Swan Canning Estuary condition assessment based on fish communities - 2020

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Final Report

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Executive summary

This report, commissioned by the Department of Biodiversity, Conservation and Attractions (DBCA), describes the monitoring and evaluation of fish communities in the Swan Canning Estuary during 2020 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 offshore sites in each of four management zones of the estuary (LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary) during summer and autumn of 2020. 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 fair (C) and fair/good condition (C/B) during the summer and autumn of 2020, respectively, consistent with the overall trend in condition since 2011. The average nearshore FCI scores for each zone of the estuary in summer increased in an upstream direction, with the LSCE being poor and the USE rated as very good. The underlying reason for the poor score in the LSCE was not determined but did not appear to be water quality related. All zones were in good condition in autumn except the MSE, which was fair.

Small-bodied, schooling species of hardyheads (Atherinidae) and gobies (Gobiidae) once again dominated catches from the nearshore waters of the estuary in 2020, representing 86% of all fish recorded and constituting the seven of the nine most abundant nearshore species overall. In particular, Wallace's Hardyhead was the most abundant species overall and in the CE and USE, reflecting the preference of this species for the fresh to brackish conditions that were present in these zones during the 2020 monitoring period. Other abundant species of small, schooling fish included the Elongate Hardyhead, Mugil's Hardyhead and Presbyter's Hardyhead, each of which prefer more saline waters, and the Bluespot Goby in the MSE and USE, the Yellow-eye Mullet in the CE and MSE and Perth Herring in the USE.

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 20-23 species in the LSCE, CE and MSE to 16 species in the USE.

Offshore fish communities

Overall, the offshore waters of the estuary were also in good (B) condition in summer and fair/good (C/B) during autumn 2020, and improvement from fair (C) in 2019. This reflects the lack of

any widespread or severe hypoxia (low dissolved oxygen) during this year's monitoring period and occurred despite the presence of dinoflagellate algae blooms of *Alexandrium* spp. in all zones except the USE and *Karlodinium* spp. in the CE. Scores in the CE zone were poor (D) in summer but did improve to fair (C) in autumn after the bloom had occurred. The CE scored comparatively poorly relative to other zones in both seasons, consistent with monitoring results observed since 2012.

As in the eight previous years of monitoring, Perth Herring was among the dominant species in offshore waters from all four zones comprising 33–67% of the total catches. Other abundant species included the Southern eagle ray and Western Striped Grunter in the LSCE (24 and 18%, respectively, of the catch) and the Yellowtail Grunter in the CE (18%), MSE (21%) and USE (38%).

Overall

In summary, and across the estuary as a whole, the ecological condition of the nearshore and offshore waters in 2020 was assessed as fair/good (C/B) and good (B), respectively, based on their fish communities. These results are consistent with the relatively stable trends in nearshore condition that have been observed since 2011. The overall FCI score for the offshore waters was the highest recorded and the first score of good (B) since 2015. These trends, particularly for offshore waters, reflects the lack of any widespread or severe hypoxia over the sampling period. Noting, that the good scores in 2020 occurred despite the presence of blooms of *Alexandrium* spp. and *Karlodinium* spp.

There is a knowledge gap on the effects of *Alexandrium* spp. on fish fauna and future FCI monitoring may facilitate understanding of how fish respond to blooms of this dinoflagellate. Once again, the offshore waters of the CE exhibited the lowest scores of any zone in 2020. The offshore waters of this zone have consistently scored poorly relative to those of the other zones across both seasons (receiving a D grade in > 50% of monitored seasons between 2012 and 2020), and DBCA has implemented additional monitoring in this zone (since late May 2020) in order to better understand the factors underlying this trend.

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Contents

1. Background

The Department of Biodiversity, Conservation and Attractions (DBCA) 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 (now DBCA), Department of Fisheries (now Department of Primary Industries and Regional Development) and Department of Water (now Department of Water and Environmental Regulation) (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). The development and rationale of the FCI, along with its implementation and outcomes to date, are summarized in Hallett et al. (2019).

2. Rationale

Separate versions of the FCI were developed for the shallow, nearshore waters (< 1.5 m deep) of the estuary and also for its deeper, offshore waters (> 1.5 m deep), as the composition of the fish communities living in these different environments tends to differ, as do the methods used to sample them (*e.g.* Chuwen et al., 2009, Hoeksema et al. 2009). 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 (Hallett et al. 2019).

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; Tweedley et al. 2017). 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 an 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 biodiversity

[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 Estuary during 2020 for the purposes of applying the FCI 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 FCI 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 the broader estuarine reporting framework of the Department of Biodiversity, Conservation and Attractions.

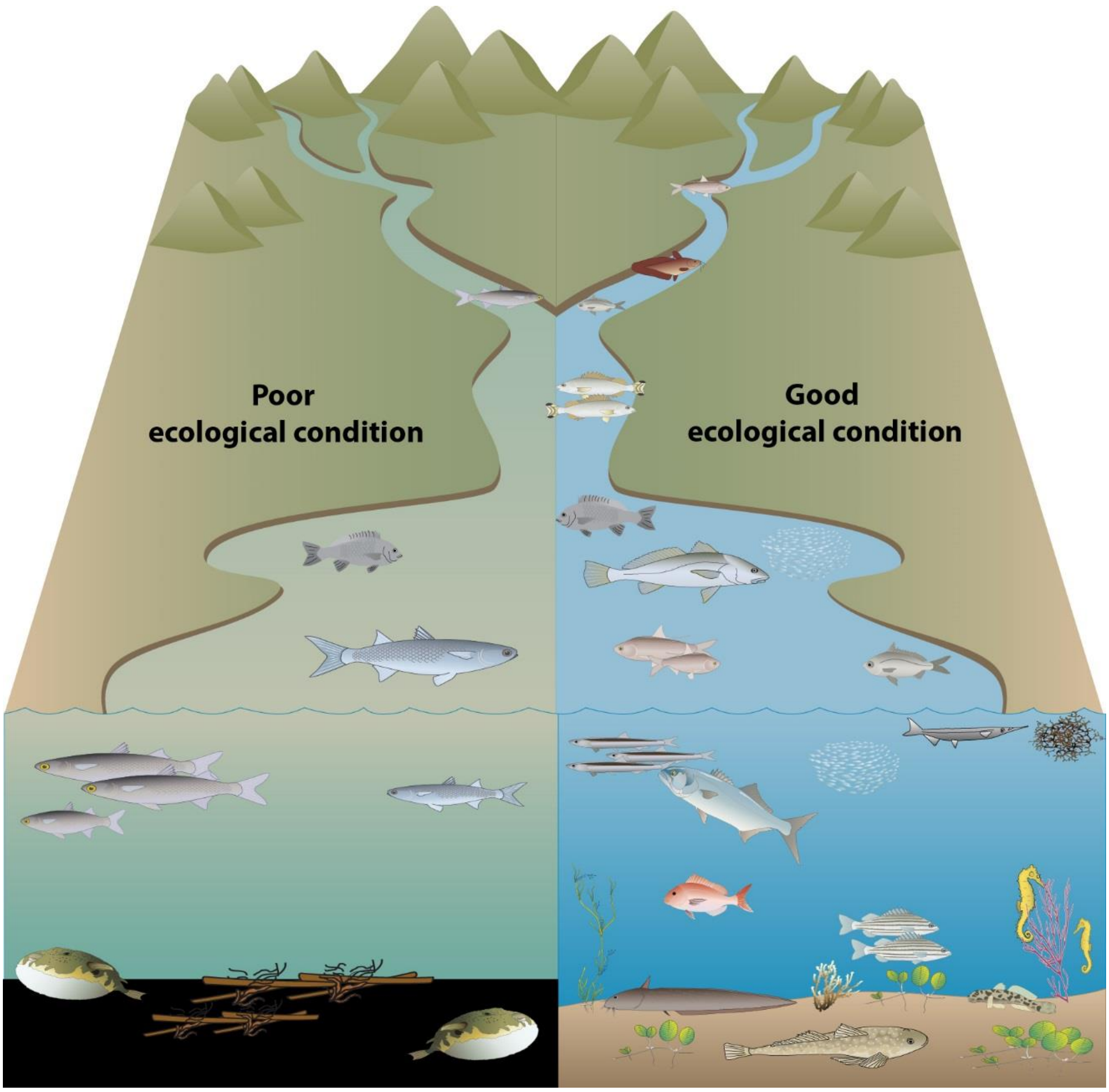


Figure 1. Conceptual diagram illustrating the predicted responses of the estuarine fish community to situations of poor and good ecological condition. (Images courtesy of the Integration and Application Network [ian.umces.edu/symbols/].)

4. Methods

Fish communities were sampled at six nearshore and six offshore sites in each of the 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 (29 January–11 February) and autumn (6–16 April) of 2020. All sampling was conducted under permits approved by Murdoch University's Animal Ethics Committee (permit number R3000-17), the Department of Primary Industries and Regional Development, Fisheries Division (exemption number 3032) and Department of Biodiversity, Conservation and Attractions (permit number FO25000254).

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 depth of water at each 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, euthanised in ice slurry and preserved on ice 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, depending on the total size 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 by experienced fish biologists, using available keys and identification guides where required. 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 method for calculating these scores is detailed in Hallett and Valesini (2012), but can be summarised simply as follows:

1. Allocate each fish species in a particular sample to its appropriate Habitat guild, Estuarine Use guild and Feeding Mode guild (Appendix iii), then calculate the values for each fish metric from the abundances of fishes in the sample.
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 2020 were then examined to assess the condition of the Swan Canning Estuary during this period and were compared to previous years through a qualitative examination of the patterns and trends in scores.

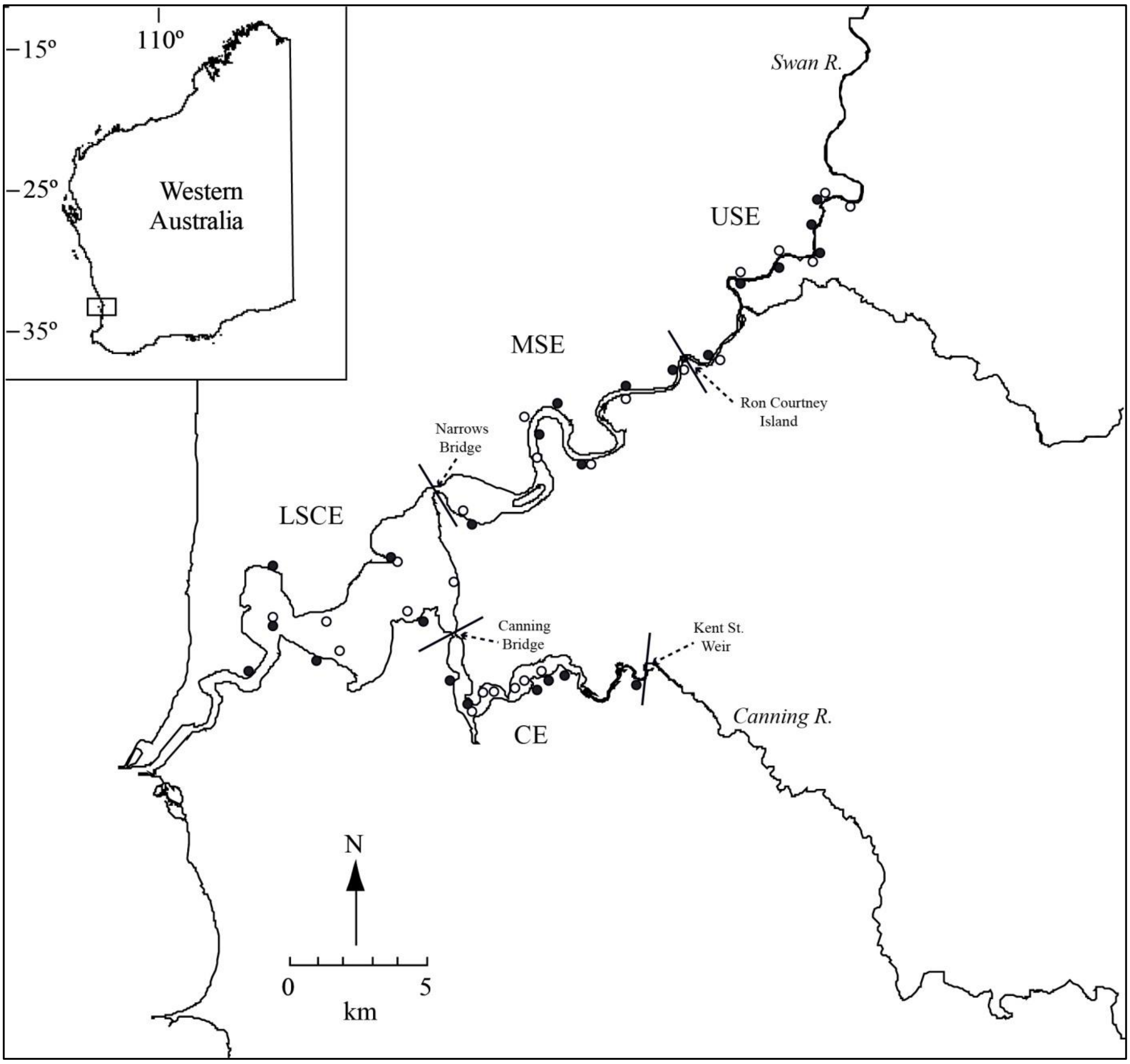


Figure 2. Locations of nearshore (black circles) and offshore (open circles) sampling sites for the Fish Community Index of estuarine condition. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

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 Jen Eliot and Kerry Trayler, DBCA and Kurt Krispyn, Murdoch University).

5. Results and discussion

5.1 Context: water quality and environmental conditions during the 2020 monitoring period

The environmental conditions present in the system during the monitoring period are shown as vertical contour plots of interpolated salinities, dissolved oxygen (DO) concentrations, chlorophyll levels and temperatures measured at regular water quality monitoring sites along the length of the both axes of the Swan Canning Estuary (Appendix iv). The water column of the USE was brackish (salinity 8-18) in late December 2019 and early January 2020, becoming more saline into February as the salt wedge moved upstream. Salinities in the LSCE and MSE were around that of full-strength sea water (~35) throughout summer. Pockets of low dissolved oxygen occurred (< 4 mg/L) in parts of the USE upstream of the Caversham Oxygenation Plant. Both the Caversham and Guildford Oxygenation plants were in operation in each week of January and February. Water temperature increased in an upstream direction from ~24 °C in the LSCE to 27-28 °C in the USE. Dinoflagellate blooms of *Alexandrium* spp. (which includes *A. minutum* and *A. pacificum*) were present above the trigger values in each of the four zones of the Swan Canning Estuary in summer, but for varying periods (Trayler and Cosgrove, 2021). Specifically, these taxa were recorded in the LSCE and MSE for 12 and 15 weeks in total, respectively, in mid-December and from mid-January to late-March (DBCA, unpublished data).

Cell densities of *Alexandrium* spp. did not exceed the trigger threshold in the USE until after the completion of summer sampling on 11 February.

The water column of the upper part of the CE (Riverton to Castledare) was stratified by freshwater flows overlying denser, saltier water in January with the degree of stratification decreasing as the year progressed and more of this zone became saline. The resultant lack of mixing of these waters producing hypoxic conditions (low dissolved oxygen; < 2 mg/L), the magnitude and extent of which changed weekly and were generally less in January than February. Relatively high to high levels of chlorophyll were detected in the upper part of the CE and blooms of *Alexandrium* spp. and *Karlodinium* spp. were recorded in this zone for 11 weeks from early-January to mid-March and from mid to late January, respectively.

During autumn sampling (6-16 April), more marine conditions, *i.e.* salinities of 26-36, had penetrated upstream into the MSE and USE (Appendix iv). Low dissolved oxygen concentrations were present in the bottom waters of the MSE in the second week of April and the Guildford Oxygenation Plant was operating, increasing oxygen concentrations in the lower part of the USE to > 10 mg/L. Relatively high concentrations of chlorophyll were detected in the lower part of the USE during the first week of April and throughout the USE during the second week of that month, some of which were associated with a bloom of *Karlodinium* spp. (DBCA, unpublished data). Pronounced stratification was present in the upper parts of the CE in April and was associated with low dissolved oxygen concentrations. Chlorophyll levels were markedly lower than in this zone in summer and no blooms of *Alexandrium* spp. or *Karlodinium* spp. were detected.

5.2 The fish community of the Swan Canning Estuary during 2020

Overall, the nearshore and offshore fish communities of the Swan Canning Estuary in 2020 were similar in composition to previous years (2012−2019). An estimated 22,699 fish, belonging to 32 species, were caught in seine net samples collected from the nearshore waters during summer and autumn 2020. The total number of fish caught in 2020 was slightly more than in 2019 (21,637) and towards the lower end of the range of values recorded annually since 2012 (*i.e.* 18,713 – 30,825). The 32 species recorded in 2020 was slightly greater than the 30 in 2019 and around the annual average of 31.4. As in previous years, and is typical for this system previously and in 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 20-23 species in the LSCE, CE and MSE to 16 species in the USE (Table 3), and were around the average values for these zones in the past.

Hardyheads (family = Atherinidae) and gobies (family = Gobiidae) once again dominated catches from the nearshore waters of the estuary in 2020, representing 86% of all fish caught and containing seven of the nine most abundant nearshore species. In particular, Wallace's hardyhead (*Leptatherina wallacei*) was again the most abundant species overall and in the CE and USE, comprising 42–44% of all fish in these zones; Table 3). This reflects the preference of this species for fresh to brackish conditions (Potter et al. 2015a,b), which were evident in these zones during the 2020 monitoring period. Another atherinid species *Craterocephalus mugiloides* and the Red-spot Goby (*Favonigobius punctatus*), both of which prefer brackish salinities were the most abundant species in the MSE (Hogan-west et al. 2019). Together with *C. mugiloides* three other atherinids, *Atherinosoma elongata*, *Atherinomorus vaigiensis* and *Leptatherina presbyteroides* all of which prefer more saline waters dominated the fish found in the LSCE. Other abundant species included the Bluespot goby

(*Pseudogobius olorum*) in the MSE and USE, the Yellow-eye Mullet (*Aldrichetta forsteri*) in the CE and MSE and Perth Herring (*Nematalosa vlaminghi*) in the USE (Table 3).

Two non-native fish species were recorded namely the Eastern Gambusia (*Gambusia holbrooki*) in all zones except the LSCE and the Pearl Cichlid (*Geophagus brasiliensis*) in the CE and USE (Table 3). It should also be noted that seine net sampling yielded two individuals of the Largemouth Goby (*Redigobius macrostoma*) from the CE. This species has not been formally recorded in the Swan-Canning Estuary before (Hogan-west et al. 2019) nor in any other estuary in Western Australia (Atlas of Living Australia, 2020). This species is generally confined to estuaries between Noosa (Queensland) and Port Phillip Bay (Victoria), although Hammer et al. (2006) did find this cryptic species in Port River Estuary (South Australia). However, these authors could not determine whether this endemic species to Australia was native to this estuary or had been introduced, likely via ballast water exchange. This new record does highlight the benefit of an annual monitoring program in helping to detect the presence of new and/or non-native species in this highly urbanised estuary.

Samples collected from offshore waters in summer and autumn 2020 using gill nets returned 2,290 fish, comprising 19 species (Table 4). This number of fish was almost 50% more than in 2019 and at the upper end of the range between 2012 and 2019 (*i.e.* 1,125 to 2352). The 19 species recorded was the same as in 2019 and similar to the long-term average of 19.7 (range = 17 to 22). Unlike in most years where the total number of species recorded from each zone decreased upstream, in 2020 between 12 and 13 species were found in the LSCE, CS and USE compared to 16 species in the MSE. This represents the largest number of species recorded in the MSE and the joint greatest with 2013 in the USE.

As in the eight previous years of monitoring, Perth Herring was among the dominant species in offshore waters overall (47%) and from all four zones, comprising 33–67% of the total catches (Table 4). The Southern Eagle Ray (*Myliobatis tenuicaudata*) and Western Striped Grunter (*Pelates octolineatus*) were abundant in the LSCE (24 and 18% of the catch, respectively) as were the Yellow-tail Trumpeter (*Amniataba caudavittata;* ~20%) and Tailor (*Pomatomus saltatrix*; ~5%) in the CE and MSE. Both terapontids (*P. octolineatus* and *A. caudavittata*) were also abundant in the USE (30 and 28%, respectively). Catches of the above four species were all at least 170% greater than those that occurred on average between 2012 and 2019.

Table 3. Compositions of the fish communities (D = Average density fish/100 m^2 and %C = percentage composition) observed across the six nearshore sites sampled in each zone of the Swan Canning Estuary during summer and autumn of 2020. Data for the three most abundant species in the catches from each zone are emboldened for emphasis. Species ordered by overall abundance. LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary. * denotes non-native species.

		LSCE (*n* = 12)		**CE** (*n* = 12)		**MSE** (*n* = 12)		**USE** (*n* = 12)	
Species	**Common name**	D	%C	D	%C	D	%C	D	%C
Leptatherina wallacei	Wallace's Hardyhead	192	3.8	**4,782**	**42.0**	**241**	**10.3**	**1,712**	**44.5**
Craterocephalus mugiloides	Mugil's Hardyhead	**561**	**11.0**	**3,633**	**31.9**	**650**	**27.6**	215	5.6
Atherinosoma elongata	Elongate Hardyhead	**3,077**	**60.3**	372	3.3	6	0.3	3	0.1
Leptatherina presbyteroides	Presbyter's Hardyhead	403	7.9	**1,012**	**8.9**	10	0.4	-	-
Aldrichetta forsteri	Yellow-eye Mullet	185	3.6	664	5.8	89	3.8	-	-
Pseudogobius olorum	Blue-spot / Swan River Goby	-	-	48	0.4	146	6.2	**682**	**17.7**
Atherinomorus vaigiensis	Ogilby's Hardyhead	**440**	**8.6**	25	0.2	228	9.7	36	0.9
Nematalosa vlaminghi	Perth Herring	-	-	57	0.5	68	2.9	**544**	**14.1**
Favonigobius punctatus	Red-spot Goby	67	1.3	132	1.2	**290**	**12.3**	176	4.6
Ostorhinchus rueppellii	Gobbleguts	21	0.4	362	3.2	156	6.6	7	0.2
Pelates octolineatus	Western Striped Grunter	52	1.0	-	-	200	8.5	5	0.1
Acanthopagrus butcheri	Southern Black Bream	-	-	23	0.2	93	4.0	113	2.9
Afurcagobius suppositus	Southwestern Goby	-	-	56	0.5	30	1.3	109	2.8
Arenigobius bifrenatus	Bridled Goby	-	-	-	-	47	2.0	121	3.1
*Gambusia holbrooki**	Eastern Gambusia	-	-	9	0.1	7	0.3	100	2.6
Mugil cephalus	Sea Mullet	-	-	75	0.7	31	1.3	-	-
Sillago burrus	Western Trumpeter Whiting	13	0.3	52	0.5	20	0.9	-	-
Favonigobius lateralis	Long-finned Goby	75	1.5	-	-	-	-	-	-
Amniataba caudavittata	Yellow-tail Trumpeter	2	< 0.1	63	0.6	8	0.3	6	0.2
Gerres subfasciatus	Roach	-	-	3	< 0.1	7	0.3	16	0.4
*Geophagus brasiliensis**	Pearl Cichlid	-	-	20	0.2	-	-	1	< 0.1

Table 3. continued.

		LSCE (*n* = 12)		CE (*n* = 12)		MSE (*n* = 12)		USE (*n* = 12)	
Species	**Common name**	D	%C	D	%C	D	%C	D	%C
Torquigener pleurogramma	Blowfish / Banded Toadfish	7	0.1	-	-	8	0.3	-	-
Engraulis australis	Southern Anchovy	1	< 0.1	-	-	12	0.5	-	-
Sillago schomburgkii	Yellow-finned Whiting	1	< 0.1	-	-	3	0.1	-	-
Platycephalus westraliae	Yellowtail Flathead	3	0.1	-	-	-	-	-	-
Pentapodus vitta	Western Butterfish	2	< 0.1	-	-	-	-	-	-
Redigobius macrostoma	Largemouth Goby	-	-	2	< 0.1	-	-	-	-
Pseudorhombus jenynsii	Small-toothed Flounder	2	< 0.1	-	-	-	-	-	-
Pugnaso curtirostris	Pugnose Pipefish	1	< 0.1	-	-	-	-	-	-
Gymnapistes marmoratus	Devilfish	1	< 0.1	-	-	-	-	-	-
Pomatomus saltatrix	Tailor	-	-	-	-	1	< 0.1	-	-
Haletta semifasciata	Blue Weed Whiting	1	< 0.1	-	-	-	-	-	-
	Total number of species	**21**		**20**		**23**		**16**	
	Average total fish density (fish 100m^{-2})	**106**		**237**		**49**		**80**	
	Total number of fish	**5,107**		**11,395**		**2,351**		**3,846**	

Table 4. Compositions of the fish communities (CR = Average catch rate [fish/net set] and %C = percentage composition) observed across the six offshore sites sampled in each zone of the Swan Canning Estuary during summer and autumn of 2020. Species ranked by total abundance. Data for the three most abundant species in the catches from each zone are emboldened for emphasis. Species ordered by overall abundance. LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary.

		LSCE (*n* = 12)		**CE** (*n* = 12)		**MSE** (*n* = 12)		**USE** (*n* = 12)	
Species	**Common name**	CR	%C	CR	%C	CR	%C	CR	%C
Nematalosa vlaminghi	Perth Herring	**201**	**38.8**	**273**	**66.7**	**342**	**62.4**	**267**	**32.8**
Amniataba caudavittata	Yellow-tail Trumpeter	**-**	**-**	**75**	**18.3**	**114**	**20.8**	**228**	**28.0**
Pelates octolineatus	Western Striped Grunter	**91**	**17.6**	9	2.2	19	3.5	**243**	**29.8**
Myliobatis tenuicaudatus	Southern Eagle Ray	**124**	**23.9**	15	3.7	1	0.2	-	-
Pomatomus saltatrix	Tailor	47	9.1	**21**	**5.1**	**32**	**5.8**	8	1.0
Acanthopagrus butcheri	Southern Black Bream	1	0.2	1	0.2	10	1.8	31	3.8
Gerres subfasciatus	Roach	13	2.5	8	2.0	7	1.3	2	0.2
Platycephalus westraliae	Yellowtail Flathead	11	2.1	-	-	9	1.6	10	1.2
Elops machnata	Giant Herring	11	2.1	-	-	2	0.4	7	0.9
Mugil cephalus	Sea Mullet	-	-	1	0.2	1	0.2	9	1.1
Cnidoglanis macrocephalus	Estuarine Cobbler	7	1.4	2	0.5	-	-	-	-
Engraulis australis	Southern Anchovy	4	0.8	1	0.2	3	0.5	1	0.1
Argyrosomus japonicus	Mulloway	-	-	1	0.2	1	0.2	6	0.7
Carcharinas leucas	Bull Shark	-	-	-	-	3	0.5	3	0.4
Sillago burrus	Western Trumpeter Whiting	5	1.0	-	-	1	0.2	-	-
Rhabdosargus sarba	Tarwhine			1	0.2	2	0.4	-	-
Sillago schomburgkii	Yellow-finned Whiting	3	0.6	-	-	-	-	-	-
Aldrichetta forsteri	Yellow-eye Mullet	-	-	1	0.2	-	-	-	-
Hippocampus angustus	Western Spiny Seahorse	-	-	-	-	1	0.2	-	-
	Total number of species	**12**		**13**		**16**		**12**	
	Average catch rate (fish/net set)	**43**		**34**		**46**		**68**	
	Total number of fish	**518**		**409**		**548**		**815**	

5.3 Ecological condition in 2020

Nearshore waters

The ecological condition, based on fish communities, of the nearshore waters of the Swan Canning Estuary was fair (C) in summer and good/fair (B/C) in autumn (Fig. 4). The condition of each zone was varied during summer (mean FCI scores 53–77) and increased in an upstream direction; with the LSCE being poor, the CE fair/poor, the MSE fair/good and the USE very good. By autumn, each of the zones were found to be in good condition, except for the MSE, which was fair.

Radar plots of the nearshore metric scores for each zone in each season revealed that the USE scored very well in the several positive metrics, *i.e.* relatively large values for the *Number of species*, *Number of trophic specialist species*, *Number of benthic-associated species*, *Number of estuarine-spawning species* and the *Proportion of estuarine-spawning individuals.* Furthermore, this zone received high scores for several negative metrics, *i.e. Proportion of detritivores* and *Total number of P. olorum.* This indicates that this zone contained estuarine-spawning benthic species, *e.g.* gobies other than *P. olorum* that do not feed on decaying organic matter, the presence and abundance of which would be facilitated by the high dissolved oxygen concentrations in this zone during summer. Relatively low scores were evident for most metrics in the LSCE except those relating to *P. olorum* and the *Proportion of detritivores*, reflecting the limited number of species recorded in this zone in this season and dominance of pelagic species such as Hardyheads and Yellow-eye Mullet and the general absence of gobies and other benthic fish. No obvious signs of deleterious impacts or disturbance were recorded at the time of sampling and these small benthic species were recorded in this zone in autumn. While there was a bloom of *Alexandrium* spp. in the LSCE at the time of sampling the affected waters were upstream of most sites, and, as such, the rationale for this poor score is not determined, but does not appear to be driven by water quality.

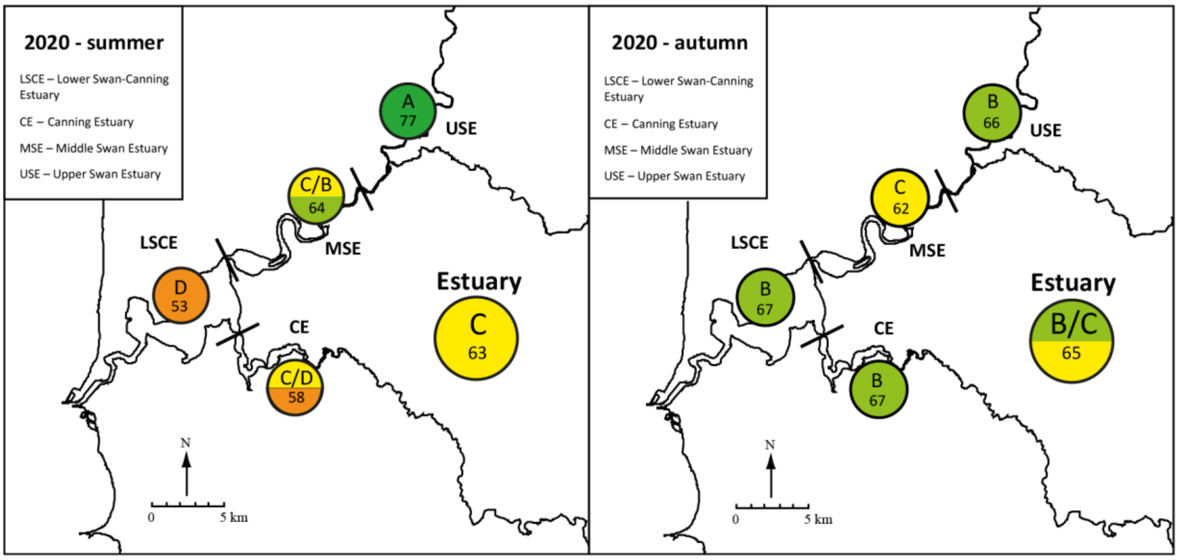
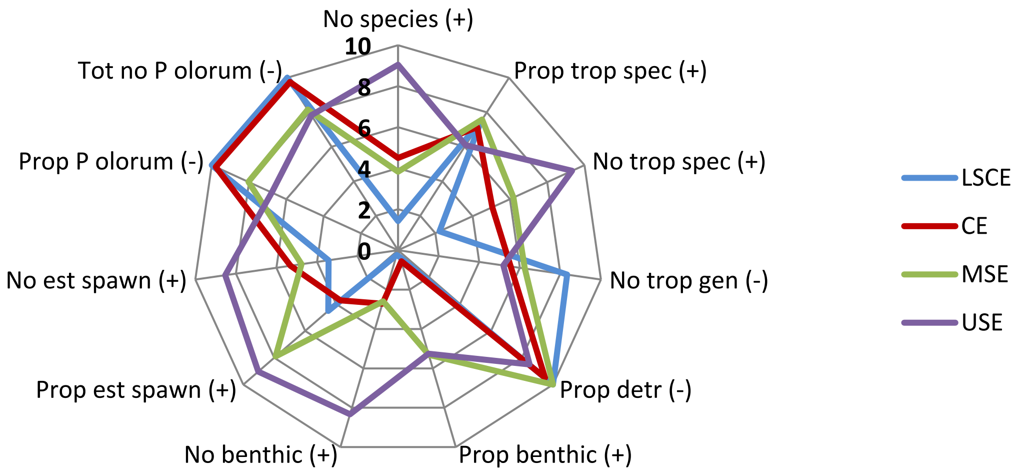


Figure 4. Average nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Estuary, and for the estuary as a whole, in summer and autumn of 2020.

In autumn, relatively high scores across all zones for metrics such as the *Proportion of detritivores* and the *Proportion of trophic specialist species* were due to the low *Number and Proportion of P. olorum*. The lower condition rating for the MSE reflects the low metric scores for the *Number of species, Number of benthic-associated species* and *Proportion of benthic-associated* *individuals* and the *Number and Proportion of estuarine-spawners.* Indeed, many of the fish recorded in this zone in this season were pelagic species that spawn in marine environments. The average nearshore FCI score for the CE was greater in autumn than in summer and it is notable that cell counts for *Alexandrium* spp., a potentially harmful species of dinoflagellate, and the ichthyotoxic *Karlodinium* spp. declined markedly over this time. Species of *Alexandrium* produce gonyautoxins and are associated with paralytic shellfish poisoning. The gonyautoxins produced by this algae can have acute and chronic impacts on zooplankton, with toxins accumulating in zooplankton, shellfish and crabs (Global Invasive Species Database, 2019). Therefore, the increase in score in the CE in autumn could be related to the reduction in cell counts of these dinoflagellates in the CE.

(a) Summer 2020



(b) Autumn 2020

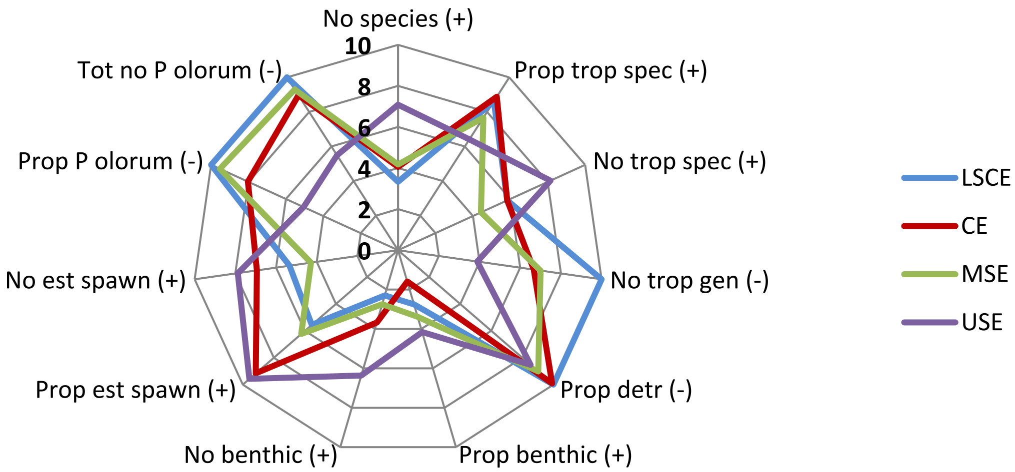


Figure 5. Average scores (0–10) for each component metric of the nearshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2020. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable. Therefore, the larger the area covered by the radar plot the better the condition in that zone. Full metric names and explanations are given in Table 1.

Offshore waters

The ecological condition of the offshore waters of the Swan Canning Estuary was good (B) in the LSCE, MSE and USE during summer of 2020, but poor (D) in the CE (Fig. 6). During autumn, the condition of the USE remained good, that in the MSE and LSCE declined to good/fair (B/C) and that in the CE improved to fair (C). Overall, the score for the estuary as a whole declined slightly from good in summer to fair/good in autumn.

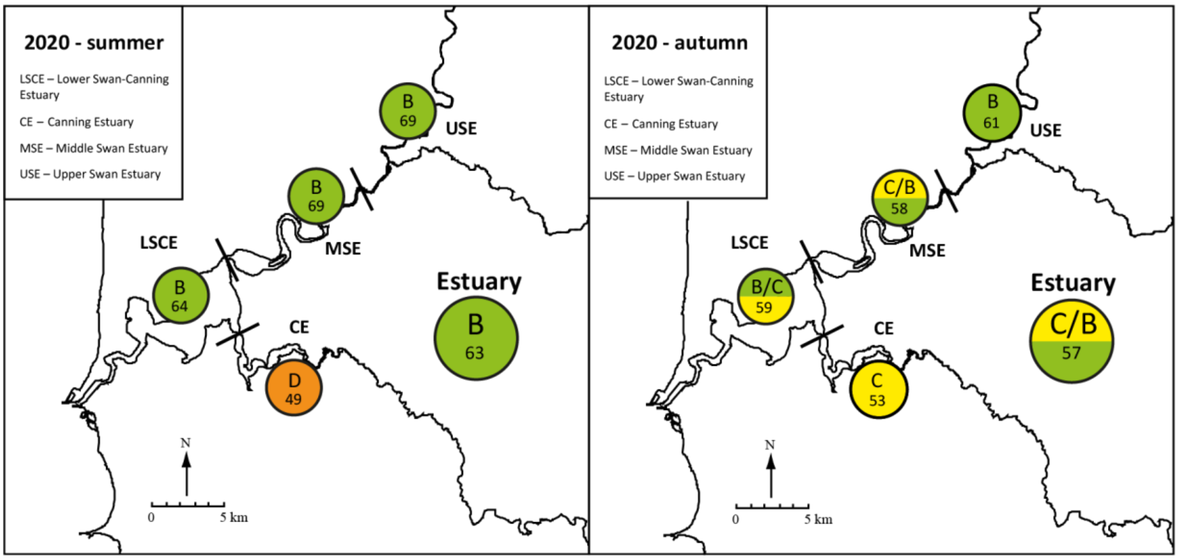


Figure 6. Average offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Estuary, and for the estuary as a whole, in summer and autumn of 2020.

Radar plots of offshore metric scores for the CE (Fig. 7) showed that the lower offshore FCI score in summer was due to very low metric scores for the *Number of species*, *Shannon-Wiener diversity*, and *Number of trophic specialist species* (all positive metrics) and the *Proportion of detritivores* (negative metric). Values for each of these metrics increased in autumn, thus accounting, in part, for the increase in FCI score for this zone. As mentioned above this zone was unique in experiencing blooms of both *Alexandrium* spp. and *Karlodinium* spp. in summer, which had decreased by autumn. Hallett et al. (2016) demonstrated that a bloom of the ichthyotoxic *Karlodinium veneficum* in the MSE and USE zones of the Swan-Canning Estuary caused a reduction in the number of species, catch rates and fish community index scores as mobile fish in the offshore waters moved away from the bloom. Such a response to the *Karlodinium* spp. could account for the lower metric scores for the *Number of species*, *Shannon-Wiener diversity*, and *Number of trophic specialist species* during summer than autumn. As, in the earlier study, fish were found to move to adjacent zones outside of the area of impact, it is possible that the slight decline in the FCI score for the LSCE from summer to autumn could be due to some of those fish returning to the CE. This theory is supported by the fact that the score for each of the above three metrics declined in this zone between those seasons. While it is possible that the blooms of *Alexandrium* spp. had an influence on the poor score for the CE in summer, blooms of this dinoflagellate were also occurring in the LSCE and MSE, both rated as in good condition at the time. Moreover, scores for these zones did not improve in autumn despite the lack of *Alexandrium* blooms. As their vegetative cells are able to encyst, and provide a seedbed for future inoculation (Anderson, 1997), it is likely that future blooms of *Alexandrium* spp. will occur in the Swan-Canning

Estuary. If future blooms did occur this would provide an opportunity to attempt to gain an understanding of whether and how this dinoflagellate affect the fish community. It is worth nothing that while the mechanism of ichthyotoxicity of *Karlodinium* is relatively well known (*e.g.* Place et al. 2012, Adolf et al. 2015), that of *Alexandrium* spp. remains poorly understood, despite it being implicated in the mortality of aquacultured salmonids (Cembella et al. 2002, Mardones et al. 2015).

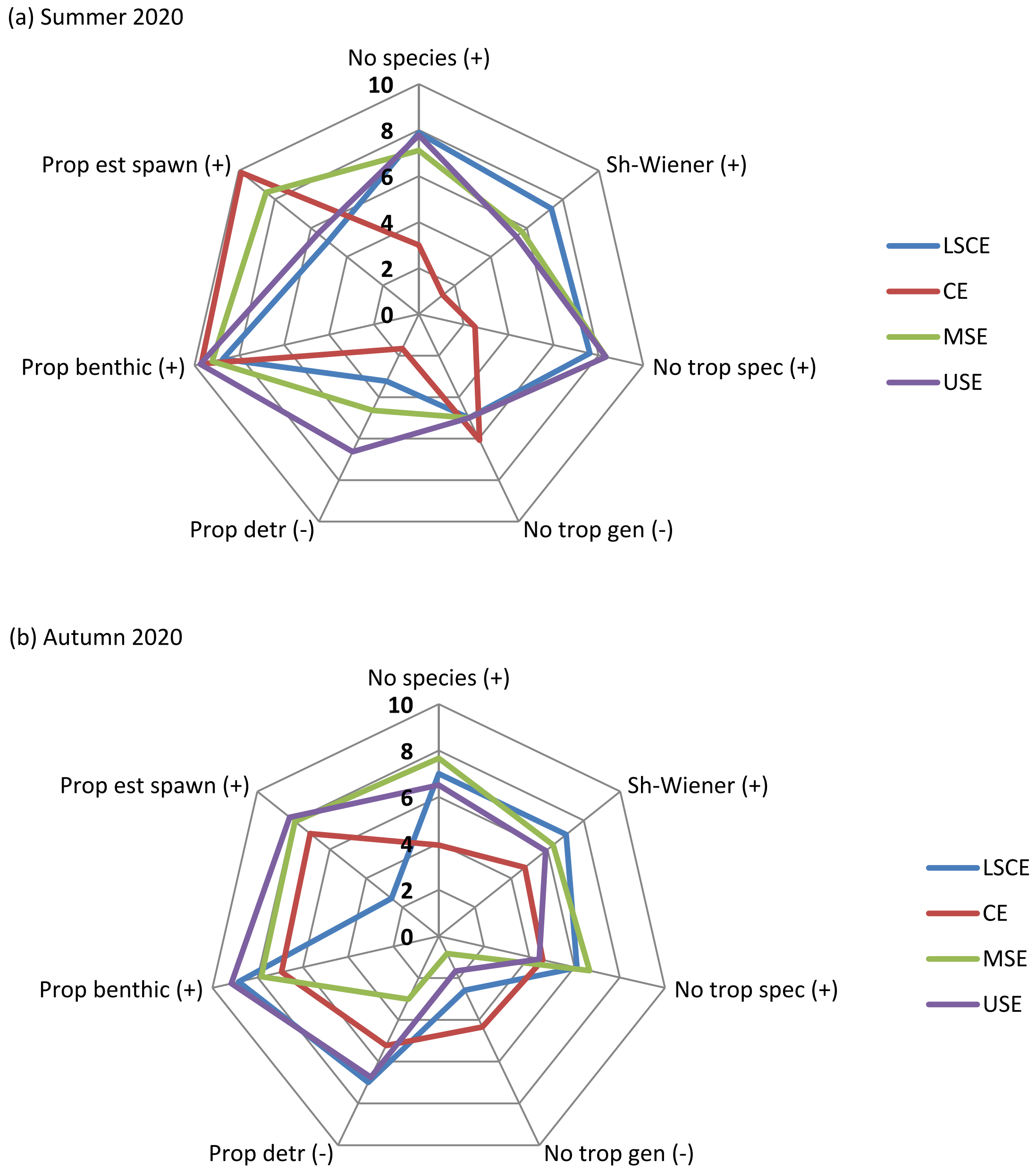


Figure 7. Average scores (0–10) for each component metric of the offshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2020. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable. Therefore, the larger the area covered by the radar plot the better the condition in that zone. Metric names and explanations are given in Table 1.

Longer term trends in ecological condition

Results indicate that the nearshore waters of the Swan Canning Estuary as a whole were in fair condition (C) during 2020, consistent with the overall trend since 2011, except for 2014 and 2016 when they were in good condition (B; Fig. 8). Similarly, the mean offshore FCI score for the estuary as a whole indicated good offshore condition (B) during 2020, the highest score for this water depth since 2015 and only the third such good condition rating in the over the last decade (Fig. 9). This reflects the consistent good scores throughout all zones (except the CE) due to the absence of any widespread or persistent hypoxia during this year's monitoring period.

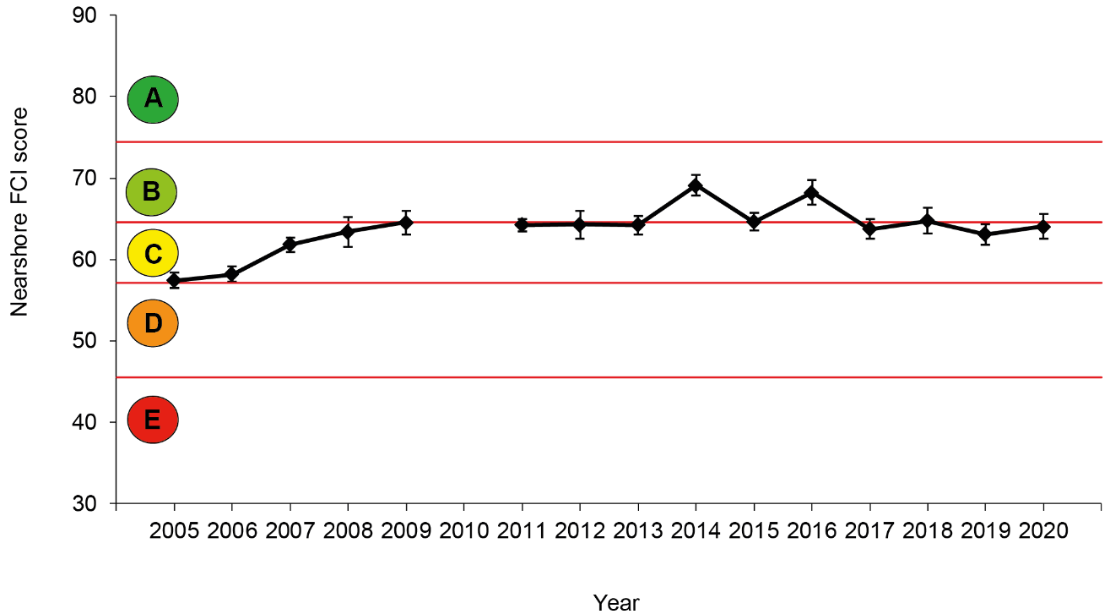


Figure 8. Trend plot of average (±SE) nearshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

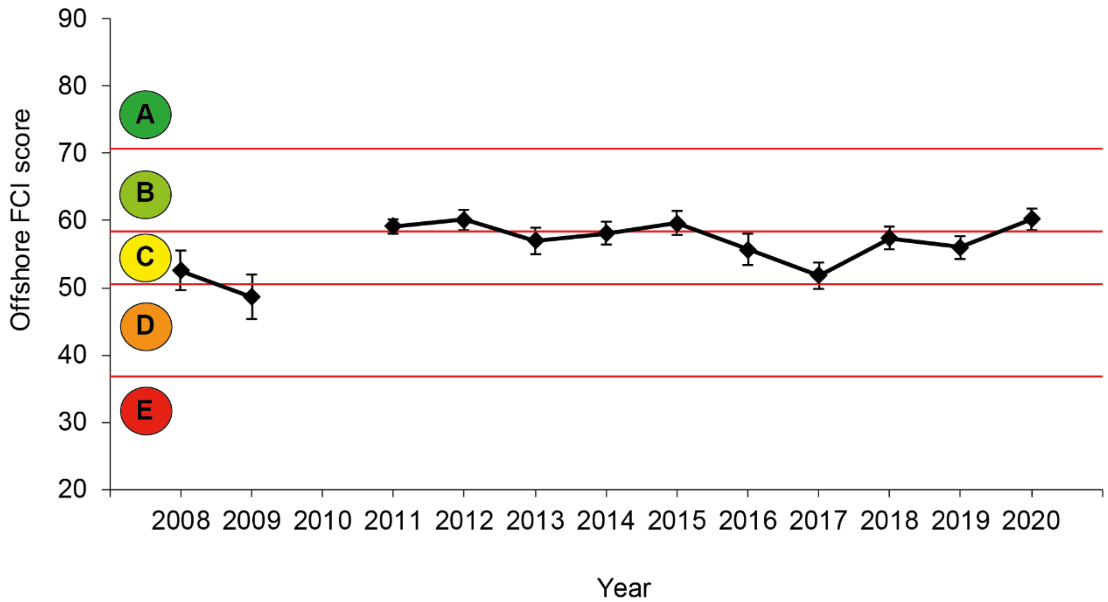


Figure 9. Trend plot of average (±SE) offshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor), for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

Summary

The Fish Community Index (FCI) considers the fish community as a whole and provides a means to assess how the structure and function of these communities in shallow, nearshore (< 1.5 m deep) and deeper, offshore waters (> 1.5 m deep) 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; Crisp et al. 2018), nor does it provide information on the size or status of the fish stocks in the estuary (*e.g.* Smith & Lenanton, 2021).

Across the estuary as a whole, the ecological condition of both nearshore and offshore waters in 2020 was assessed as fair/good (C/B) and good (B) respectively, based on their fish communities (Table 5). These results are consistent with the relatively stable trends in condition that have been observed in nearshore waters since 2011 and represent the highest score recorded in the offshore waters to date and the first score of good (B) for five years. These trends, particularly for offshore waters, reflect the lack of any widespread or severe hypoxia over this period. Moreover, the good scores in 2020 occurred despite the presence of blooms of *Alexandrium* spp. and *Karlodinium* spp., which have been implicated in fish kills elsewhere in the world (Cembella et al. 2002, Mardones et al. 2015) and, in the case of the latter taxa, in the Swan-Canning Estuary (Adolf et al., 2015). There is a knowledge gap on the effects of *Alexandrium* spp. on the fish fauna. As it is likely that this algae will bloom in this estuary in the future, the FCI monitoring may assist in understanding fish responses to this toxic dinoflagellate as it has done in respect for *Karlodinium veneficum* (*e.g.* Hallett et al. 2016).

Overall, the offshore waters of the CE exhibited by far the lowest scores of any zone in 2020. Since the start of regular fish community monitoring in 2012, the offshore waters of this zone have consistently scored poorly relative to other zones across both seasons (receiving a poor [D] grade in > 50% of monitored seasons). Additional monitoring water quality in this zone has been initiated since May 2020 to better understand the factors underlying this trend.

Table 5. Fish Community Index (FCI) scores and corresponding ecological condition grades for each zone of the estuary, and the estuary as a whole, during the 2020 monitoring period (mean of all summer and autumn of 2020). 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	59.9	C	61.5	B
MSE	62.9	C	63.4	B
USE	71.1	B	65.1	B
CE	62.4	C	50.7	C/D
Estuary	64.1	C/B	60.2	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.

Rees, A.J.J., Yearsley, G.K., Gowlett-Holmes, K. and Pogonoski, J. Codes for Australian Aquatic Biota (on-line version). CSIRO Marine and Atmospheric Research, World Wide Web electronic publication, 1999 onwards. Available at: http://www.cmar.csiro.au/caab/. Last accessed 29 January 2021.

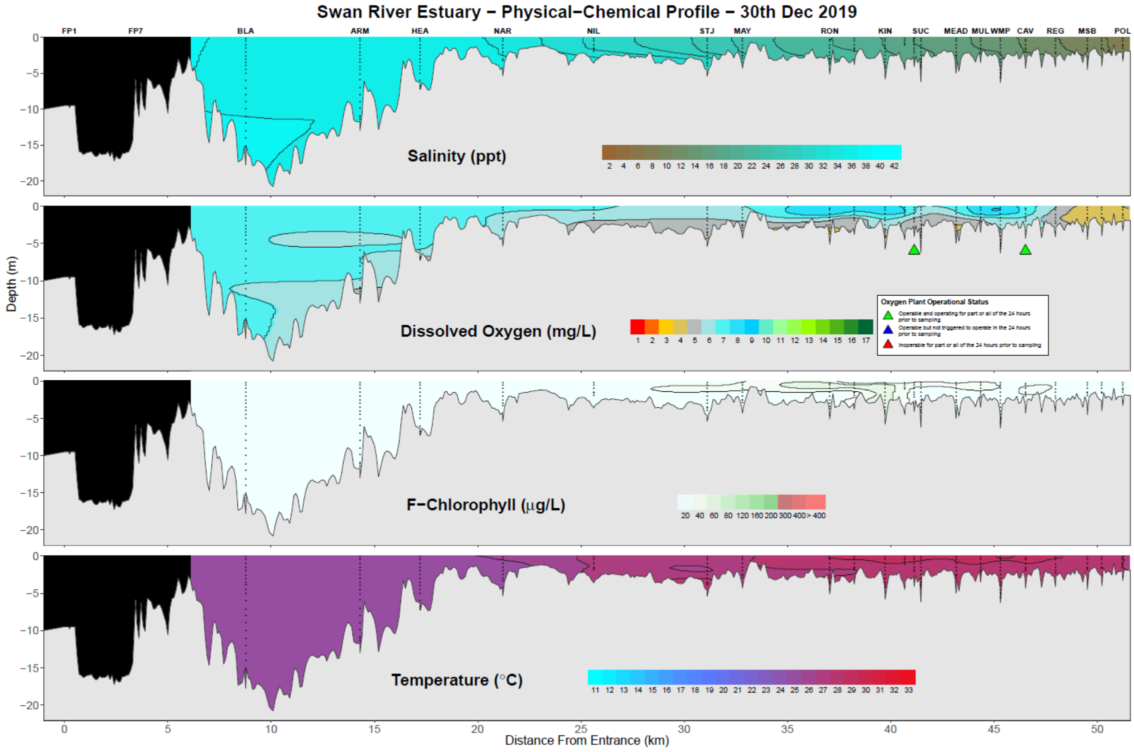
Appendix (iii). List of species caught from the Swan Canning Estuary, and their functional guilds: D, Demersal; P, Pelagic; BP, Bentho-pelagic; SP, Small pelagic; SB, Small benthic; MS, Marine straggler; MM, Marine migrant; SA, Semi-anadromous; ES, Estuarine species; FM, Freshwater migrant; ZB, Zoobenthivore;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

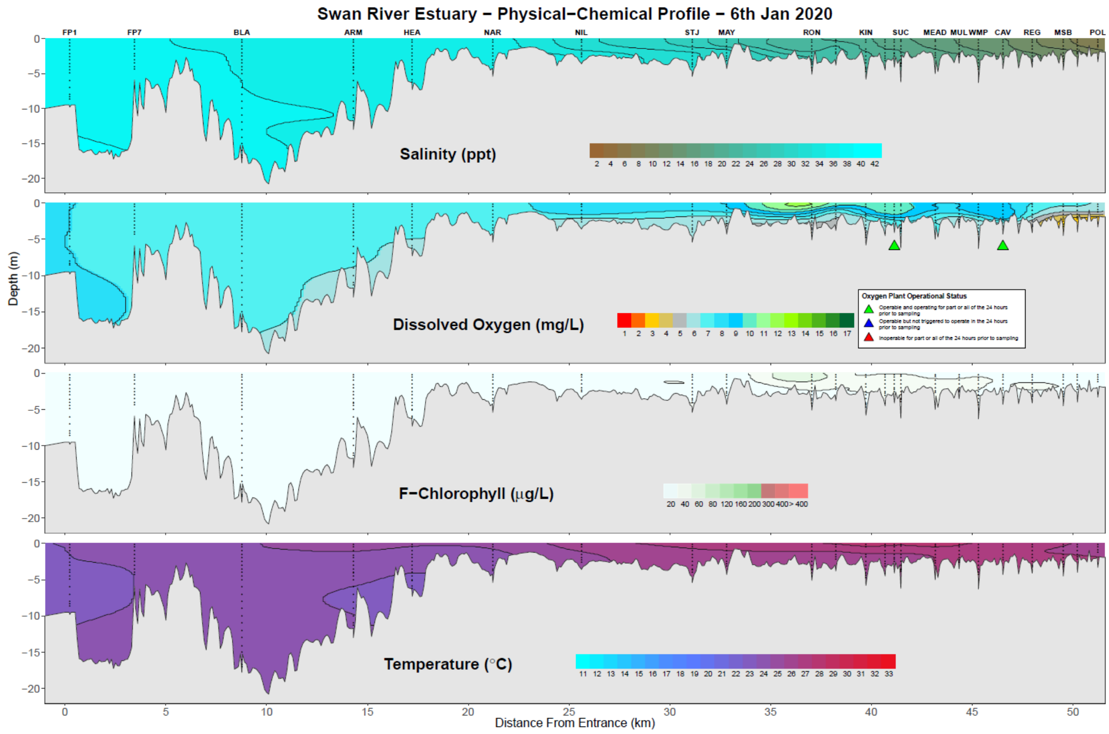
Species name	Common name	Family	Habitat Guild	Estuarine Use Guild	Feeding Mode Guild
Heterodontus portusjacksoni	Port Jackson Shark	Heterodontidae	D	MS	ZB
Carcharhinus leucas	Bull Shark	Carcharhinidae	P	MS	PV
Myliobatis tenuicaudatus	Southern Eagle Ray	Myliobatidae	D	MS	ZB
Elops machnata	Australian Giant Herring	Elopidae	BP	MS	PV
Sardinops sagax	Australian Sardine	Clupeidae	P	MS	ZP
Spratelloides robustus	Blue Sprat	Clupeidae	SP	MM	ZP
Hyperlophus vittatus	Sandy Sprat	Clupeidae	SP	MM	ZP
Nematalosa vlaminghi	Perth Herring	Clupeidae	BP	SA	DV
Sardinella lemuru	Scaly Mackerel	Clupeidae	P	MS	ZP
Engraulis australis	Australian Anchovy	Engraulidae	SP	ES	ZP
Galaxias occidentalis	Western Galaxias	Galaxiidae	SB	FM	ZB
Carassius auratus	Goldfish	Cyprinidae	BP	FM	OV
Cnidoglanis macrocephalus	Estuary Cobbler	Plotosidae	D	MM	ZB
Tandanus bostocki	Freshwater Cobbler	Plotosidae	D	FM	ZB
Hyporhamphus melanochir	Southern Garfish	Hemiramphidae	P	ES	HV
Hyporhamphus regularis	River Garfish	Hemiramphidae	P	FM	HV
Gambusia holbrooki	Eastern Gambusia	Poeciliidae	SP	FM	ZB
Leptatherina presbyteroides	Silver Fish	Atherinidae	SP	MM	ZP
Atherinomorus vaigiensis	Common Hardyhead	Atherinidae	SP	MM	ZB
Atherinosoma elongata	Elongate Hardyhead	Atherinidae	SP	ES	ZB
Leptatherina wallacei	Western Hardyhead	Atherinidae	SP	ES	ZP
Craterocephalus mugiloides	Spotted Hardyhead	Atherinidae	SP	ES	ZB
Cleidopus gloriamaris	Australian Pineapplefish	Monocentrididae	D	MS	ZB
Phyllopteryx taeniolatus	Common Seadragon	Syngnathidae	D	MS	ZB
Hippocampus angustus	Western Spiny Seahorse	Syngnathidae	D	MS	ZP
Urocampus carinirostris	Hairy Pipefish	Syngnathidae	D	ES	ZP
Stigmatopora argus	Spotted Pipefish	Syngnathidae	D	MS	ZP
Stigmatopora nigra	Widebody Pipefish	Syngnathidae	D	MS	ZB
Pugnaso curtirostris	Pugnose Pipefish	Syngnathidae	D	MS	ZP
Vanacampus phillipi	Port Phillip Pipefish	Syngnathidae	D	MS	ZB
Filicampus tigris	Tiger Pipefish	Syngnathidae	D	MS	ZP
Gymnapistes marmoratus	Soldier	Tetrarogidae	D	MS	ZB
Chelidonichthys kumu	Red Gurnard	Triglidae	D	MS	ZB
Leviprora inops	Longhead Flathead	Platycephalidae	D	MS	PV
Platycephalus laevigatus	Rock Flathead	Platycephalidae	D	MS	PV
Platycephalus westraliae	Yellowtail Flathead	Platycephalidae	D	ES	PV
Pegasus lancifer	Sculptured Seamoth	Pegasidae	D	MS	ZB
Nannoperca vittata	Western Pygmy Perch	Percichthyidae	BP	FM	ZB
Amniataba caudavittata	Yellowtail Grunter	Terapontidae	BP	ES	OP
Bidyanus bidyanus	Silver Perch	Terapontidae	BP	FM	OV
Pelates octolineatus	Western Striped Grunter	Terapontidae	BP	MM	OV
Pelsartia humeralis	Sea Trumpeter	Terapontidae	BP	MS	OV
Siphamia cephalotes	Wood's Siphonfish	Apogonidae	BP	MS	ZB
Ostorhinchus rueppellii	Western Gobbleguts	Apogonidae	BP	ES	ZB
Sillaginodes punctatus	King George Whiting	Sillaginidae	D	MM	ZB
Sillago bassensis	Southern School Whiting	Sillaginidae	D	MS	ZB
Sillago burrus	Western Trumpeter Whiting	Sillaginidae	D	MM	ZB
Sillago schomburgkii	Yellowfin Whiting	Sillaginidae	D	MM	ZB
Sillago vittata	Western School Whiting	Sillaginidae	D	MM	ZB
Pomatomus saltatrix	Tailor	Pomatomidae	P	MM	PV
Trachurus novaezelandiae	Yellowtail Scad	Carangidae	P	MS	ZB
Scomberoides tol	Needleskin Queenfish	Carangidae	P	MS	PV
Pseudocaranx georgianus	Silver Trevally	Carangidae	BP	MM	ZB

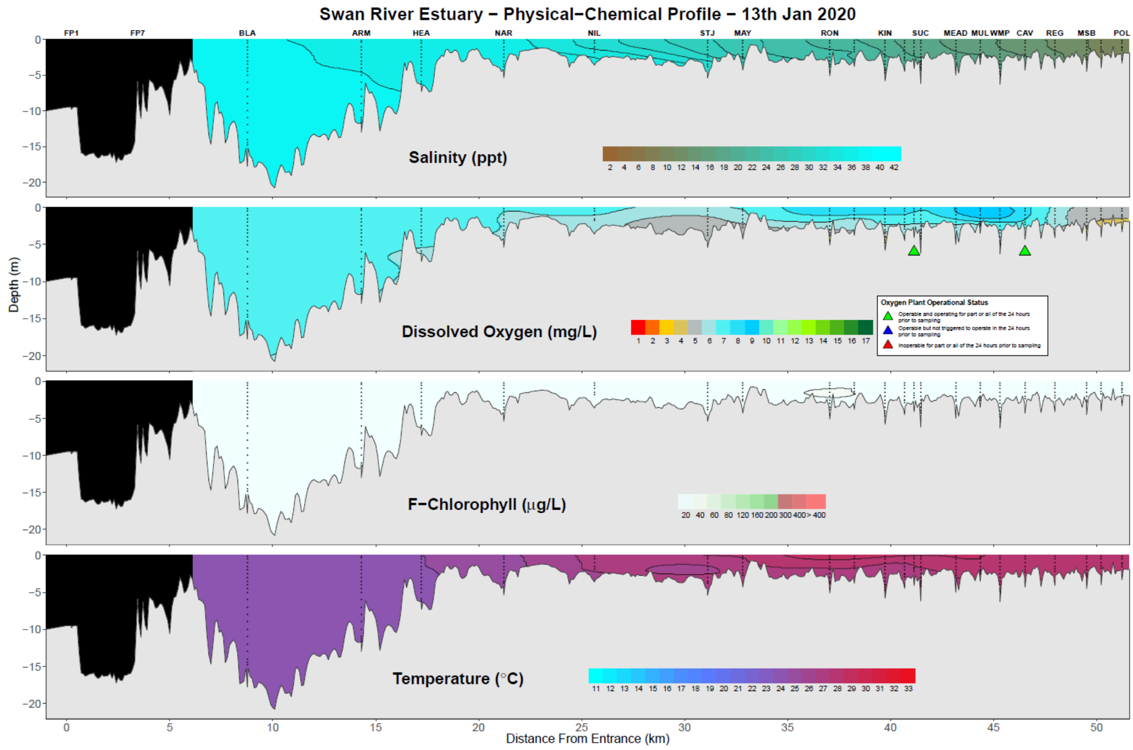
Species name	Common name	Family	Habitat Guild	Estuarine Use Guild	Feeding Mode Guild
Pseudocaranx wrighti	Skipjack Trevally	Carangidae	BP	MM	ZB
Arripis georgianus	Australian Herring	Arripidae	P	MM	PV
Pentapodus vitta	Western Butterfish	Nemipteridae	BP	MS	ZB
Gerres subfasciatus	Common Silverbiddy	Gerreidae	BP	MM	ZB
Acanthopagrus butcheri	Black Bream	Sparidae	BP	ES	OP
Rhabdosargus sarba	Tarwhine	Sparidae	BP	MM	ZB
Argyrosomus japonicus	Mulloway	Sciaenidae	BP	MM	PV
Parupeneus spilurus	Blacksaddle Goatfish	Mullidae	D	MS	ZB
Neatypus obliquus	Footballer Sweep	Scorpididae	P	MS	ZP
Scorpis aequipinnis	Sea Sweep	Scorpididae	P	MS	ZP
Enoplosus armatus	Old Wife	Enoplosidae	D	MS	ZB
Geophagus brasiliensis	[a cichlid]	Cichlidae	BP	FM	OV
Aldrichetta forsteri	Yelloweye Mullet	Mugilidae	P	MM	OV
Mugil cephalus	Sea Mullet	Mugilidae	P	MM	DV
Sphyraena novaehollandiae	Snook	Sphyraenidae	P	MS	PV
Sphyraena obtusata	Yellowtail Barracuda	Sphyraenidae	P	MS	PV
Neoodax balteatus	Little Weed Whiting	Odacidae	D	MS	OV
Siphonognathus radiatus	Longray Weed Whiting	Odacidae	D	MS	OV
Haletta semifasciata	Blue Weed Whiting	Odacidae	D	MS	OV
Heteroscarus acroptilus	Rainbow Cale	Odacidae	D	MS	OV
Parapercis haackei	Wavy Grubfish	Pinguipedidae	D	MS	ZB
Lesueurina platycephala	Flathead Sandfish	Leptoscopidae	D	MS	ZB
Istiblennius meleagris	Peacock Rockskipper	Blenniidae	D	MS	HV
Omobranchus germaini	Germain's Blenny	Blenniidae	SB	MS	ZB
Parablennius intermedius	Horned Blenny	Blenniidae	D	MS	ZB
Parablennius postoculomaculatus	False Tasmanian Blenny	Blenniidae	SB	MS	OV
Petroscirtes breviceps	Shorthead Sabretooth Blenny	Blenniidae	SB	MS	OV
Cristiceps australis	Southern Crested Weedfish	Clinidae	D	MS	ZB
Pseudocalliurichthys goodladi	Longspine Dragonet	Callionymidae	D	MS	ZB
Eocallionymus papilio	Painted Stinkfish	Callionymidae	D	MS	ZB
Callogobius mucosus	Sculptured Goby	Gobiidae	SB	MS	ZB
Favonigobius lateralis	Southern Longfin Goby	Gobiidae	SB	MM	ZB
Nesogobius pulchellus	Sailfin Goby	Gobiidae	SB	MS	ZB
Arenigobius bifrenatus	Bridled Goby	Gobiidae	SB	ES	ZB
Pseudogobius olorum	Bluespot Goby	Gobiidae	SB	ES	OV
Callogobius depressus	Flathead Goby	Gobiidae	SB	MS	ZB
Favonigobius punctatus	Yellowspotted Sandgoby	Gobiidae	SB	ES	ZB
Afurcagobius suppositus	Southwestern Goby	Gobiidae	SB	ES	ZB
Redigobius macrostoma	Largemouth Goby	Gobiidae	SB	ES	ZB
Tridentiger trigonocephalus	Trident Goby	Gobiidae	SB	MS	ZB
Pseudorhombus jenynsii	Smalltooth Flounder	Paralichthyidae	D	MM	ZB
Ammotretis rostratus	Longsnout Flounder	Pleuronectidae	D	MM	ZB
Ammotretis elongatus	Elongate Flounder	Pleuronectidae	D	MM	ZB
Cynoglossus broadhursti	Southern Tongue Sole	Cynoglossidae	D	MS	ZB
Acanthaluteres brownii	Spinytail Leatherjacket	Monacanthidae	D	MS	OV
Acanthaluteres vittiger	Toothbrush Leatherjacket	Monacanthidae	D	MS	OV
Eubalichthys mosaicus	Mosaic Leatherjacket	Monacanthidae	D	MS	OV
Scobinichthys granulatus	Rough Leatherjacket	Monacanthidae	D	MS	OV
Monacanthus chinensis	Fanbelly Leatherjacket	Monacanthidae	D	MM	OV
Chaetodermis penicilligerus	Tasselled Leatherjacket	Monacanthidae	D	MS	OV
Brachaluteres jacksonianus	Southern Pygmy Leatherjacket	Monacanthidae	D	MS	OV
Meuschenia freycineti	Sixspine Leatherjacket	Monacanthidae	D	MM	OV
Acanthaluteres spilomelanurus	Bridled Leatherjacket	Monacanthidae	D	MM	OV
Torquigener pleurogramma	Weeping Toadfish	Tetraodontidae	BP	MM	OP
Contusus brevicaudus	Prickly Toadfish	Tetraodontidae	BP	MS	OP
Polyspina piosae	Orangebarred Puffer	Tetraodontidae	BP	MS	OP
Diodon nicthemerus	Globefish	Diodontidae	D	MS	ZB

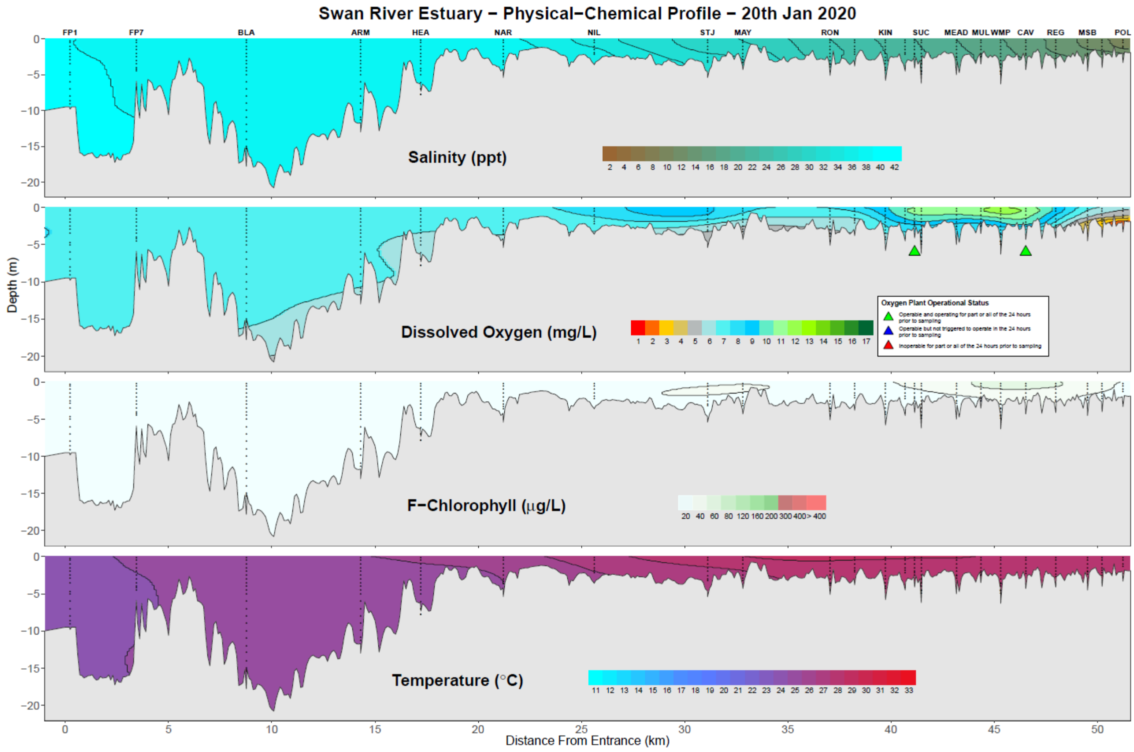
Appendix (iv). A representative selection of vertical contour plots of salinity, dissolved oxygen concentrations (mg/L), Chlorophyll fluorescence (µg/L) and water temperature (°C) measured at monitoring stations along the length of the Swan Canning Estuary on occasions throughout the summer to autumn period of fish community sampling. Prepared by the Department of Biodiversity, Conservation and Attractions (https://www.dbca.wa.gov.au/science/riverpark-monitoring).

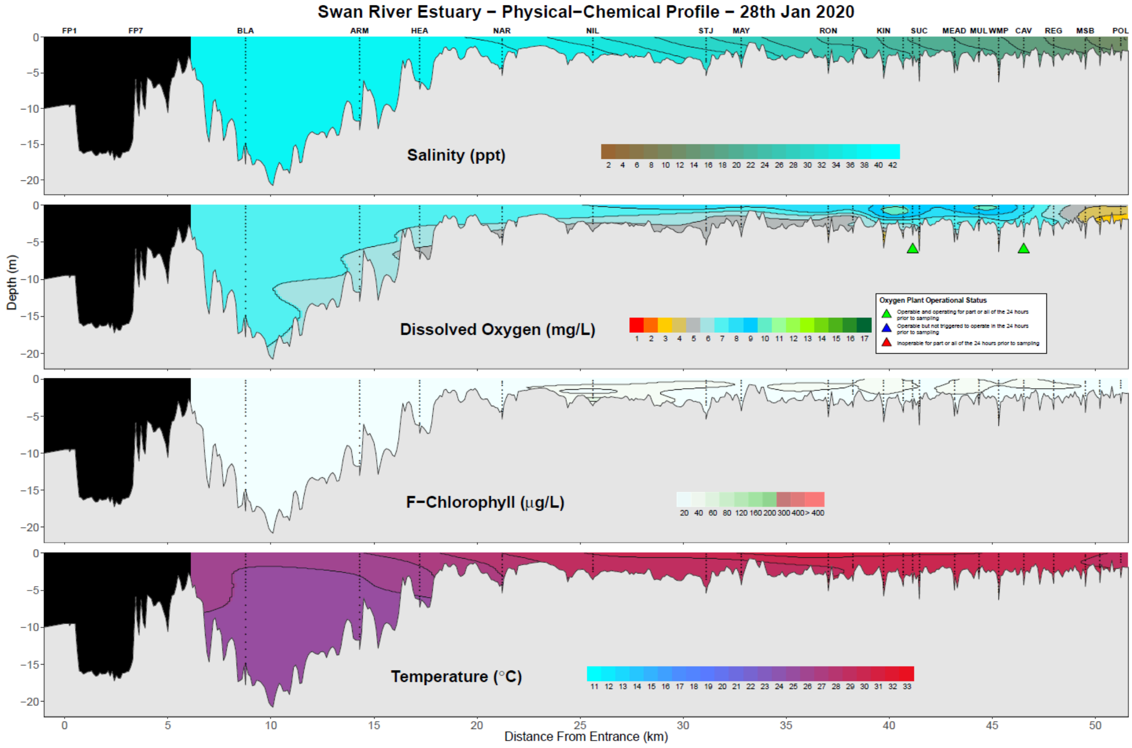
LSCE, MSE and USE zones in summer through autumn 2020.

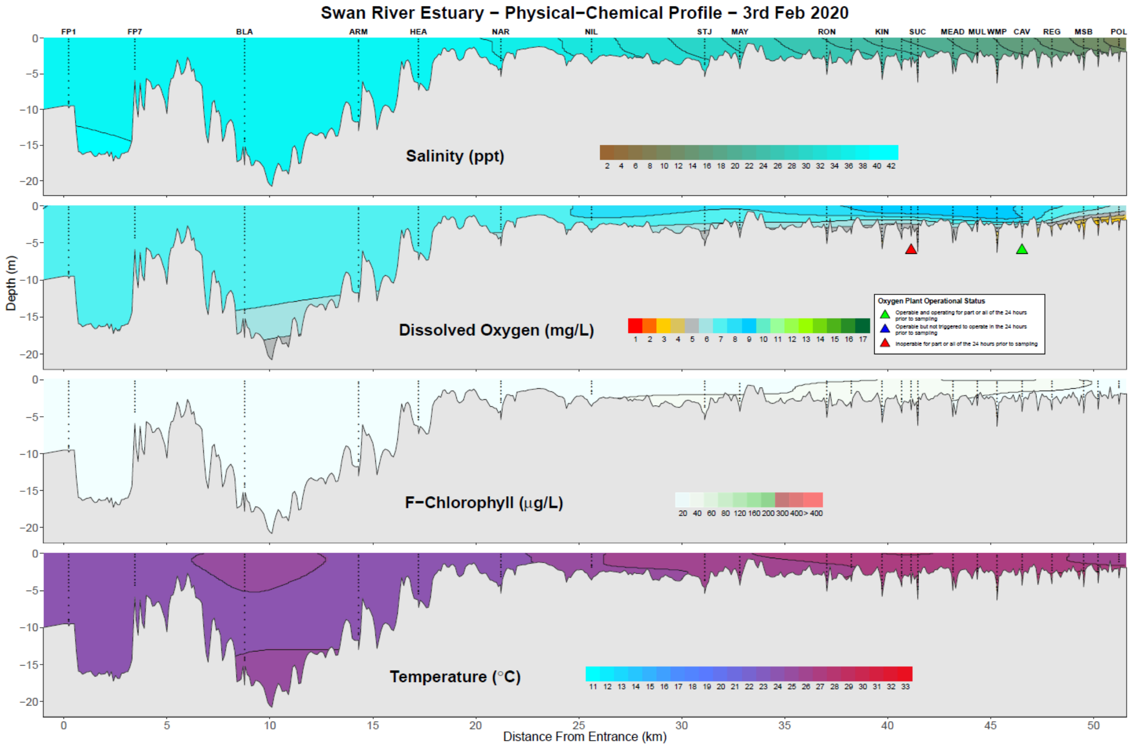


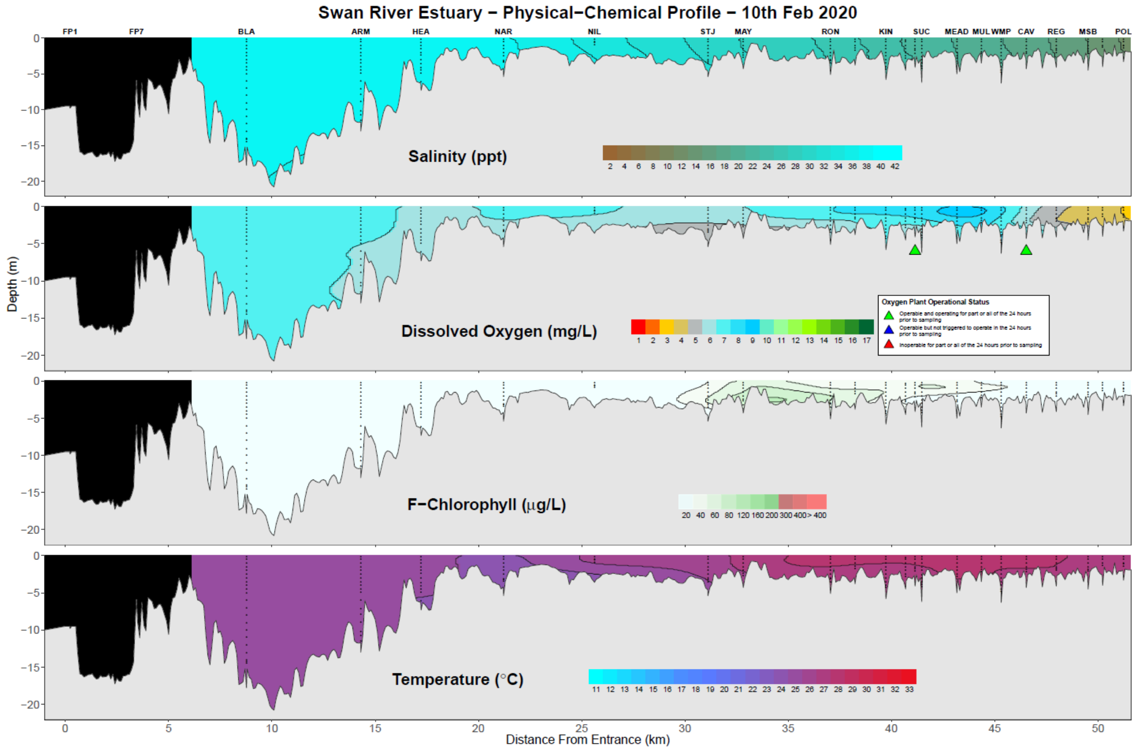


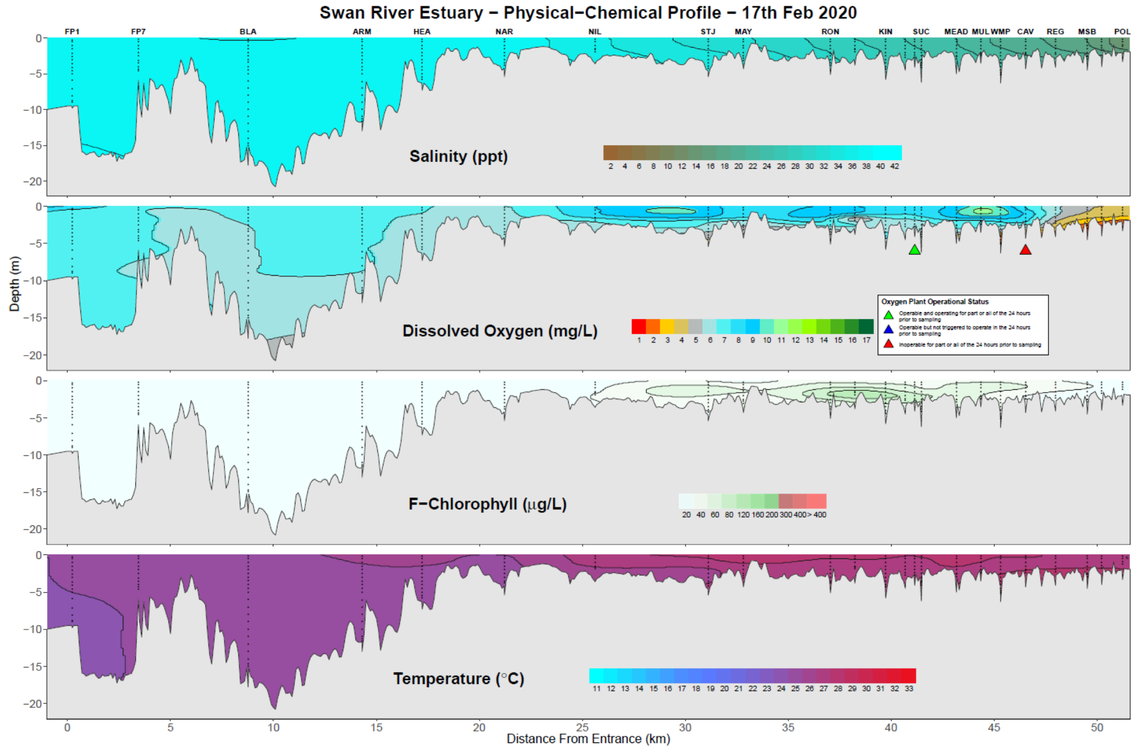

Swan River Estuary – Physical–Chemical Profile – 13th Jan 2020
FP1 FP7 BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEAD MUL WMP CAV REG MSB POL
Salinity (ppt)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Depth (m)
Dissolved Oxygen (mg/L)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
20 40 60 80 120 160 200 300 400 > 400
Temperature (°C)
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
0 5 10 15 20 25 30 35 40 45 50
Distance From Entrance (km)

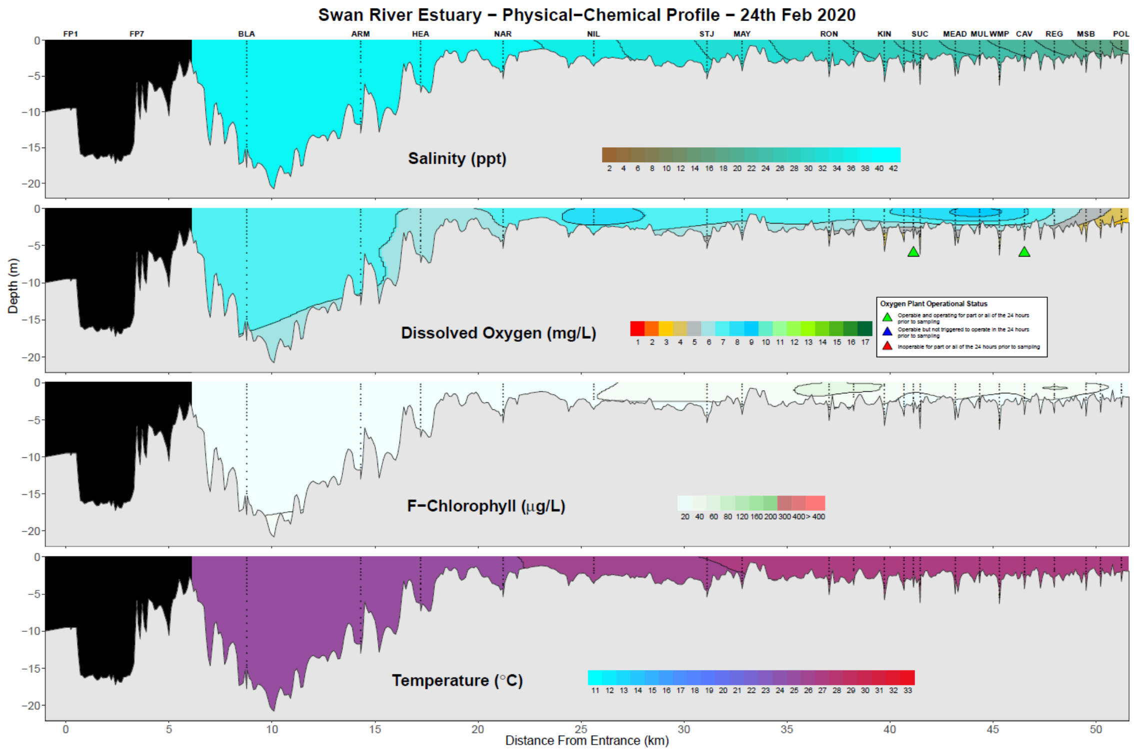

Swan River Estuary – Physical–Chemical Profile – 20th Jan 2020
FP1 FP7 BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEAD MUL WMP CAV REG MSB POL
Salinity (ppt)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Depth (m)
Dissolved Oxygen (mg/L)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
20 40 60 80 120 160 200 300 400 > 400
Temperature (°C)
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
0 5 10 15 20 25 30 35 40 45 50
Distance From Entrance (km)

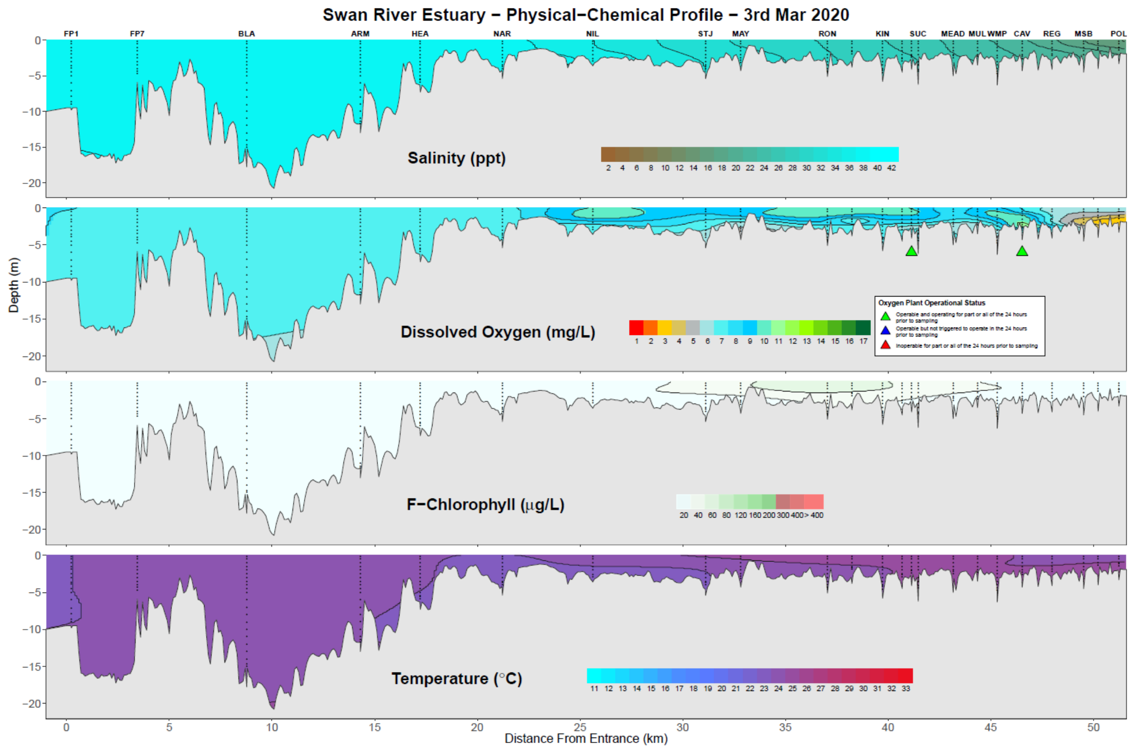

Swan River Estuary – Physical–Chemical Profile – 28th Jan 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

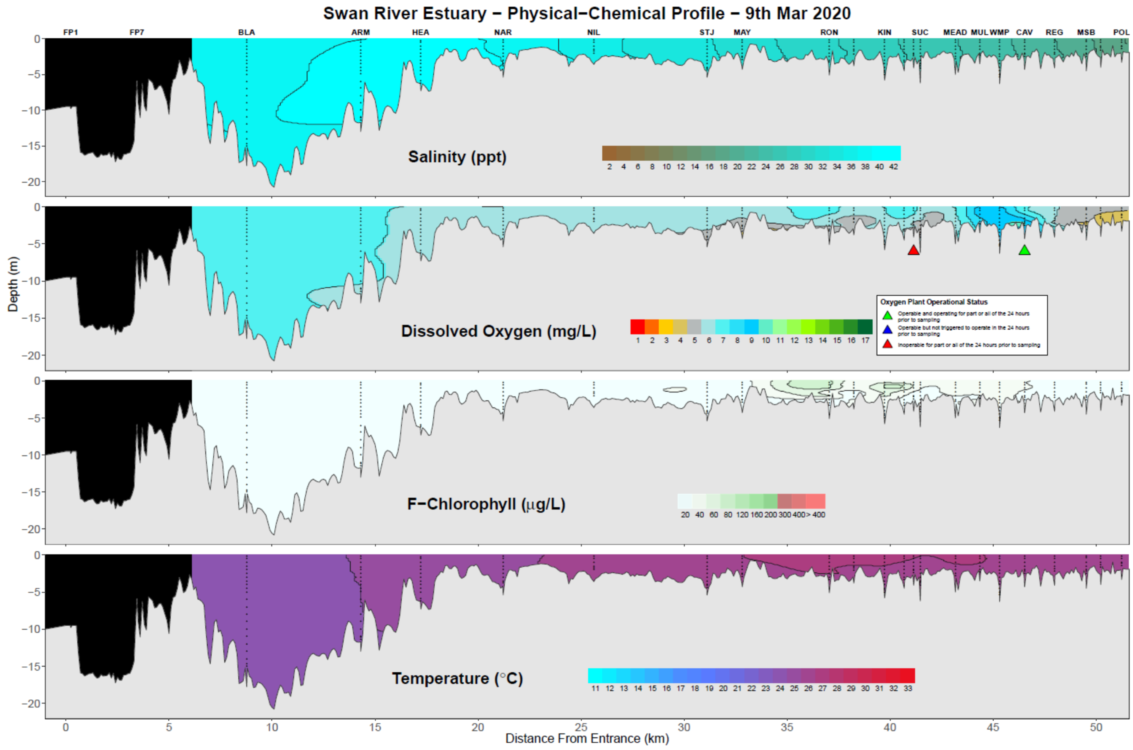

Swan River Estuary – Physical–Chemical Profile – 3rd Feb 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

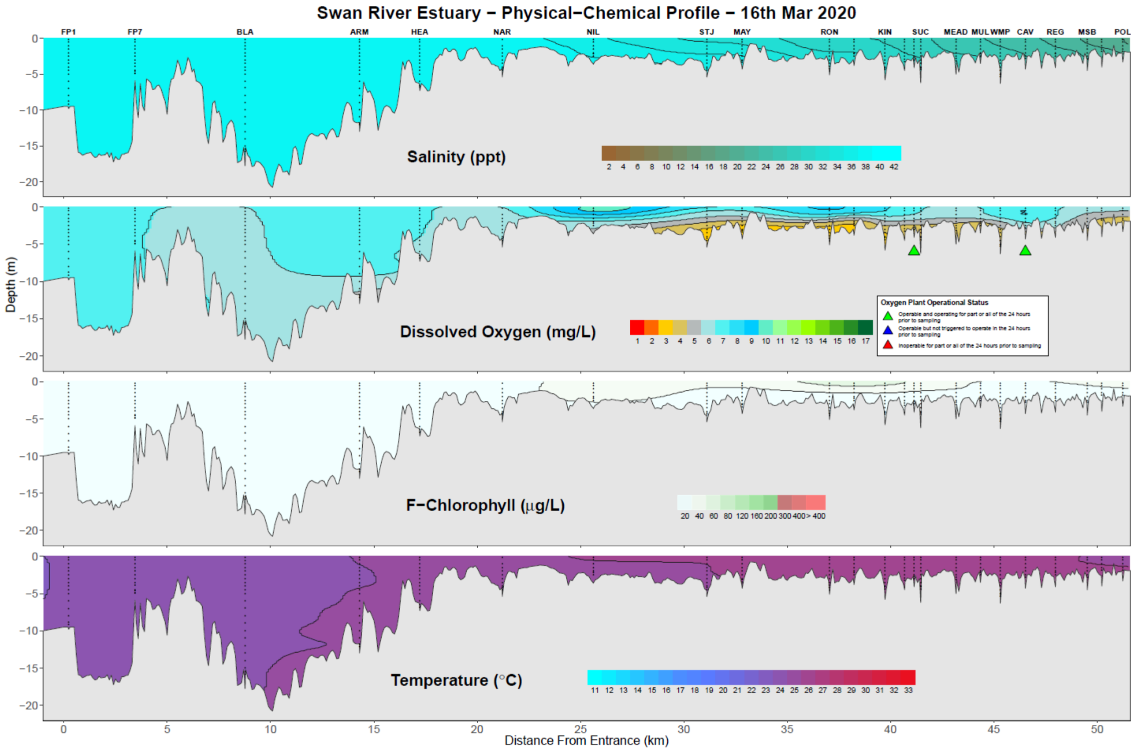

Swan River Estuary – Physical–Chemical Profile – 10th Feb 2020
FP1 FP7 BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEAD MUL WMP CAV REG MSB POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

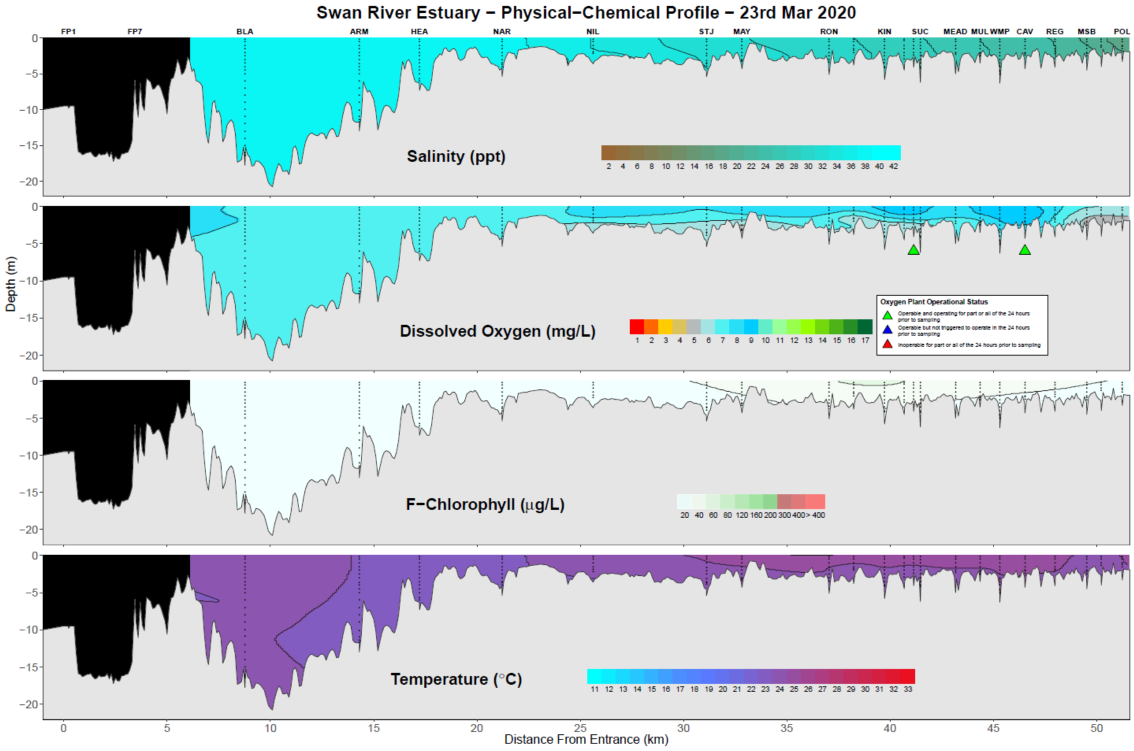

Swan River Estuary – Physical–Chemical Profile – 17th Feb 2020
FP1 FP7 BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEAD MUL WMP CAV REG MSB POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

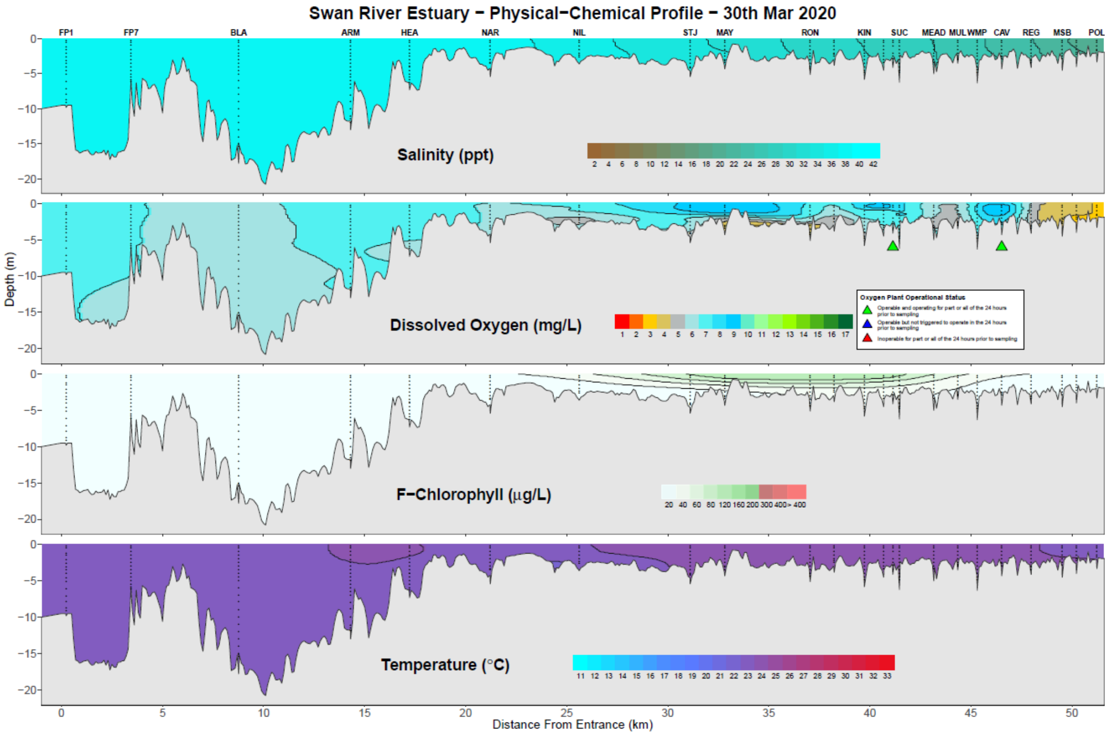

Swan River Estuary – Physical–Chemical Profile – 24th Feb 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

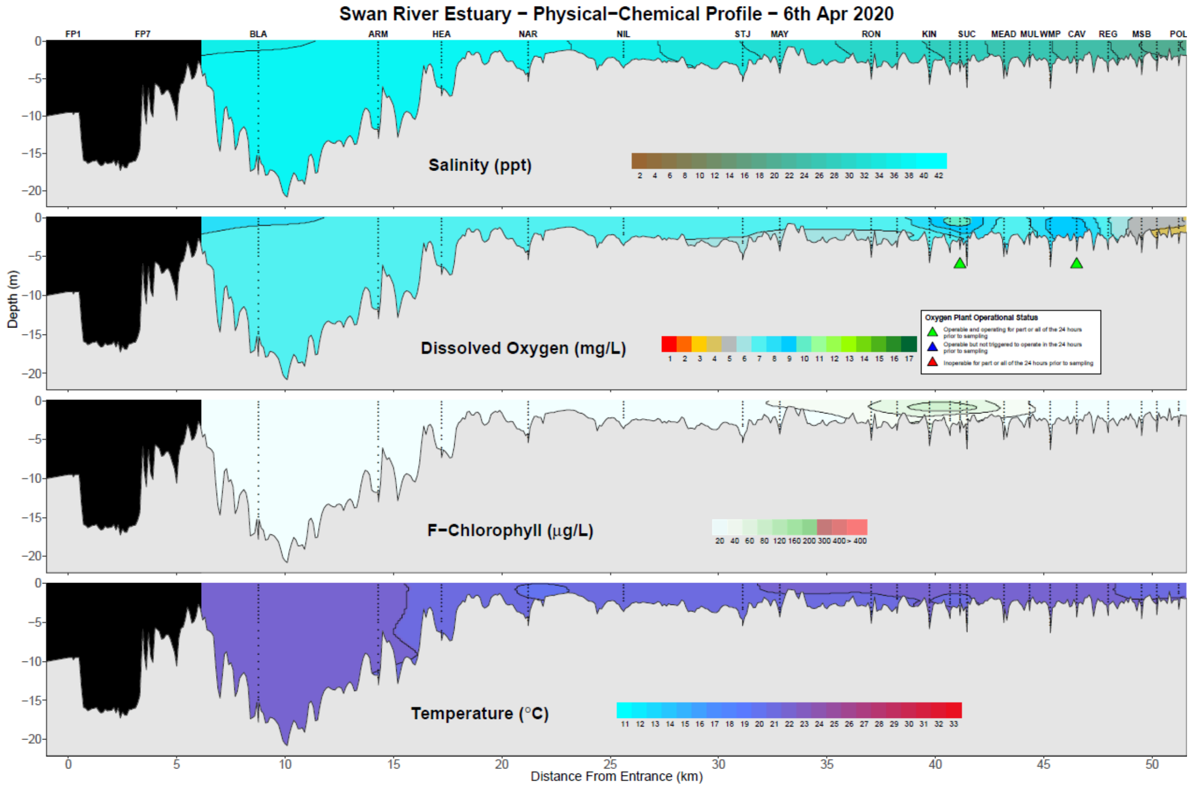

Swan River Estuary – Physical–Chemical Profile – 3rd Mar 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

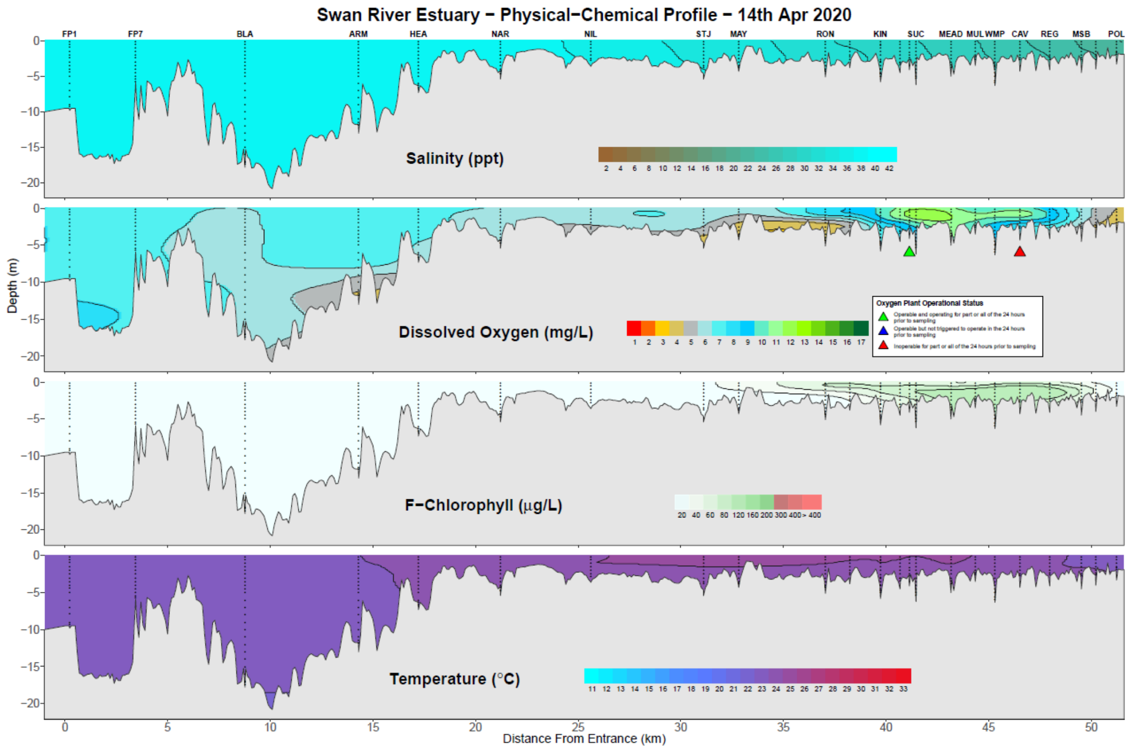

Swan River Estuary – Physical–Chemical Profile – 9th Mar 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

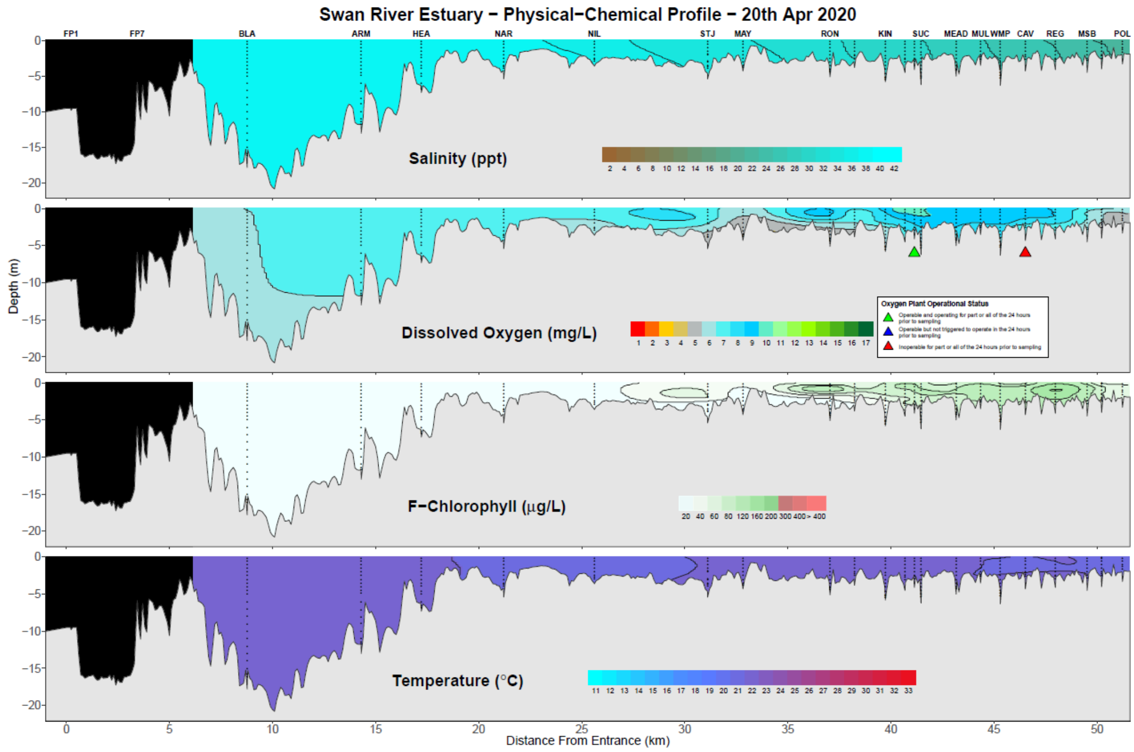

Swan River Estuary – Physical–Chemical Profile – 16th Mar 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

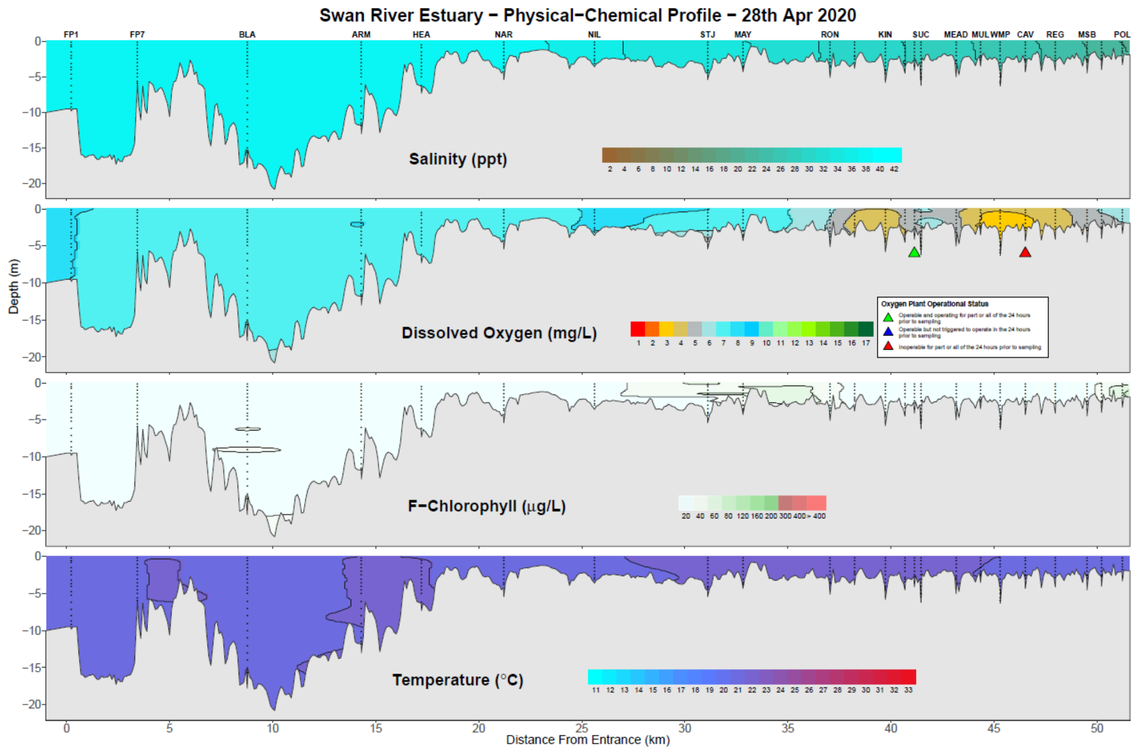

Swan River Estuary − Physical−Chemical Profile − 23rd Mar 2020
FP1 FP7 BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEAD MUL WMP CAV REG MSB POL
Salinity (ppt)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Dissolved Oxygen (mg/L)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
20 40 60 80 120 160 200 300 400 > 400
Temperature (°C)
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Depth (m)
Distance From Entrance (km)


Swan River Estuary − Physical−Chemical Profile − 30th Mar 2020
FP1 FP7 BLA ARM HEA NAR NIL STJ MAY RON KIN SUC MEAD MUL WMP CAV REG MSB POL
Salinity (ppt)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Dissolved Oxygen (mg/L)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
20 40 60 80 120 160 200 300 400 > 400
Temperature (°C)
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Depth (m)
Distance From Entrance (km)

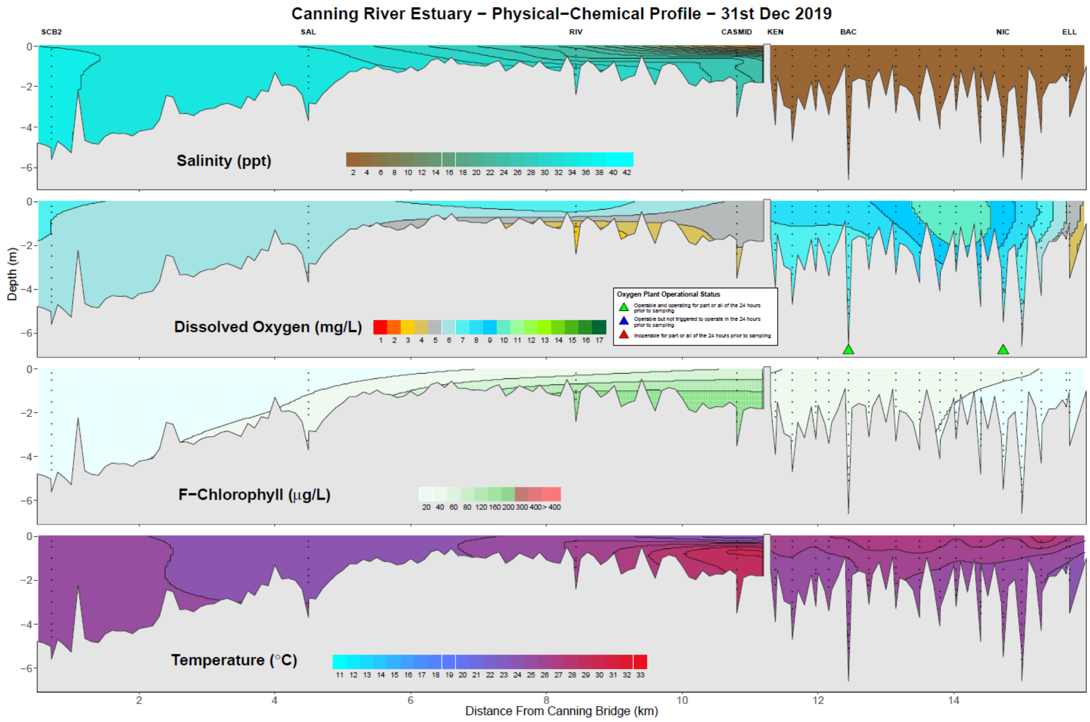

Swan River Estuary − Physical−Chemical Profile − 6th Apr 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

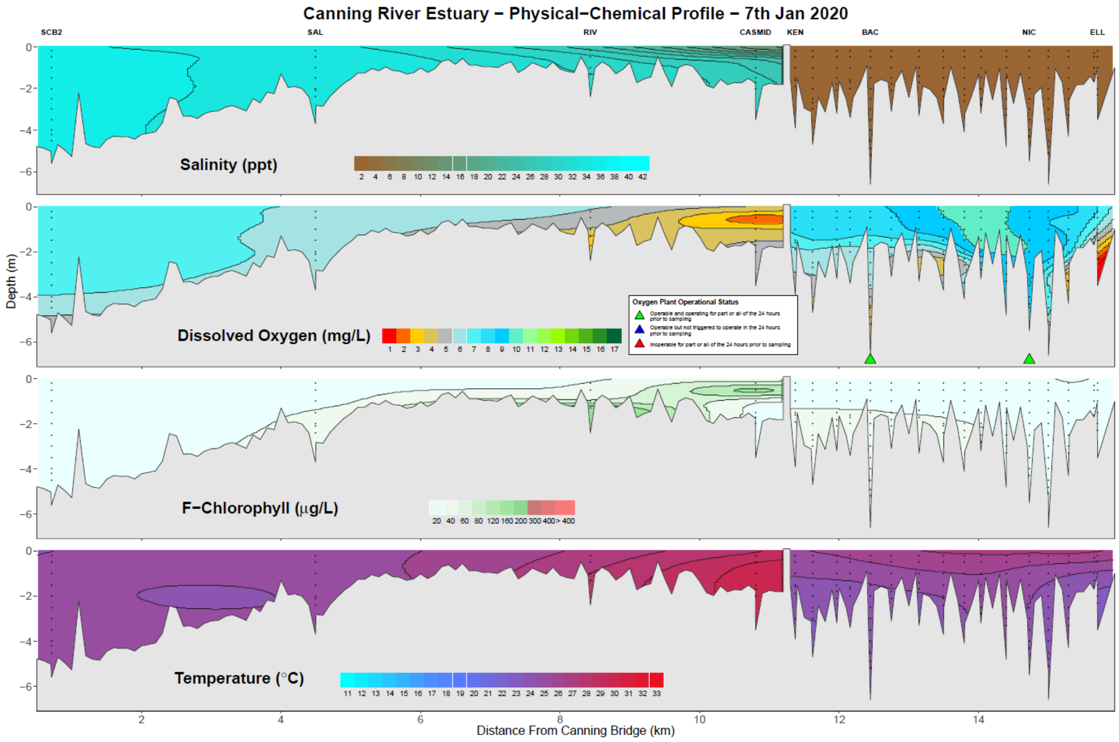

Swan River Estuary − Physical−Chemical Profile − 14th Apr 2020
FP1
FP7
BLA
ARM
HEA
NAR
NIL
STJ
MAY
RON
KIN
SUC
MEAD
MUL
WMP
CAV
REG
MSB
POL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)

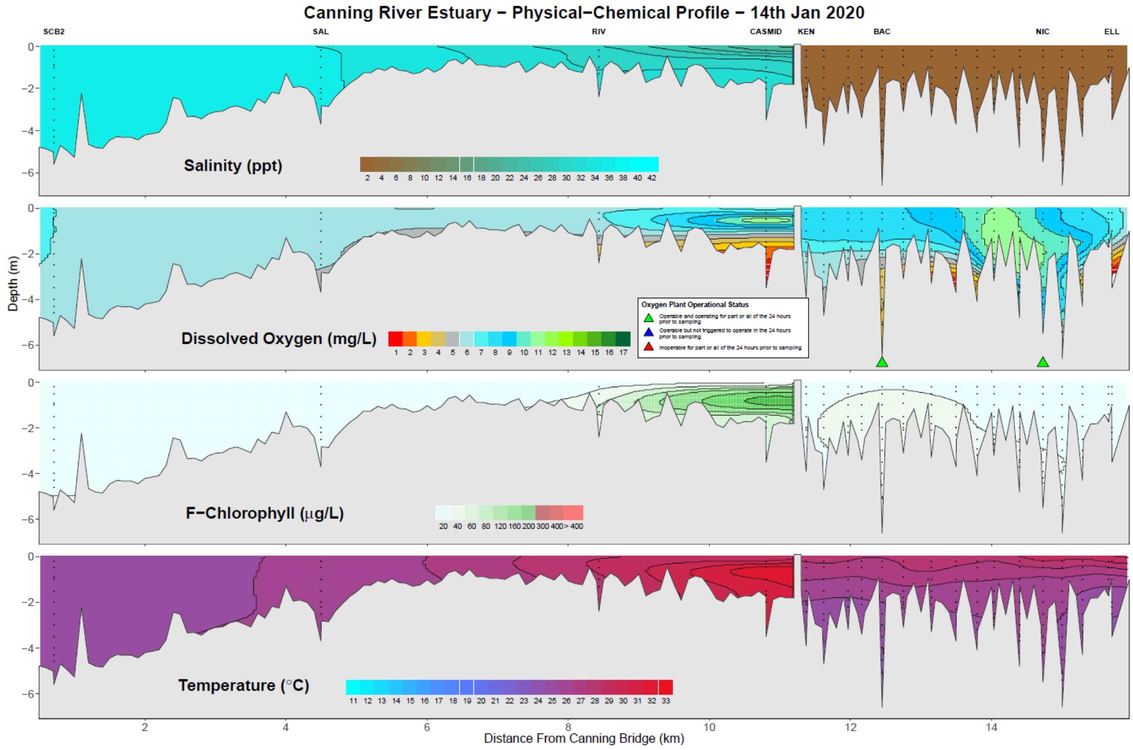

Swan River Estuary – Physical–Chemical Profile – 20th Apr 2020
Salinity (ppt)
Dissolved Oxygen (mg/L)
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)
Oxygen Plant Operational Status

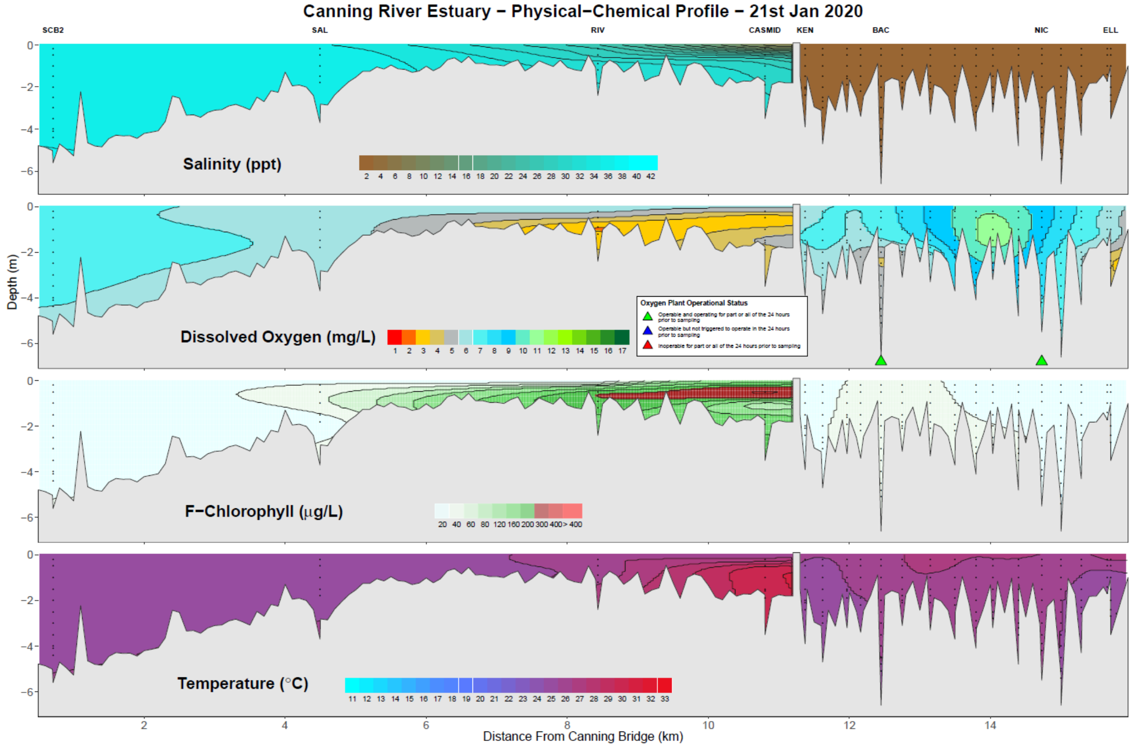

Swan River Estuary – Physical–Chemical Profile – 28th Apr 2020
Salinity (ppt)
Dissolved Oxygen (mg/L)
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Entrance (km)
Oxygen Plant Operational Status

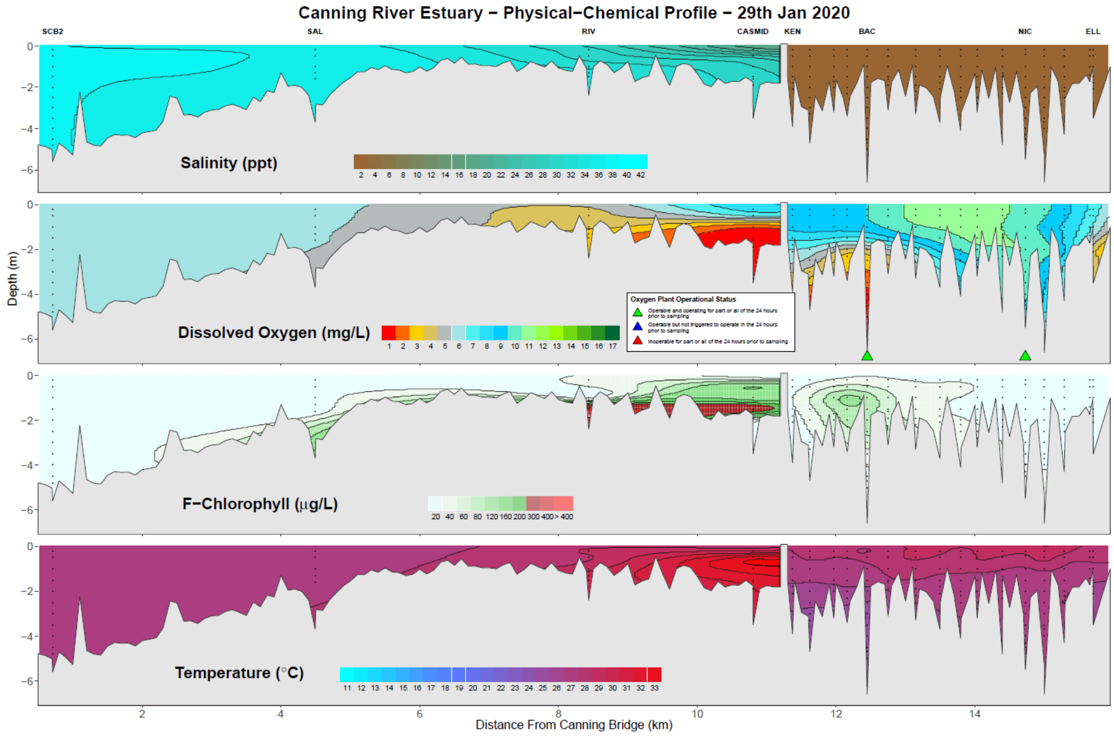
CE zone in summer through autumn 2020.

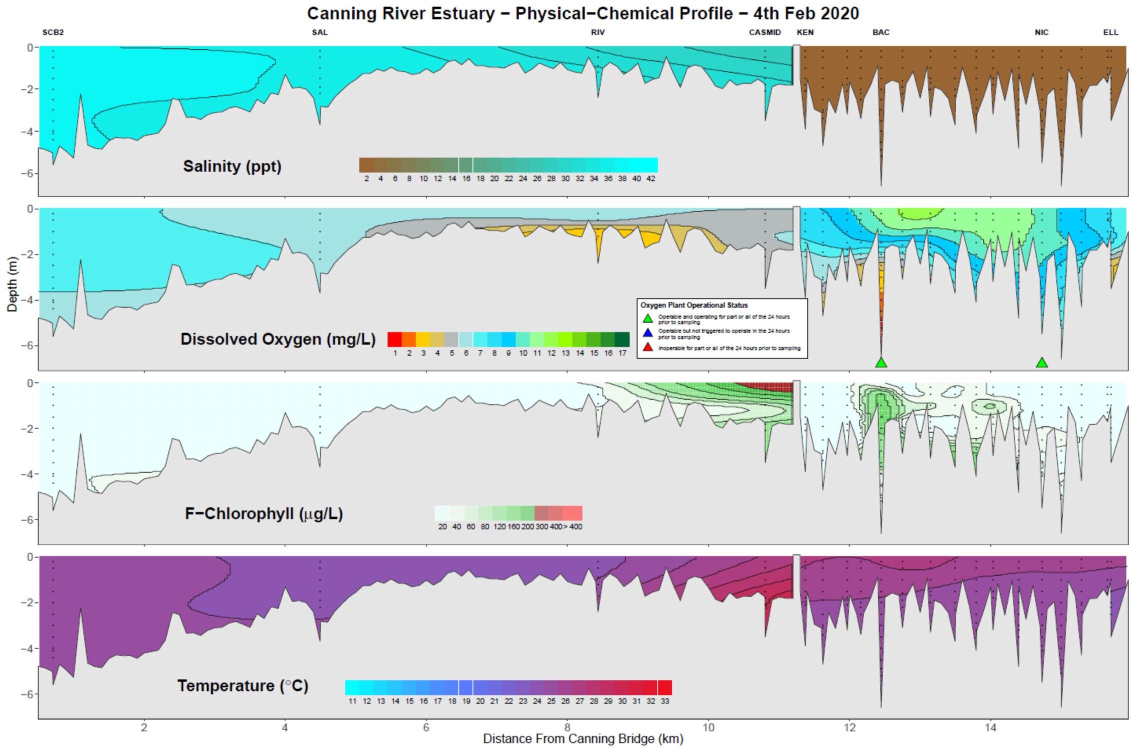


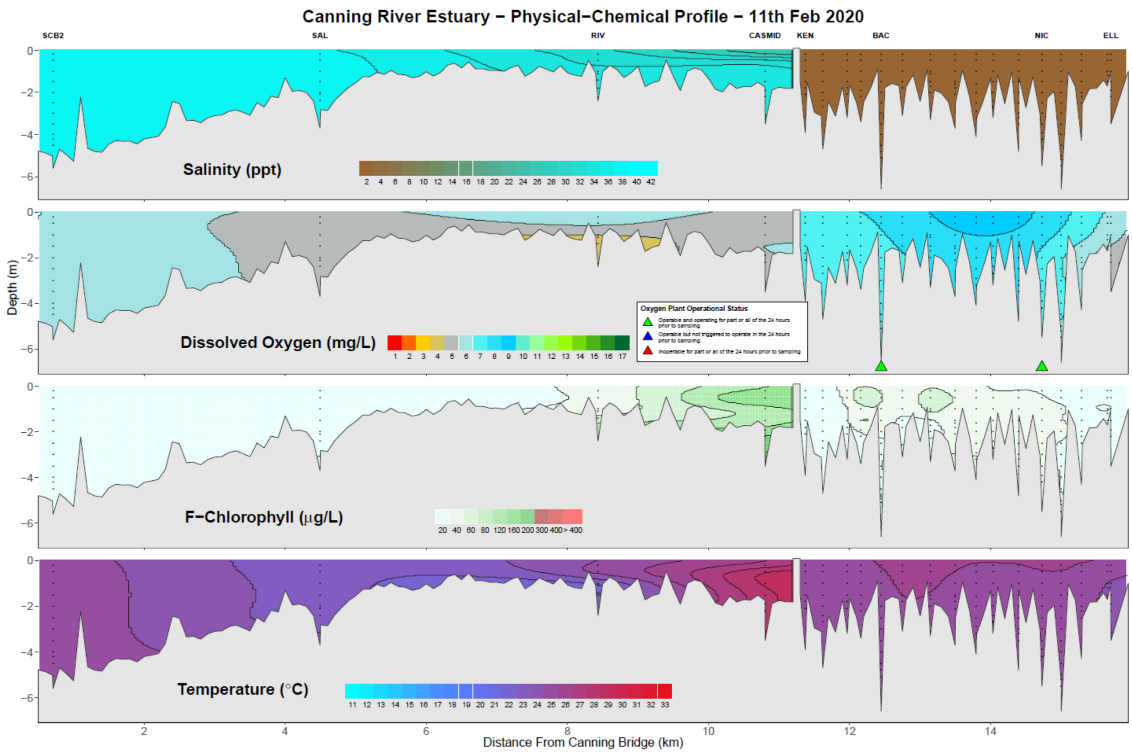


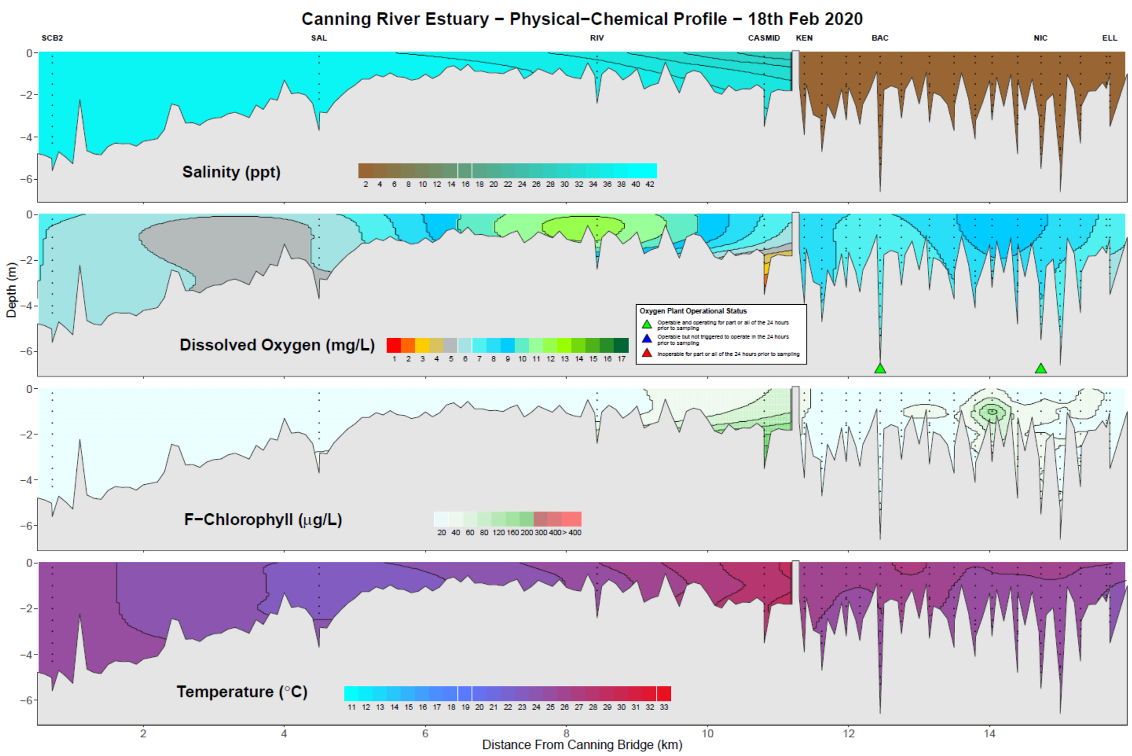

Canning River Estuary − Physical−Chemical Profile − 14th Jan 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

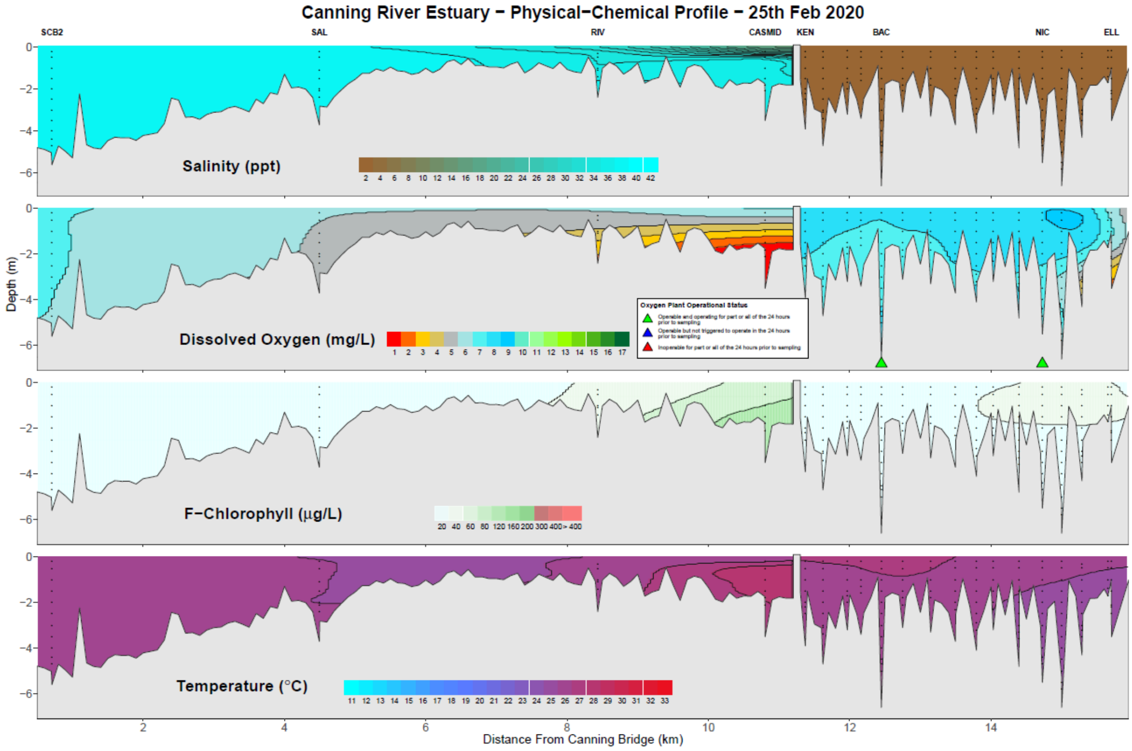

Canning River Estuary − Physical−Chemical Profile − 21st Jan 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

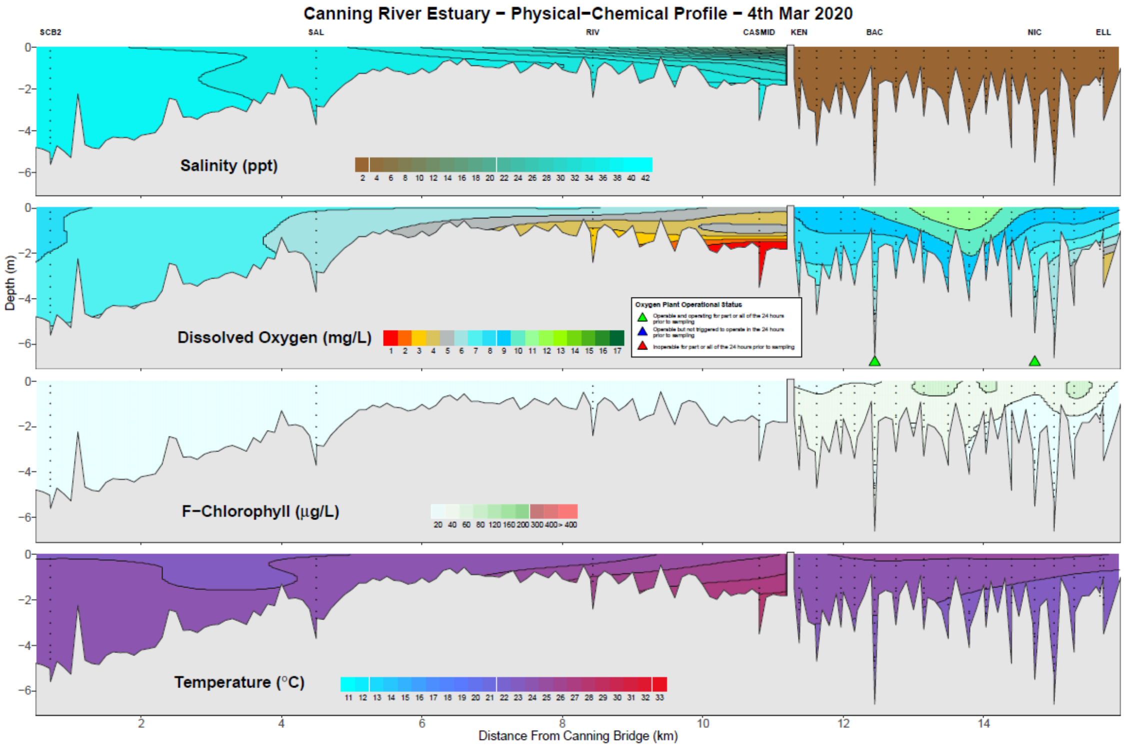

Canning River Estuary − Physical−Chemical Profile − 29th Jan 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

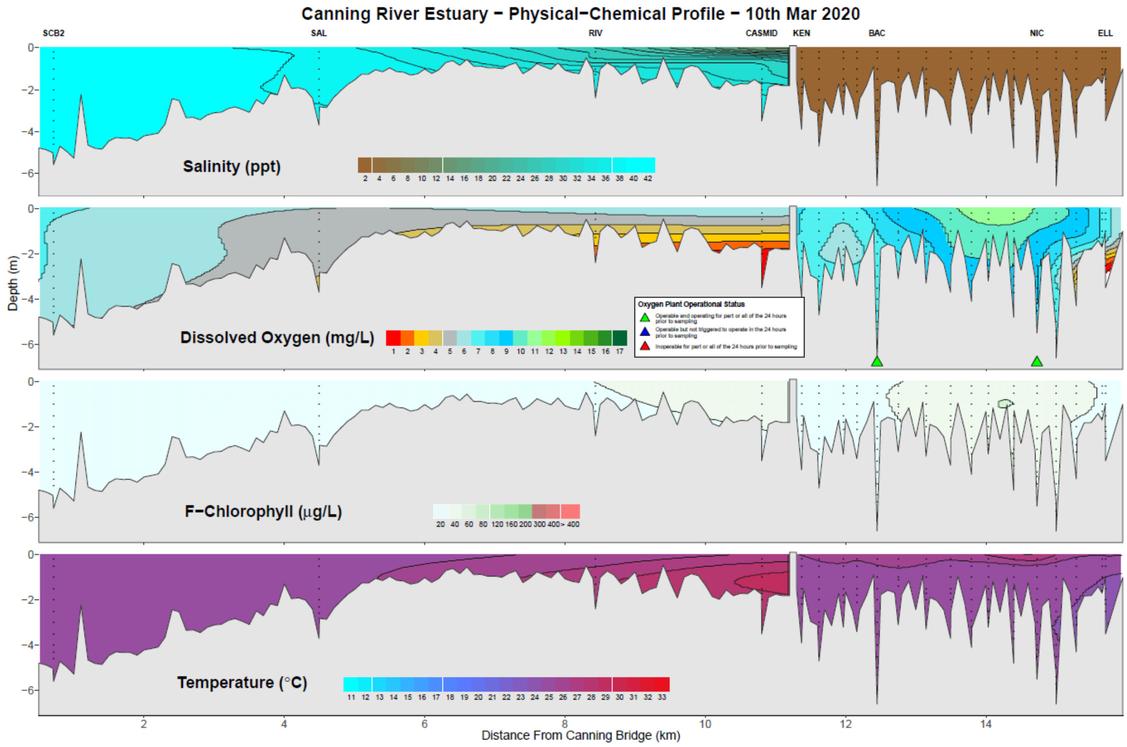

Canning River Estuary − Physical−Chemical Profile − 4th Feb 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

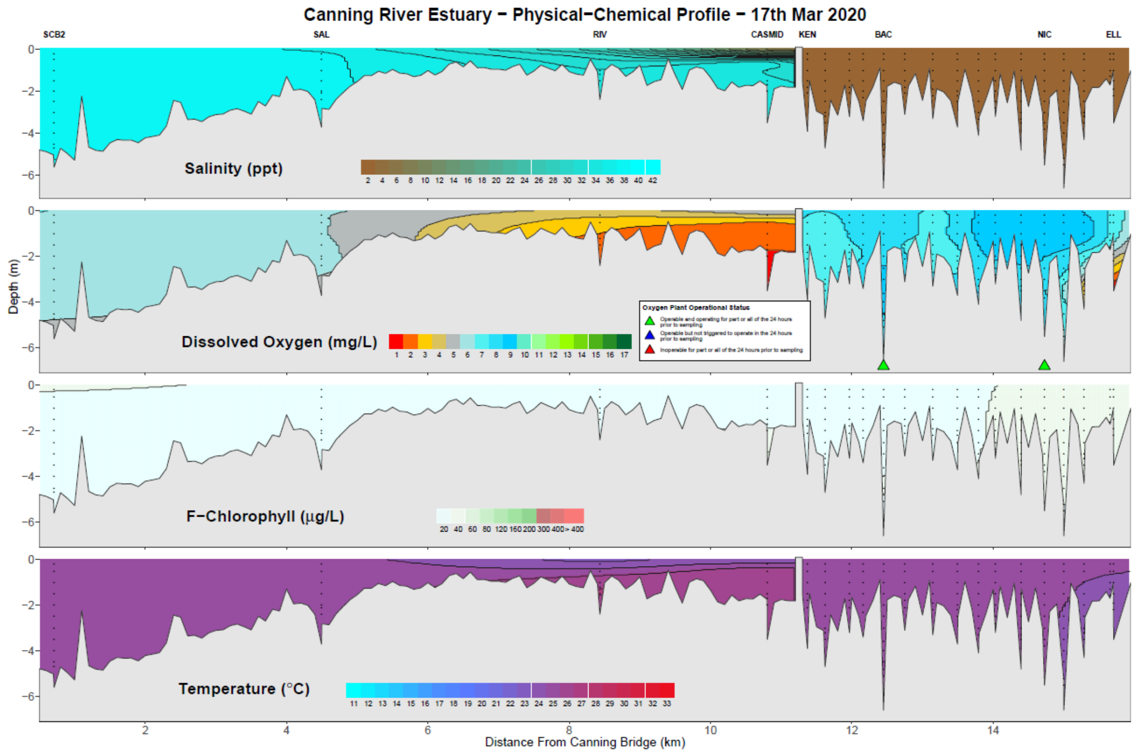

Canning River Estuary – Physical–Chemical Profile – 11th Feb 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

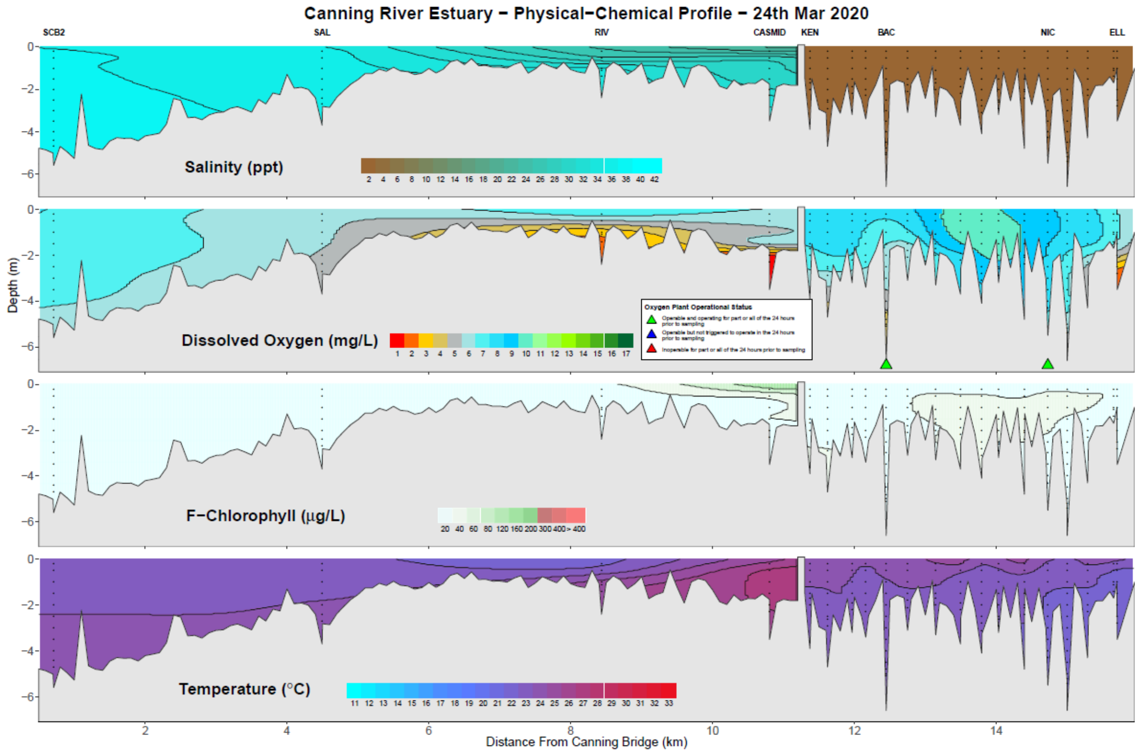

Canning River Estuary – Physical–Chemical Profile – 18th Feb 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

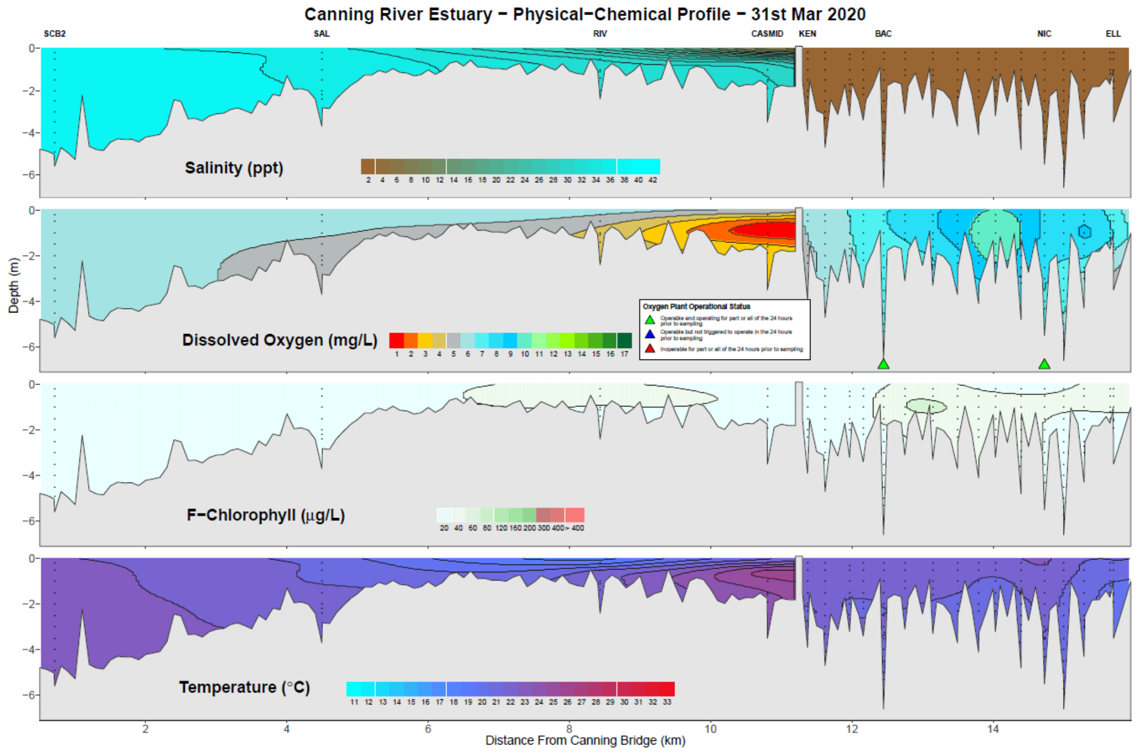

Canning River Estuary – Physical–Chemical Profile – 25th Feb 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Depth (m)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Distance From Canning Bridge (km)

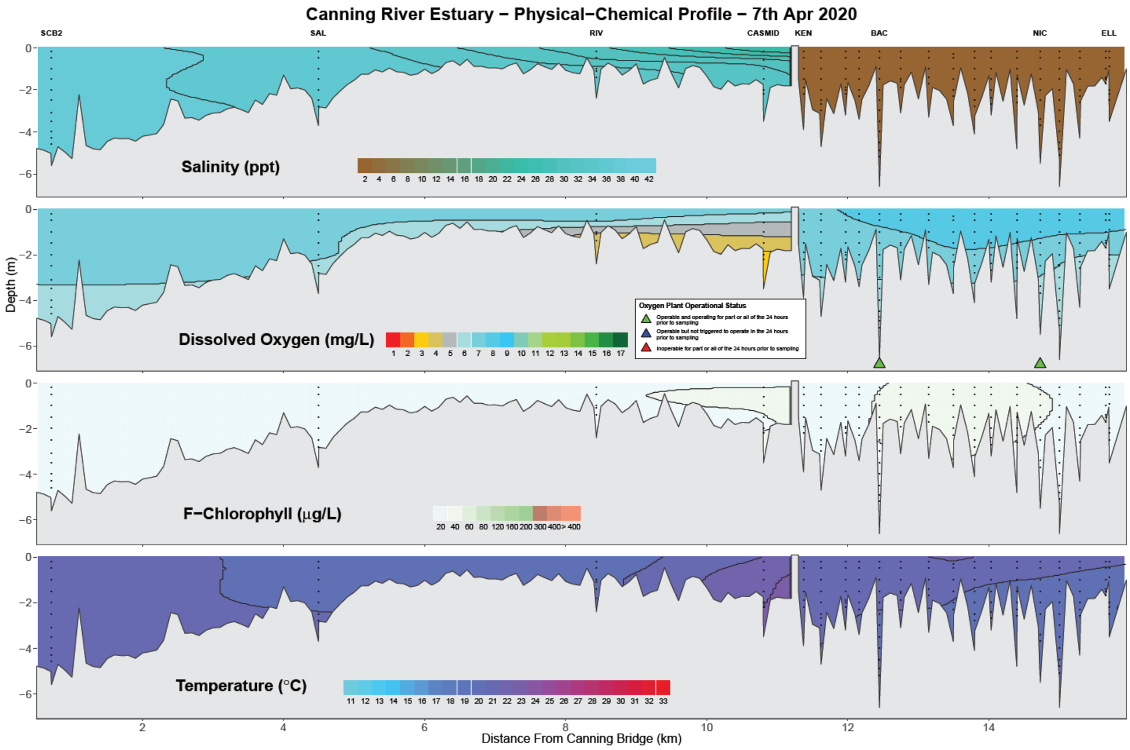

Canning River Estuary – Physical–Chemical Profile – 4th Mar 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Depth (m)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Distance From Canning Bridge (km)

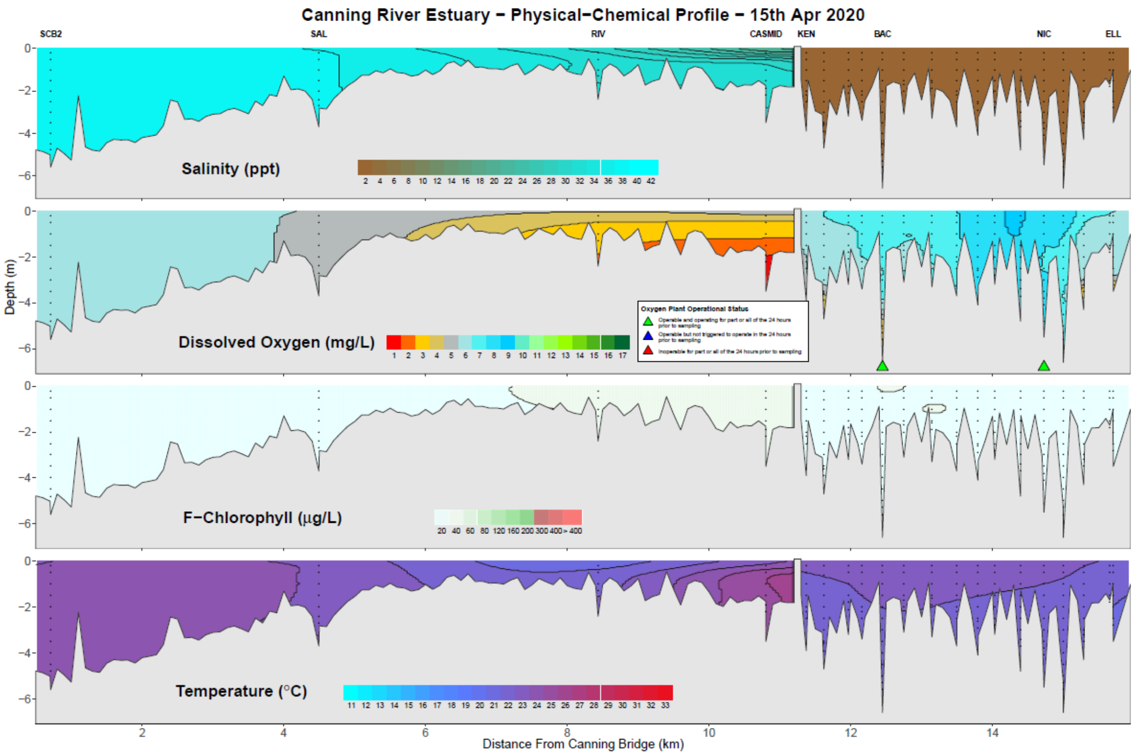

Canning River Estuary − Physical−Chemical Profile − 10th Mar 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

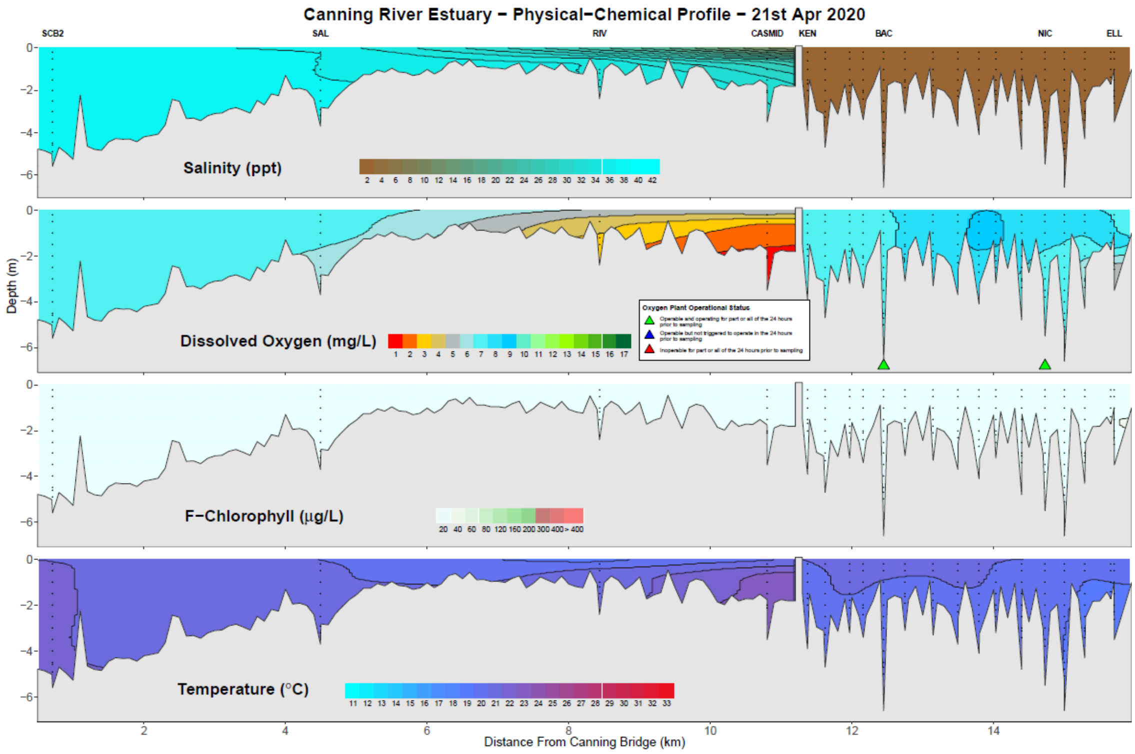

Canning River Estuary − Physical−Chemical Profile − 17th Mar 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F−Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)

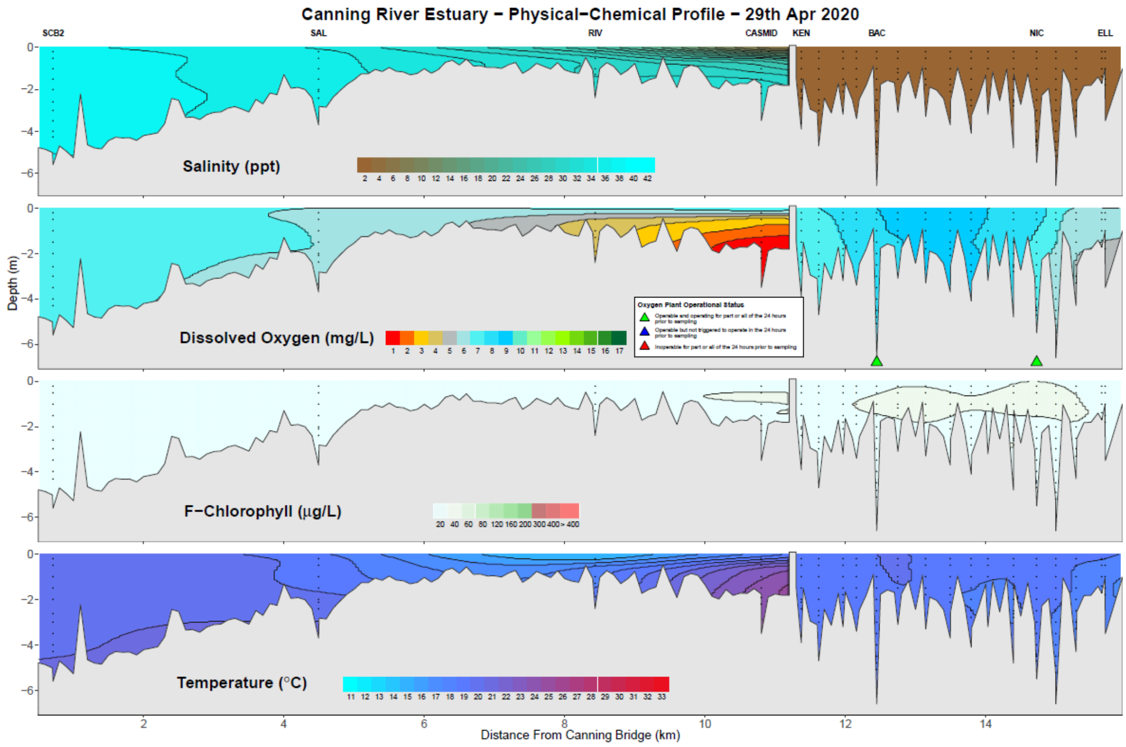

Canning River Estuary – Physical–Chemical Profile – 24th Mar 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)


Canning River Estuary – Physical–Chemical Profile – 31st Mar 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)


Canning River Estuary – Physical–Chemical Profile – 7th Apr 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)


Canning River Estuary – Physical–Chemical Profile – 15th Apr 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)


Canning River Estuary – Physical–Chemical Profile – 21st Apr 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)


Canning River Estuary – Physical–Chemical Profile – 29th Apr 2020
SCB2
SAL
RIV
CASMID
KEN
BAC
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)
Oxygen Plant Operational Status
F–Chlorophyll (µg/L)
Temperature (°C)
Depth (m)
Distance From Canning Bridge (km)