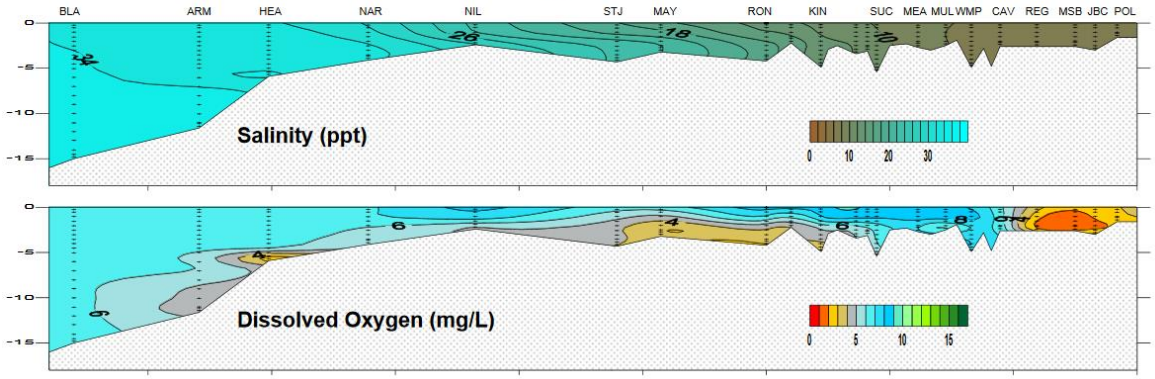
Swan River Estuary - Physical-chemical Profile - 5th February 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



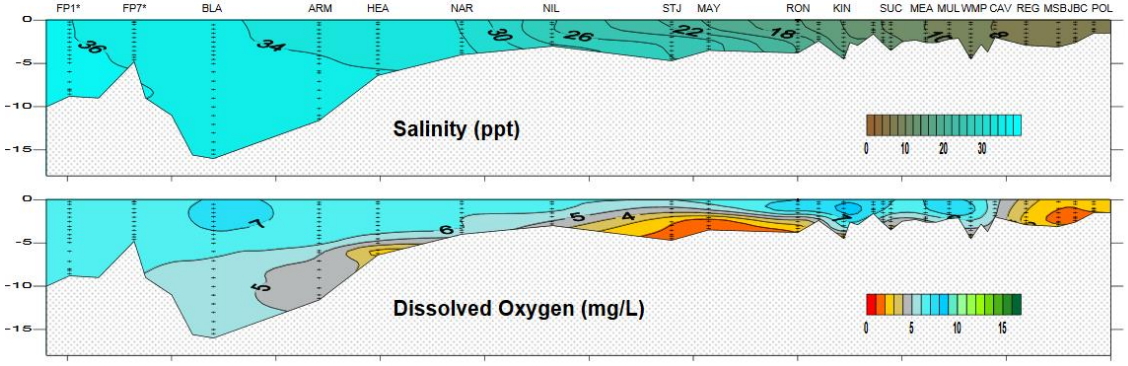
Swan River Estuary - Physical-chemical Profile - 12th February 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



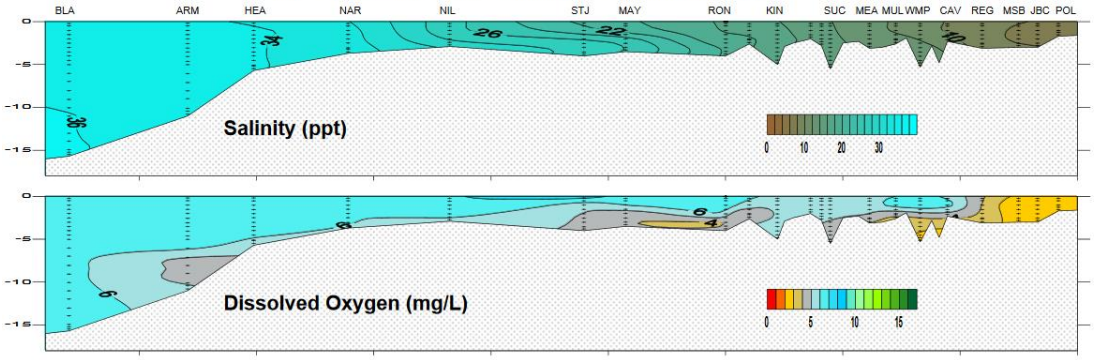
Swan River Estuary - Physical-chemical Profile - 19th February 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



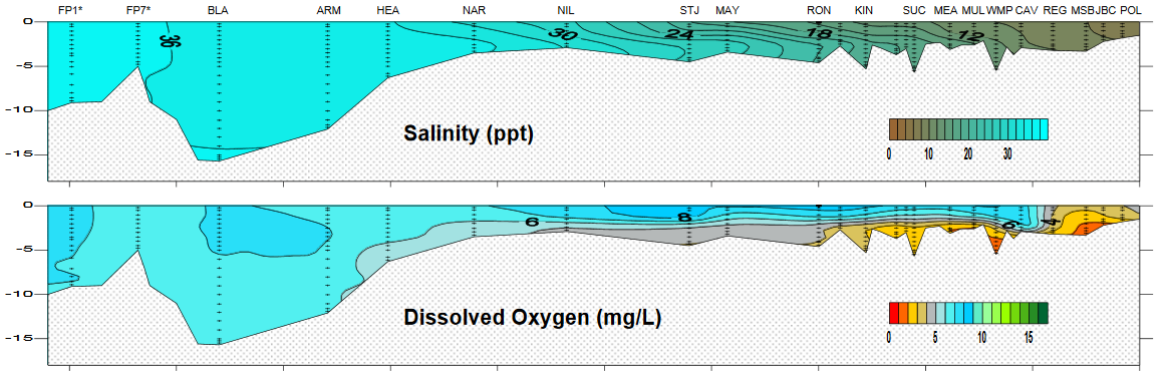
Swan River Estuary - Physical-chemical Profile - 26th February 2018

Prepared by Water Science Branch, Department of Water and Environmental Science



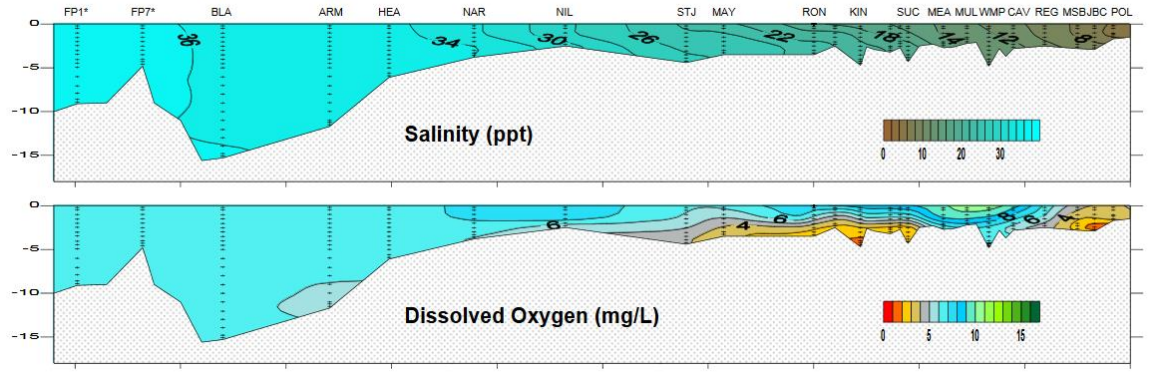
Swan River Estuary - Physical-chemical Profile - 6th March 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



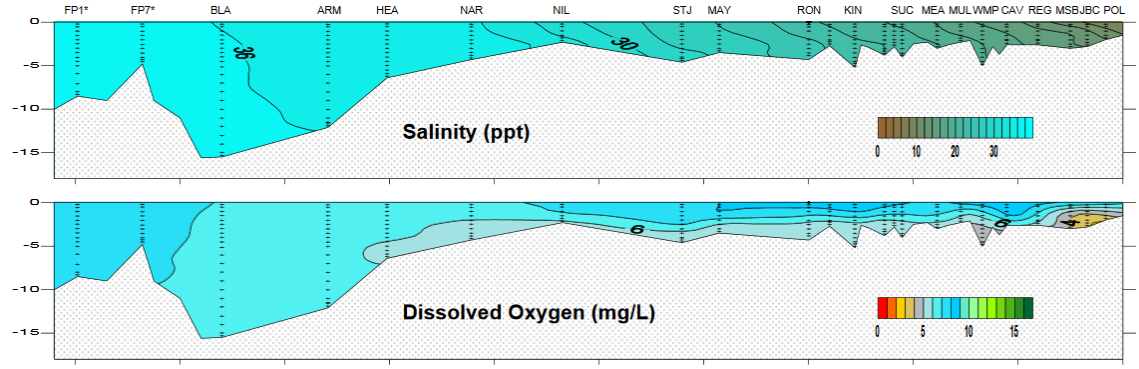
Swan River Estuary - Physical-chemical Profile - 19th March 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



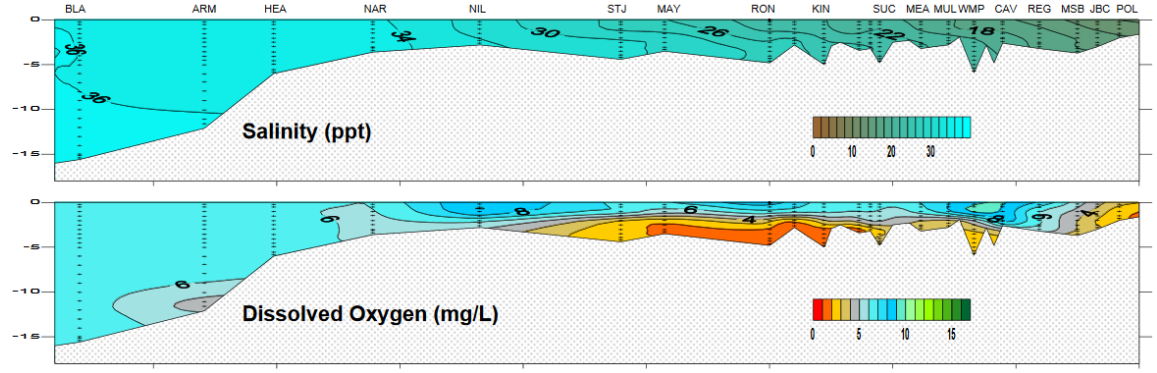
Swan River Estuary - Physical-chemical Profile - 3rd April 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



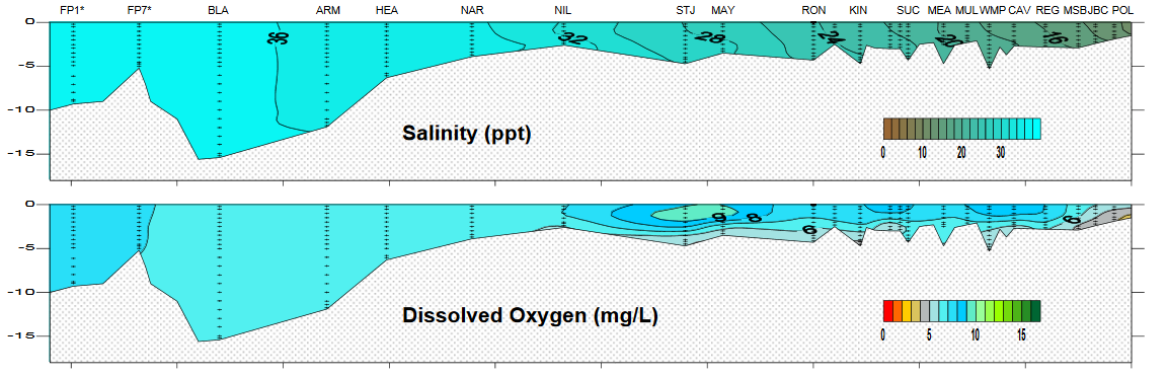
Swan River Estuary - Physical-chemical Profile - 9th April 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



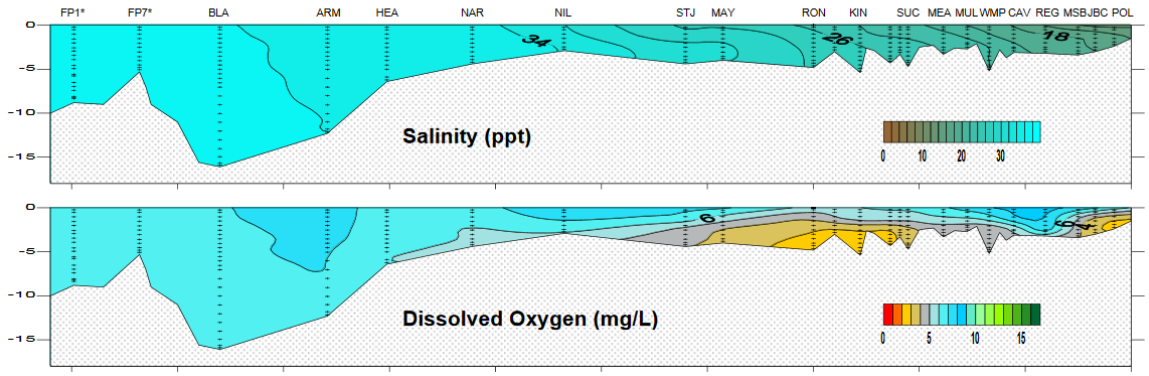
Swan River Estuary - Physical-chemical Profile - 16th April 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



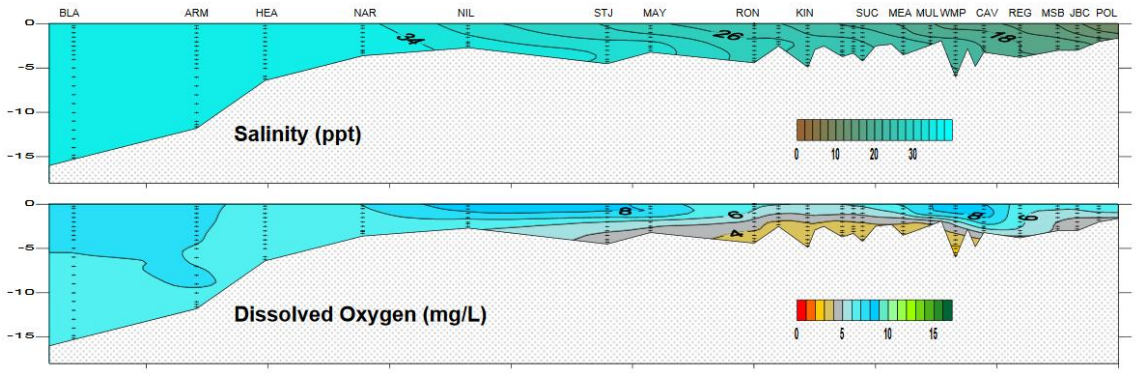
Swan River Estuary - Physical-chemical Profile - 30th April 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



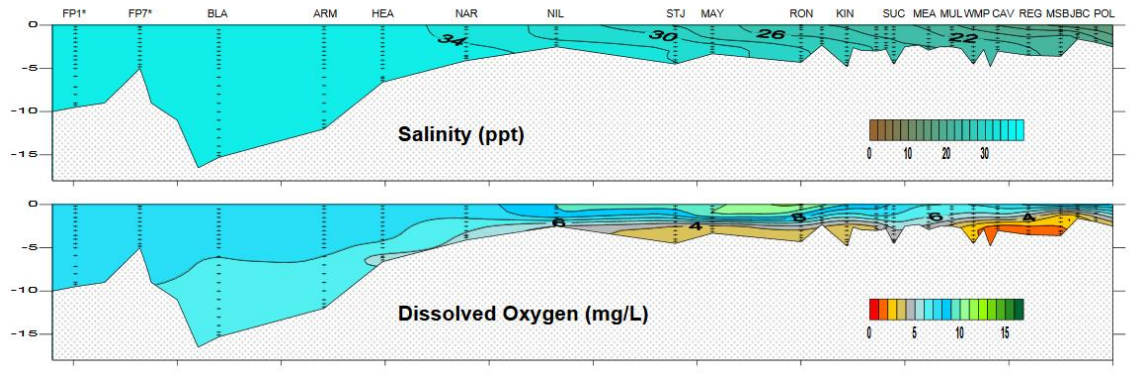
Swan River Estuary - Physical-chemical Profile - 7th May 2018

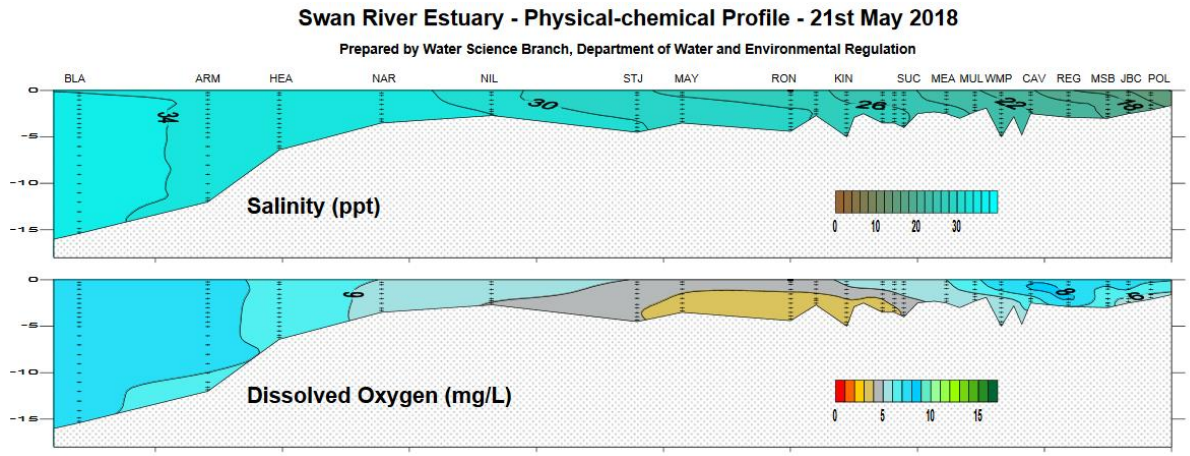
Prepared by Water Science Branch, Department of Water and Environmental Regulation

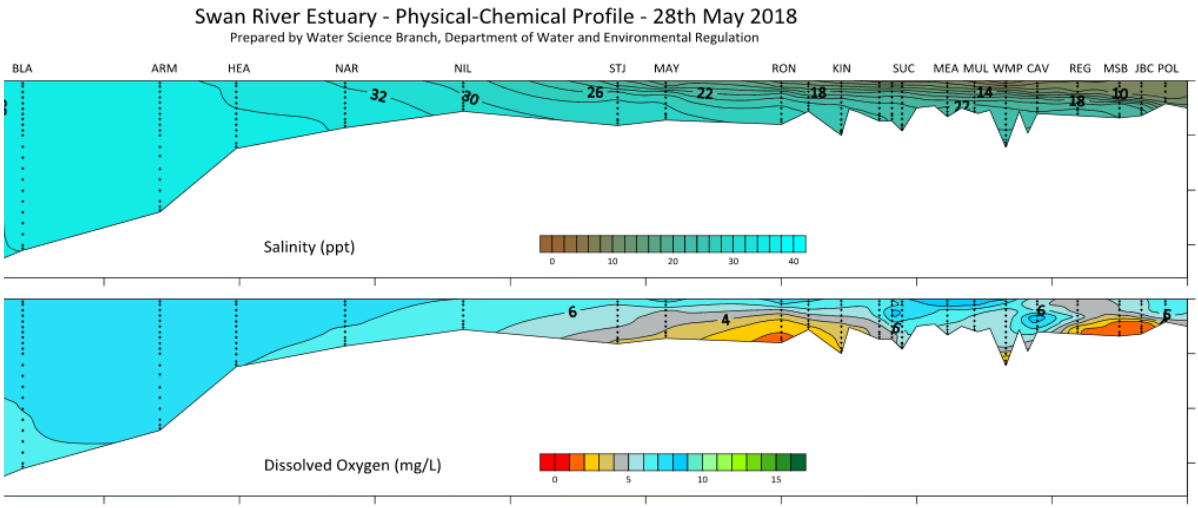


Swan River Estuary - Physical-chemical Profile - 14th May 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation




Swan River Estuary - Physical-chemical Profile - 21st May 2018
Prepared by Water Science Branch, Department of Water and Environmental Regulation
BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEA MUL WMP CAV REG MSB JBC POL
Salinity (ppt)
Dissolved Oxygen (mg/L)


Swan River Estuary - Physical-Chemical Profile - 28th May 2018
Prepared by Water Science Branch, Department of Water and Environmental Regulation
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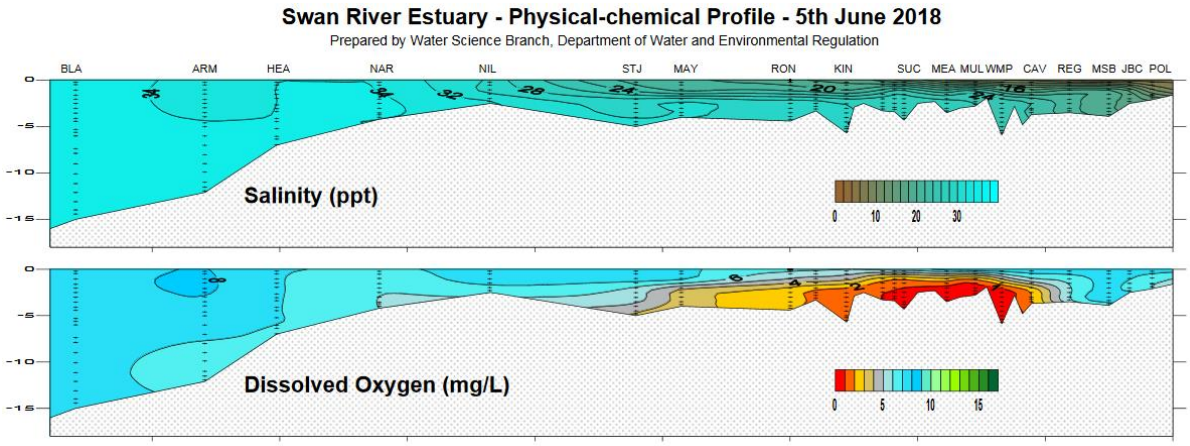
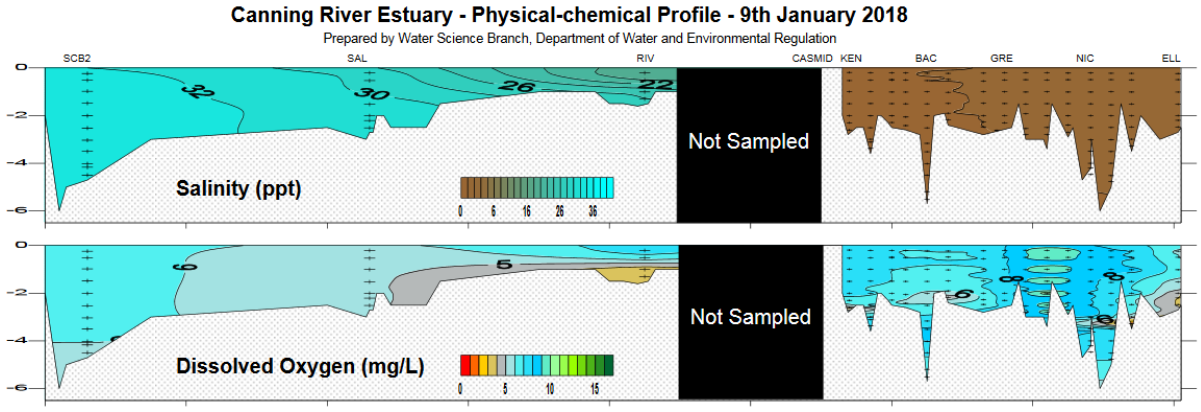
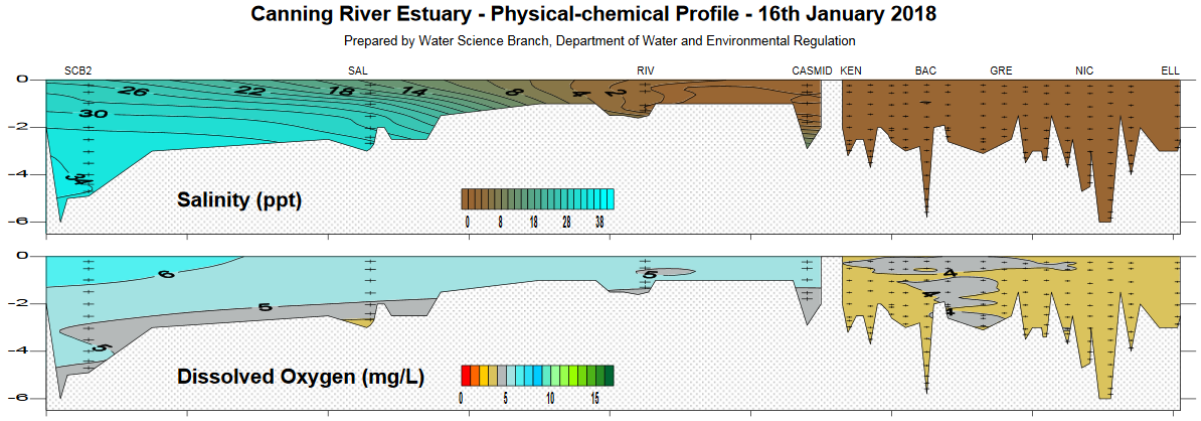
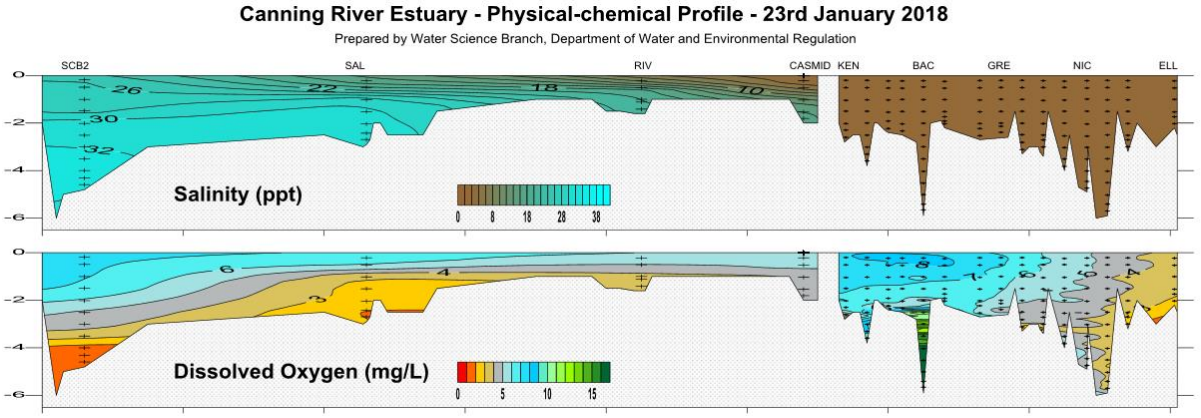
Salinity (ppt)
Dissolved Oxygen (mg/L)

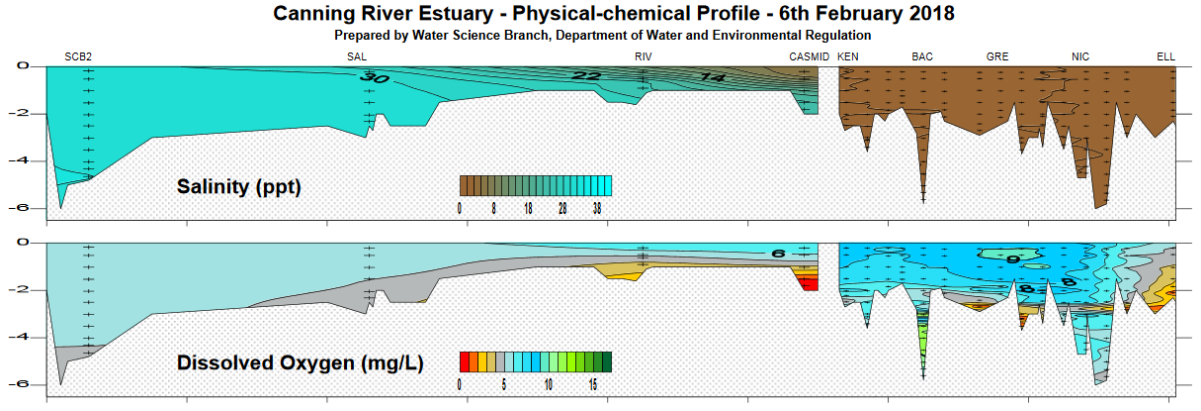

Swan River Estuary - Physical-chemical Profile - 5th June 2018
Prepared by Water Science Branch, Department of Water and Environmental Regulation
BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEA MUL WMP CAV REG MSB JBC POL
Salinity (ppt)
Dissolved Oxygen (mg/L)

CE zone in summer through autumn 2018.



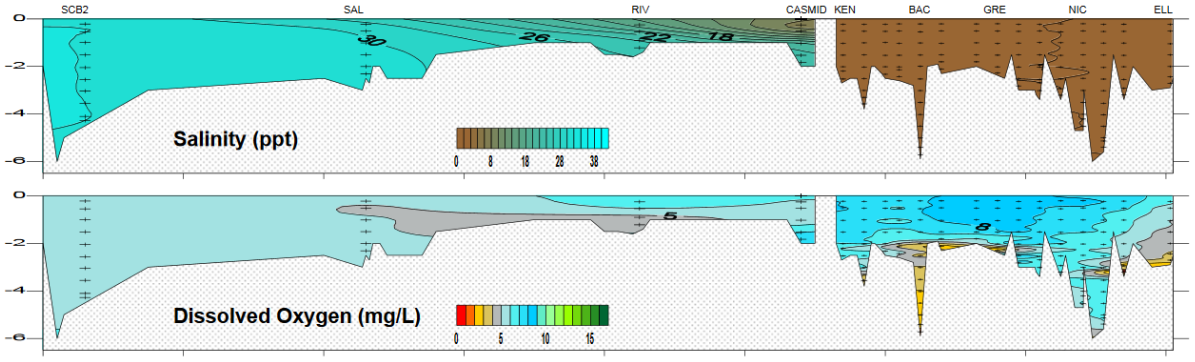






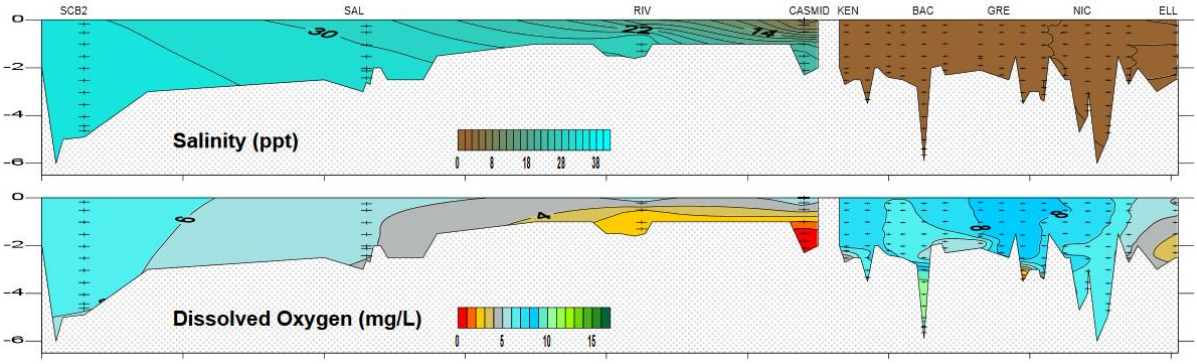
Canning River Estuary - Physical-chemical Profile - 13th February 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



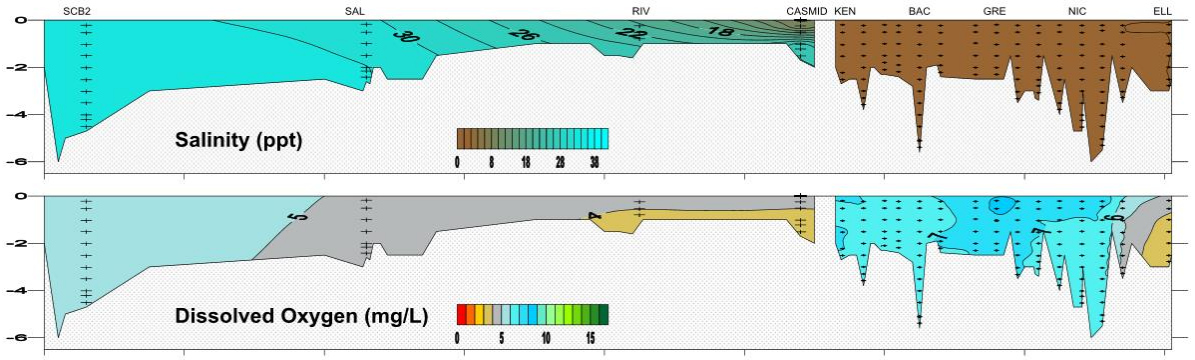
Canning River Estuary - Physical-chemical Profile - 20th February 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



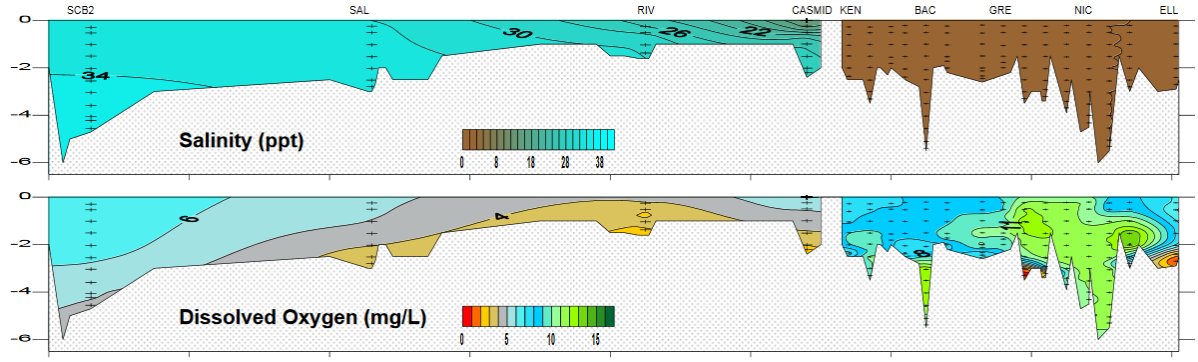
Canning River Estuary - Physical-chemical Profile - 27th February 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



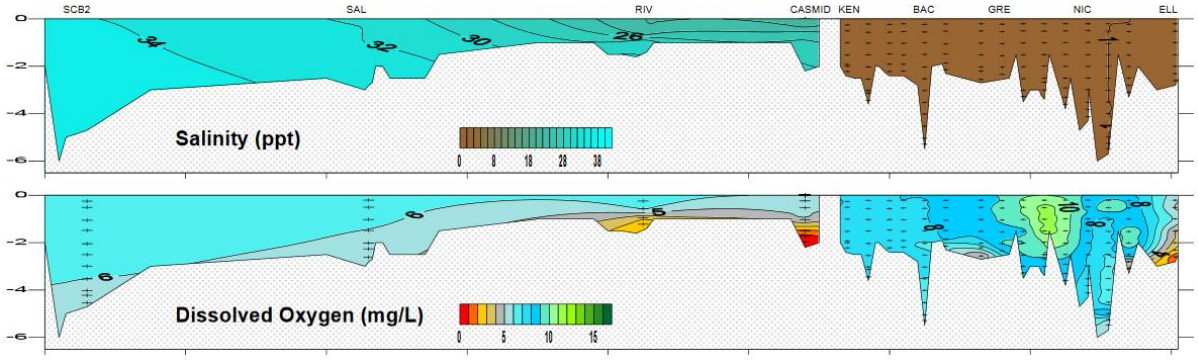
Canning River Estuary - Physical-chemical Profile - 7th March 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



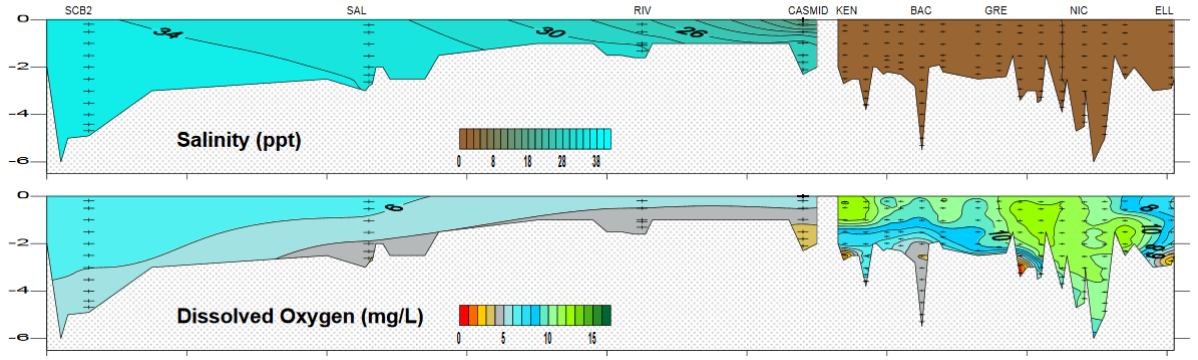
Canning River Estuary - Physical-chemical Profile - 20th March 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



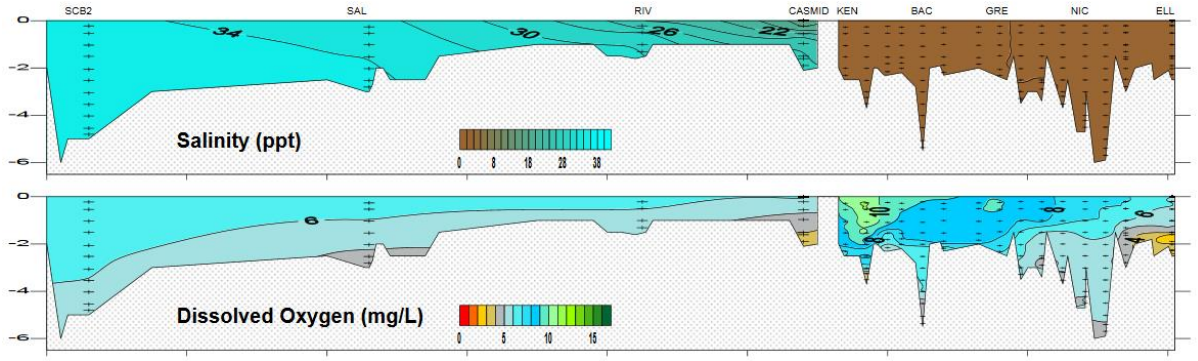
Canning River Estuary - Physical-chemical Profile - 4th April 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



Canning River Estuary - Physical-chemical Profile - 17th April 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation



Canning River Estuary - Physical-chemical Profile - 1st May 2018

Prepared by Water Science Branch, Department of Water and Environmental Regulation