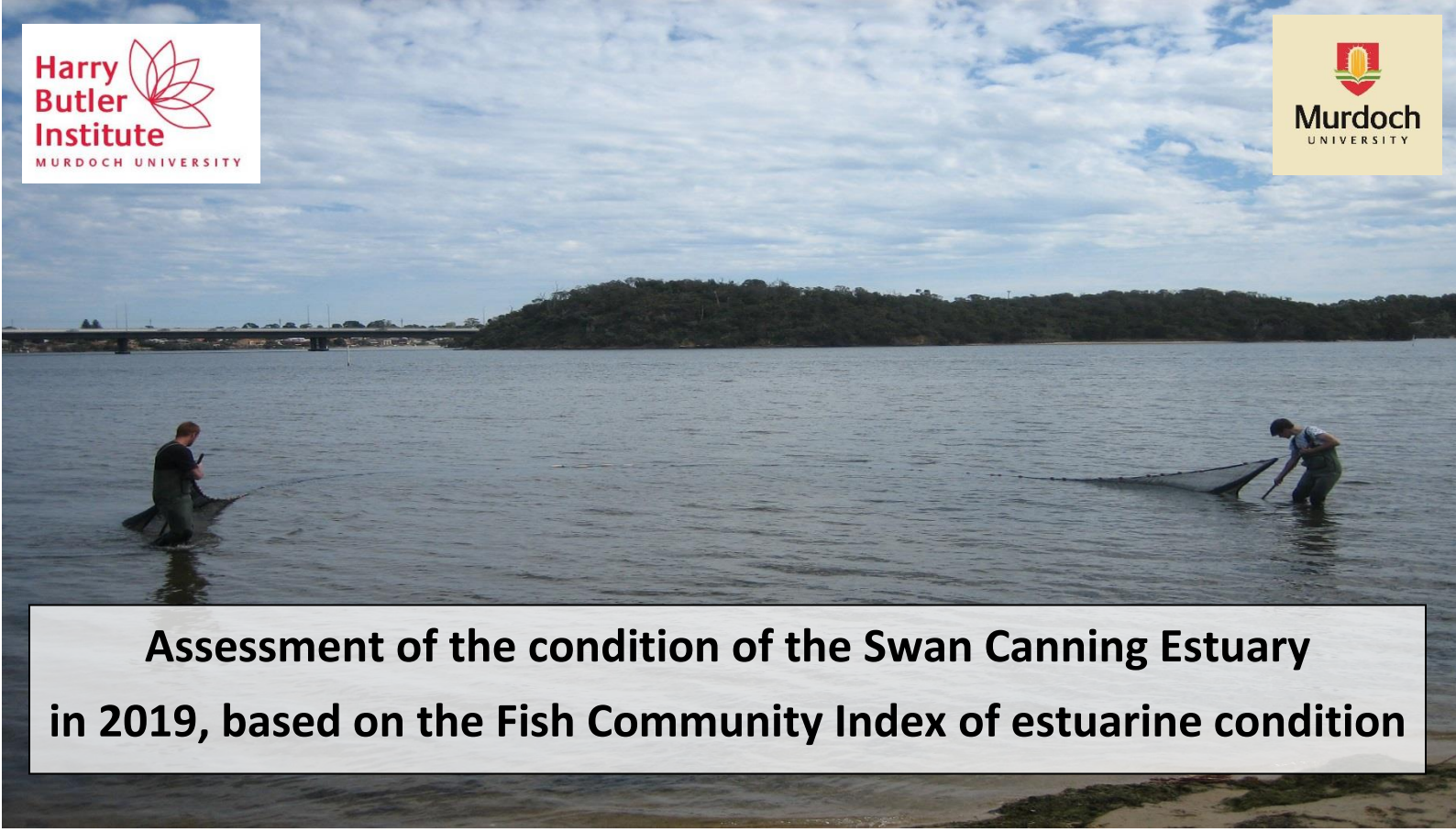

Assessment of the condition of the Swan Canning Estuary in 2019, based on the Fish Community Index of estuarine condition

2019

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Final Report

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–September 2019, 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 2019 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 (Lower Swan Canning Estuary, LSCE; Canning Estuary, CE; Middle Swan Estuary, MSE; Upper Swan Estuary, USE) during summer and autumn of 2019. 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 condition (C) during 2019, 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 broadly fair (C) condition in summer, with the exception of the USE, whose condition in summer was good (B).

Small-bodied, schooling species of hardyheads (Atherinidae) and gobies (Gobiidae) once again dominated catches from the nearshore waters of the estuary in 2019, constituting the five 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 2019 monitoring period. Other abundant species of small, schooling fish included the Elongate hardyhead, Mugil's hardyhead and Sandy sprat, which prefer more saline waters, the Bluespot goby in the CE and USE, Red-spot goby in the MSE, and Southwestern goby 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 23 species in the LSCE to 16 species in the USE.

Offshore fish communities

Overall, the offshore waters of the estuary were also in fair (C) condition during 2019, reflecting the lack of any widespread or severe hypoxia (low dissolved oxygen) during this year's monitoring period. A decline in condition of the offshore waters of the MSE was observed between summer and

autumn and may reflect the presence of dinoflagellate blooms at that time. The CE scored comparatively poorly relative to other zones in both seasons, consistent with monitoring results observed since 2012, and additional information is needed to explain this trend.

As in the seven previous years of monitoring, Perth herring was among the dominant species in offshore waters from all four zones, comprising 46–90% of the total catches. The Southern eagle ray (*Myliobatis tenuicaudata*) was abundant in the LSCE (23% of the catch) and Yellowtail grunter (*Amniataba caudavittata*) and Black bream (*Acanthopagrus butcheri*) in the USE (14–18%).

Overall

In summary, and across the estuary as a whole, the ecological condition of both nearshore and offshore waters in 2019 was assessed as fair (C), based on their fish communities. These results are consistent with the relatively stable trends in condition that have been observed since 2011.

Overall, the offshore waters of the CE exhibited the lowest scores of any zone in 2019. Since the start of regular fish community monitoring in 2012, 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), and some additional monitoring may be necessary moving forward to better understand the factors underlying this trend.

Assessment of the condition of the Swan Canning Estuary in 2019, 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). The development and rationale of the FCI, along with its implementation and outcomes to date, are summarized in Hallett et al. (2019).

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 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 Riverpark during 2019 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 the broader estuarine reporting framework of the Department of Biodiversity, Conservation and Attractions.

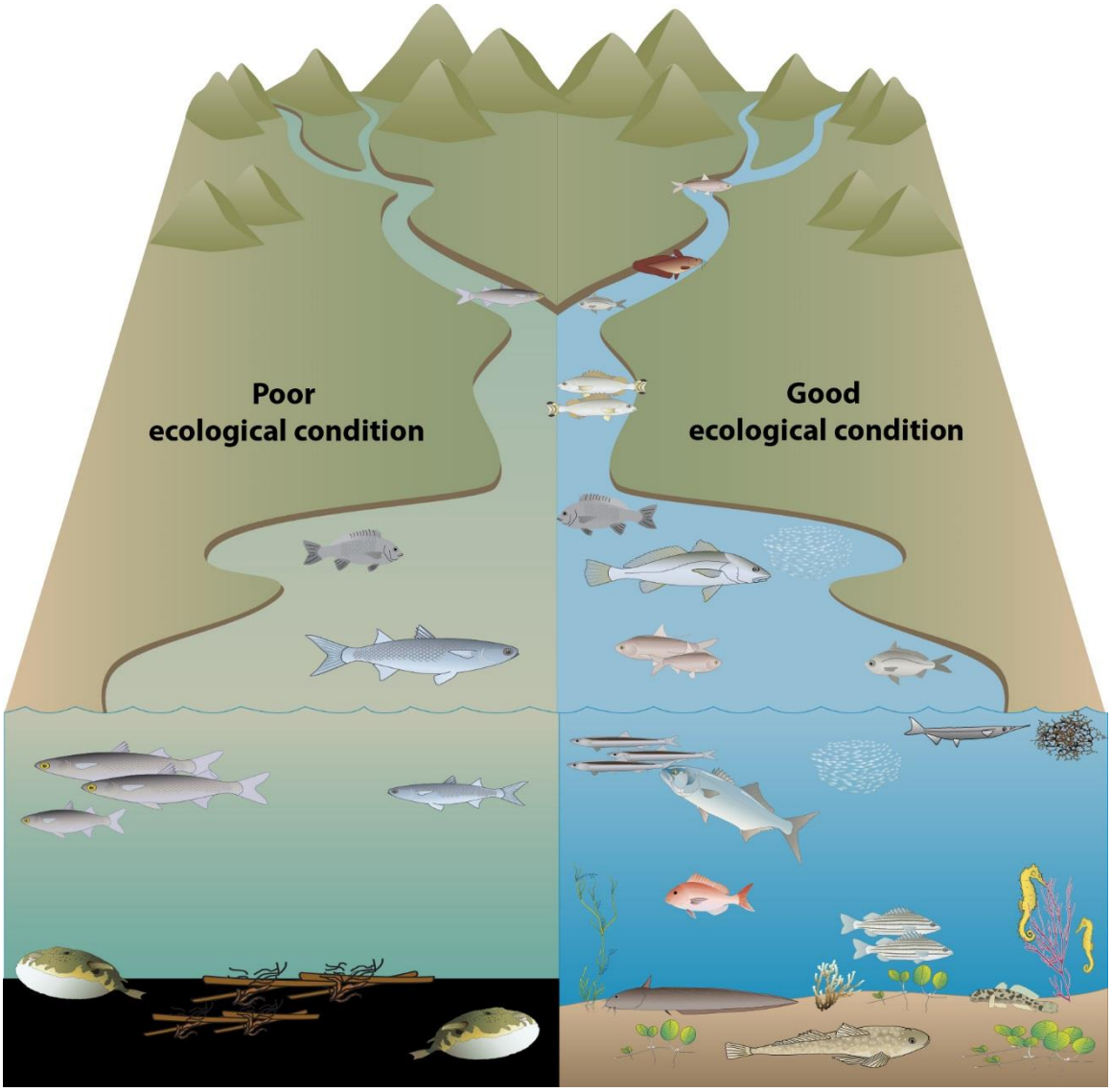


Figure 1. Conceptual diagram illustrating the predicted responses of the estuarine fish community to situations of poor and good ecological condition. (Images courtesy of the Integration and Application Network [ian.umces.edu/symbols/].)

4. Methods

Fish communities were sampled at six nearshore and six offshore sites in each of 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 and autumn) of 2019. In summer, logistical issues meant that the CE was sampled during January (9^{th} – 15^{th}), the MSE and USE in mid-February (12^{th} – 19^{th}) and the LSCE in early March (6^{th} – 7^{th}), whereas

all autumn sampling was completed in April (2nd – 22nd). All sampling was conducted under permits approved by Murdoch University's animal ethics committee (permit number R3000-17) and the Department of Primary Industries and Regional Development, Fisheries Division (exemption number 3032).

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, euthanased 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 2019 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.

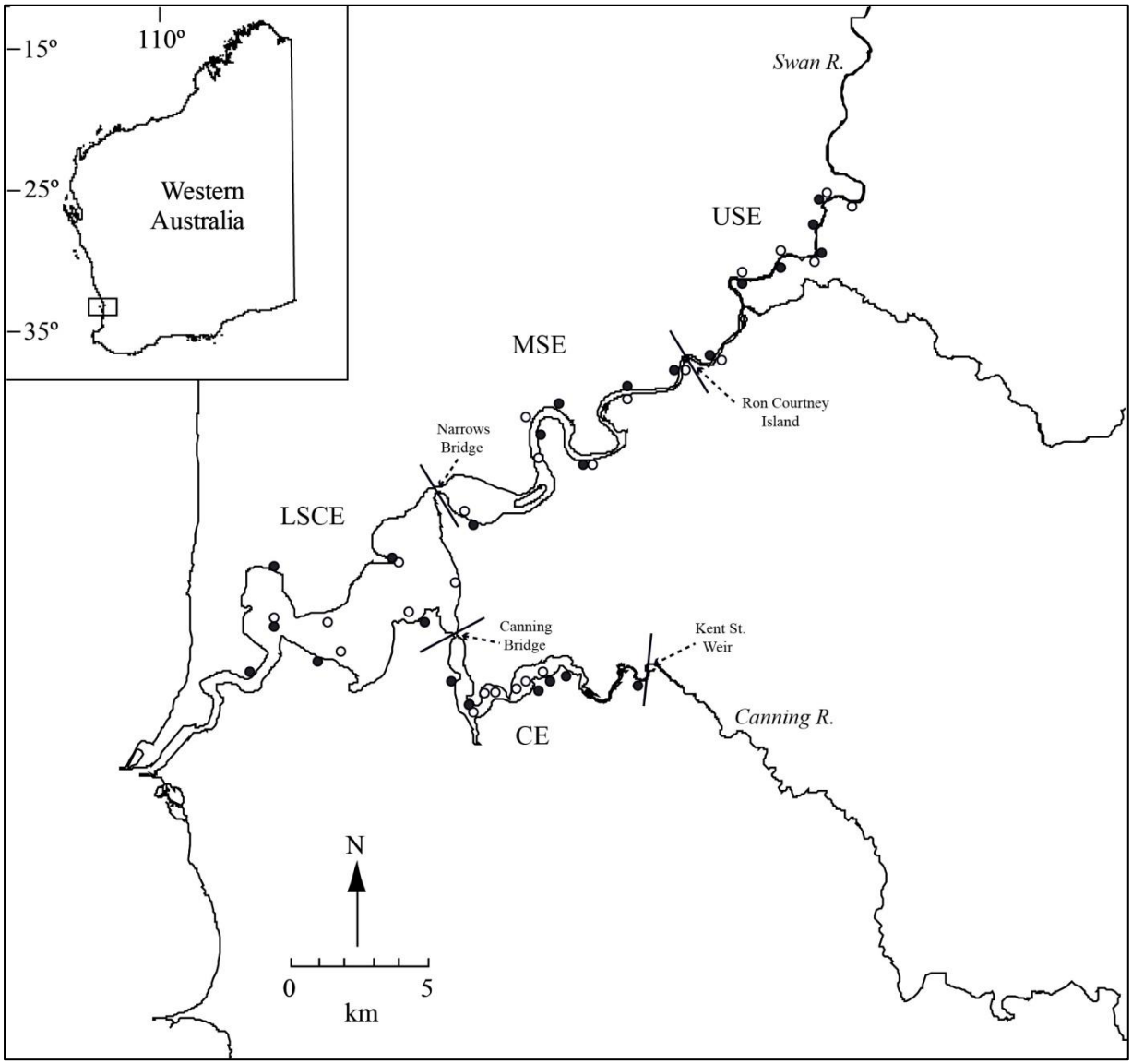


Figure 2. Locations of nearshore (black circles) and offshore (open circles) sampling sites for the Fish Community Index of estuarine condition. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

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 Steeg Hoeksema, Jen Eliot and Kerry Trayler, DBCA).

5. Results and discussion

5.1 Context: water quality and environmental conditions during the 2019 monitoring period

The environmental conditions present in the system during the monitoring period are shown as 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 (Appendix iv). The water column of the USE was brackish (salinity <18) in early January 2019. Pockets of low dissolved oxygen occurred throughout the MSE and USE during January and February, associated with a halocline. Dinoflagellate blooms of *Karlodinium* sp. and *Alexandrium* sp. were present in the MSE and USE in summer and autumn. By early April, more marine conditions (i.e. salinities of 26-36) had penetrated upstream into the MSE, with less evidence of low dissolved oxygen in the bottom waters.

Throughout summer sampling of the CE in January, the water column of the upper part of this zone was stratified by freshwater flows overlying denser, saltier water, with the resultant lack of mixing of these waters producing hypoxic conditions (low dissolved oxygen; <2mg/L). Similar conditions were evident during autumn sampling of the CE in early April (Appendix iv).

5.2 The fish community of the Swan Canning Estuary during 2019

Overall, the nearshore and offshore fish communities of the Swan Canning Estuary in 2019 were similar in composition to previous years (2012−2018). An estimated 21,637 fish, belonging to 30 species, were caught in seine net samples collected from the nearshore waters of the Swan Canning Estuary during summer and autumn 2019. 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 23 species in the LSCE to 16 species in the USE (Table 3).

The hardyheads (Atherinidae) and gobies (Gobiidae) once again dominated catches from the nearshore waters of the estuary in 2019, with the five 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 26–66% 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 2019 monitoring period. In contrast, the LSCE was dominated by two other atherinids, *Atherinosoma elongata* and *Craterocephalus mugiloides,* as well as the Sandy sprat (*Hyperlophus vittatus*), all of which prefer more saline waters. Other abundant species included the Bluespot goby (*Pseudogobius olorum*) in the CE and USE, Red-spot goby (*Favonigobius punctatus*) in the MSE, and Southwestern goby (*Afurcagobius suppositus*) in the USE, each of which comprised ~6–15% of the catches in each zone (Table 3).

Samples collected from offshore waters in summer and autumn 2019 using gill nets returned 1,560 fish, comprising 19 species (Table 4). The total number of species recorded from each zone declined upstream, from 14 in the LSCE to 8 in the USE. As in the seven previous years of monitoring, Perth herring (*Nematalosa vlaminghi*) was among the dominant species in offshore waters from all four zones, comprising 46–90% of the total catches (Table 4). The Southern eagle ray (*Myliobatis tenuicaudata*) was abundant in the LSCE (23% of the catch) and Yellowtail grunter (*Amniataba caudavittata*) and Black bream (*Acanthopagrus butcheri*) in the USE (14–18%).

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 2019. 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	0.7	0.4	**524.0**	**66.3**	**54.7**	**25.7**	**242.0**	**64.8**
Craterocephalus mugiloides	Mugil's hardyhead	**33.0**	**18.6**	**78.0**	**9.9**	**60.1**	**28.2**	12.3	3.3
Pseudogobius olorum	Blue-spot goby	0.2	0.1	**82.8**	**10.5**	15.9	7.5	**55.0**	**14.7**
Afurcagobius suppositus	Southwestern goby	-	-	24.1	3.0	5.5	2.6	**21.9**	**5.9**
Atherinosoma elongata	Elongate hardyhead	**38.4**	**21.6**	12.6	1.6	-	-	-	-
Hyperlophus vittatus	Sandy sprat	**37.4**	**21.0**	-	-	-	-	-	-
Torquigener pleurogramma	Blowfish/Banded toadfish	16.6	9.3	5.1	0.6	14.1	6.6	0.2	0.1
Gambusia holbrooki	Mosquito fish *	-	-	13.4	1.7	1.1	0.5	17.2	4.6
Leptatherina presbyteroides	Presbyter's hardyhead/ silverfish	23.1	13.0	3.7	0.5	0.1	0.1	-	-
Favonigobius punctatus	Red-spot goby	0.2	0.1	3.6	0.5	**19.1**	**9.0**	3.7	1.0
Aldrichetta forsteri	Yellow-eye mullet	0.3	0.2	12.6	1.6	6.2	2.9	2.9	0.8
Amniataba caudavittata	Yellowtail grunter	1.2	0.7	13.5	1.7	2.7	1.3	2.7	0.7
Acanthopagrus butcheri	Black bream	0.1	0.1	2.4	0.3	9.5	4.5	5.4	1.4
Ostorhinchus rueppelli	Gobbleguts	9.6	5.4	1.9	0.2	3.4	1.6	-	-
Arenigobius bifrenatus	Bridled goby	<0.1	<0.1	4.5	0.6	6.3	2.9	0.7	0.2
Pelates octolineatus	Western striped grunter	4.7	2.7	-	-	5.5	2.6	-	-
Favonigobius lateralis	Long-finned goby	6.5	3.7	2.9	0.4	-	-	-	-
Atherinomorus vaigensis	Ogilby's hardyhead	3.2	1.8	<0.1	0.0	5.5	2.6	-	-
Engraulis australis	Southern anchovy	0.1	0.1	0.1	0.0	0.7	0.3	4.4	1.2
Gerres subfasciatus	Roach	-	-	2.3	0.3	1.2	0.5	1.8	0.5
Nematalosa vlaminghi	Perth herring	-	-	0.4	0.1	0.6	0.3	3.2	0.8
Sillago burrus	Western trumpeter whiting	0.5	0.3	1.1	0.1	0.4	0.2	-	-

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)									
Mugil cephalus	Sea mullet	<0.1	<0.1	1.0	0.1	0.2	0.1	0.3	0.1
Sillaginodes punctata	King George whiting	0.8	0.4	-	-	-	-	-	-
Gymnapistes marmoratus	Devilfish	0.3	0.2	-	-	-	-	-	-
Geophagus brasiliensis	Pearl cichlid *	-	-	0.22	<0.1	-	-	<0.1	<0.1
Scobinichthys granulatus	Rough leatherjacket	0.3	0.2	-	-	-	-	-	-
Sillago schomburgkii	Yellow-finned whiting	-	-	0.22	<0.1	-	-	-	-
Stigmatopora argus	Spotted pipefish	0.1	0.1	-	-	-	-	-	-
Sillago vittata	Western school whiting	-	-	-	-	0.1	0.1	-	-

	23 Species		**23 Species**		**21 Species**		**16 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
	178	**2,472**	**790**	**11,003**	**213**	**2,961**	**374**	**5,201**

Table 4. Compositions of the fish communities observed across the six offshore sites sampled in each zone of the Swan Canning Estuary during summer and autumn of 2019. 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	**8.8**	**45.9**	**24.5**	**70.7**	**31.8**	**89.5**	**25.3**	**62.6**
Amniataba caudavittata	Yellowtail grunter	-	-	**2.6**	**7.5**	0.8	2.1	**7.4**	**18.3**
Acanthopagrus butcheri	Black bream	-	-	0.6	1.7	**1.0**	**2.8**	**5.8**	**14.2**
Myliobatis tenuicaudatus	Southern eagle ray	**4.4**	**22.9**	0.1	0.2	**0.9**	**2.6**	-	-
Pomatomus saltatrix	Tailor	1.0	5.2	2.1	6.0	0.1	0.2	0.3	0.8
Pelates octolineatus	Western striped grunter	**1.8**	**9.5**	0.8	2.2	0.3	0.7	-	-
Mugil cephalus	Sea mullet	-	-	**2.6**	**7.5**	-	-	0.1	0.2
Platycephalus westraliae	Yellowtail flathead	0.9	4.8	0.6	1.7	0.4	1.2	-	-
Argyrosomus japonicus	Mulloway	-	-	-	-	-	-	1.3	3.3
Gerres subfasciatus	Roach	0.6	3.0	0.2	0.5	0.3	0.7	-	-
Cnidoglanis macrocephalus	Estuary cobbler	0.2	0.9	0.5	1.4	-	-	-	-
Sillago vittata	Western school whiting	0.6	3.0	-	-	-	-	-	-
Elops machnata	Giant herring	0.3	1.3	-	-	-	-	0.2	0.4
Carcharinas leucas	Bull shark	0.1	0.4	-	-	0.1	0.2	0.1	0.2
Sillago schomburgkii	Yellow-finned whiting	0.3	1.3	-	-	-	-	-	-
Sillago burrus	Western trumpeter whiting	0.2	0.9	-	-	-	-	-	-
Pseudocaranx dentex	Silver trevally	0.1	0.4	0.1	0.2	-	-	-	-
Rhabdosargus sarba	Tarwhine	-	-	0.2	0.5	-	-	-	-
Engraulis australis	Southern anchovy	0.1	0.4	-	-	-	-	-	-
		14 Species		**12 Species**		**9 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	**231**	**35**	**416**	**36**	**427**	**41**	**486**

5.3 Ecological condition in 2019

Nearshore waters

The ecological condition (based on fish communities) of the nearshore waters of the Riverpark was generally fair (C) throughout much of the monitoring period (Fig. 4). The condition of each zone was fair during summer (mean FCI scores 59–63), except for the USE, which exhibited good condition (B; mean FCI score of 71). Similarly, during autumn, the condition of each zone was fair, as was that of the estuary, on average.

Radar plots of the nearshore metric scores for each zone in each season revealed broadly similar patterns in summer and autumn (Fig. 5). Relatively high scores were evident for the positive metrics *Proportion of trophic specialists* and (with the exception of the LSCE) *Proportion of estuarine spawners*, and the negative metric *Proportion of detritivores,* indicating that fish communities were largely characterized by fish that spawn in the estuary and have specific feeding requirements, with relatively few fish that feed on decaying organic matter.

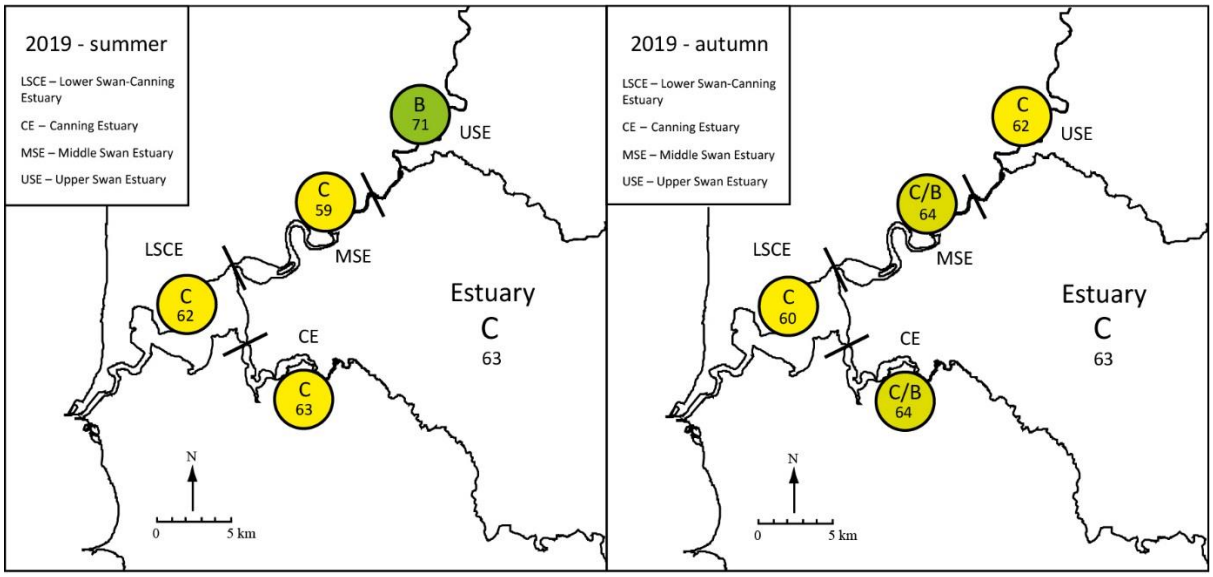
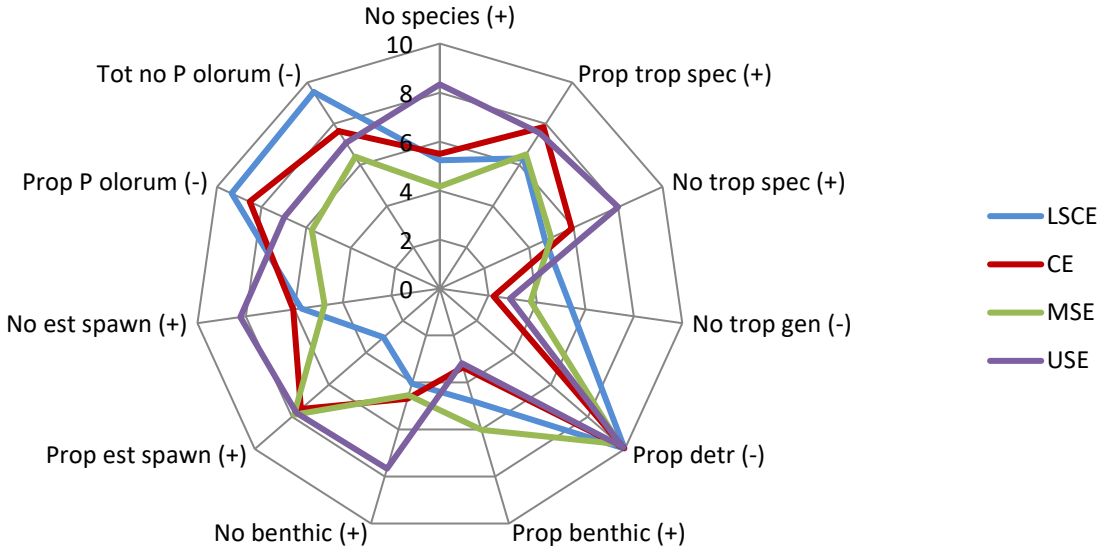


Figure 4. Average nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2019.

(a) Summer 2019



(b) Autumn 2019

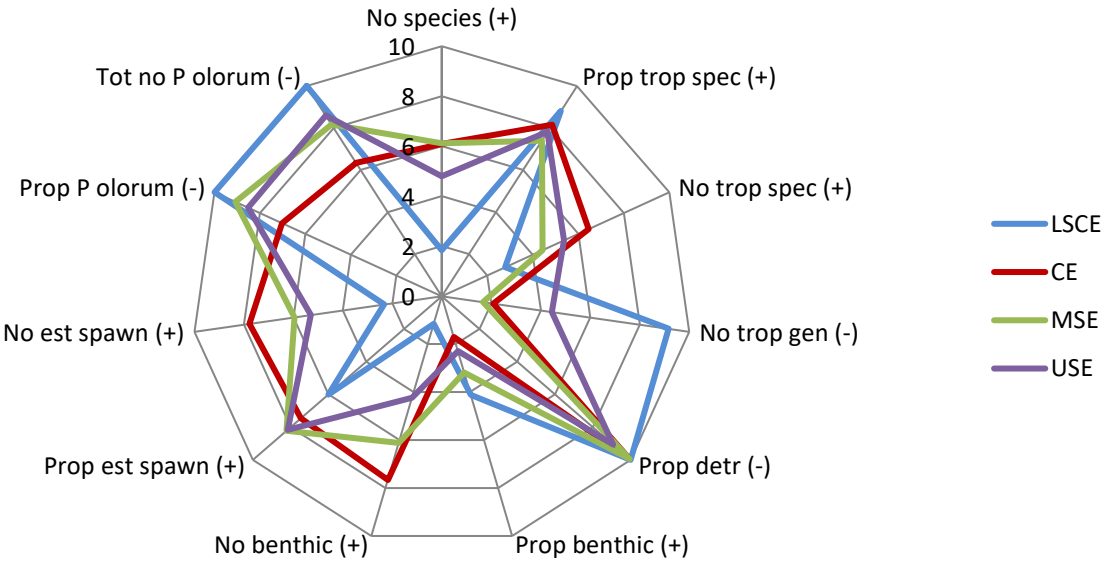


Figure 5. Average scores (0–10) for each component metric of the nearshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2019. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying 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) in the LSCE and USE during summer of 2019, yet fair (C) in the MSE and poor/fair in the CE (Fig. 6). During autumn, the condition of the LSCE and USE remained good, whilst that in the MSE and CE had declined to poor (D). In the case of the MSE, this may reflect the impact of a notable bloom of *Alexandrium* sp., a potentially harmful species of dinoflagellate. *Alexandrium* produces gonyautoxins and is associated with paralytic shellfish poisoning. The gonyautoxins produced by this algae can have acute and chronic impacts on zooplankton and fish, with toxins accumulating in zooplankton, shellfish and crabs (Global Invasive Species Database, 2019). *Alexandrium* was first detected at the Nile St sampling site in late January and spread both downstream (to the Heathcote site in the LSCE) and upstream (to the Powerlines site in USE). The MSE was affected over the longest period with peak integrated water samples of 9890 cells/mL in mid-March (Nile St). Oxygen levels were depleted in the MSE during the peak of the bloom, but this was short-lived (see Appendix iv). Highest densities of *Alexandrium* were also detected in the USE early April (6,994 cells/mL at the Middle Swan Bridge site). Densities of *Alexandrium* were generally lower in the LSCE, peaking at 104 cells/mL near the old Swan Brewery. The harmful algae, *Karlodinium* sp. was detected in both the MSE and USE during January to April, but densities remained below 4,000 cells/mL. No fish kills were observed between January and April.

Offshore condition in the CE zone was poor/fair in summer (D/C) and poor (D) in autumn, though there were no corresponding harmful algal blooms or low oxygen conditions detected in sampling to explain the change. This zone has been observed to exhibit periodic accumulations of benthic blue-green algae in summer to autumn months and it is possible that these may be influencing the fish communities, perhaps through their consumption of oxygen at night, or another as yet unidentified mechanism (pers. comm., Dr Kerry Trayler, DBCA; Dr James Tweedley, Murdoch University). Presently benthic algae is not monitored routinely in this or other parts of the Swan Canning Estuary.

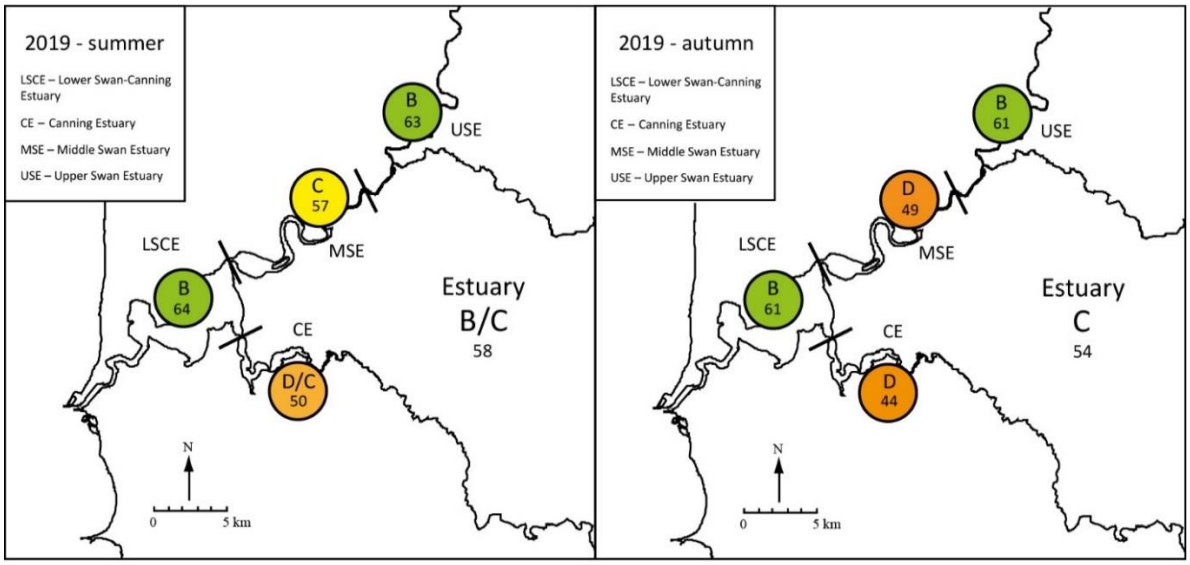


Figure 6. Average offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2019.

Radar plots of offshore metric scores for each zone in each season (Fig. 7) show that the decline in offshore FCI scores in the MSE from summer to autumn was driven by decreases in the number and diversity of species and the number of specialist feeders. This was indicated by lower average scores for *Number of species*, *Shannon-Wiener diversity*, and *Proportion of trophic specialists* (all positive metrics) during autumn. In contrast, the decline in condition of the CE was driven by decreases in the proportions of bottom-dwelling (benthic) species and those that spawn in the estuary, and an increase in the proportion of detritivores (Fig. 7).

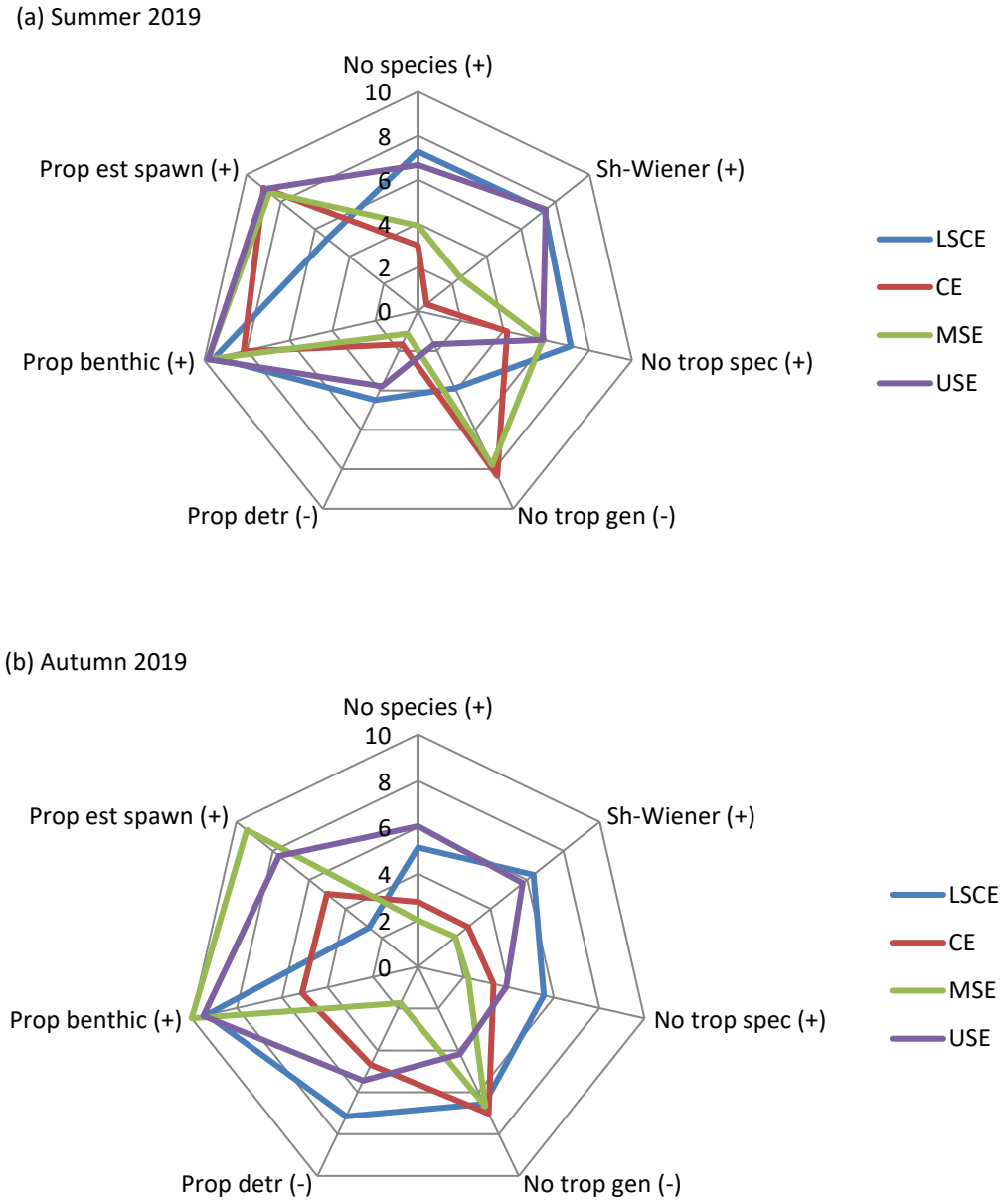


Figure 7. Average scores (0–10) for each component metric of the offshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2019. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying 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).

Longer term trends in ecological condition

Results indicate that the nearshore waters of the estuary as a whole were in fair condition (C) during 2019, consistent with the overall trend since 2011 (Fig. 8). Similarly, the mean offshore FCI score for the estuary as a whole indicated fair offshore condition during 2019 (Fig. 9), reflecting the lack of any widespread or severe hypoxia during this year's monitoring period.

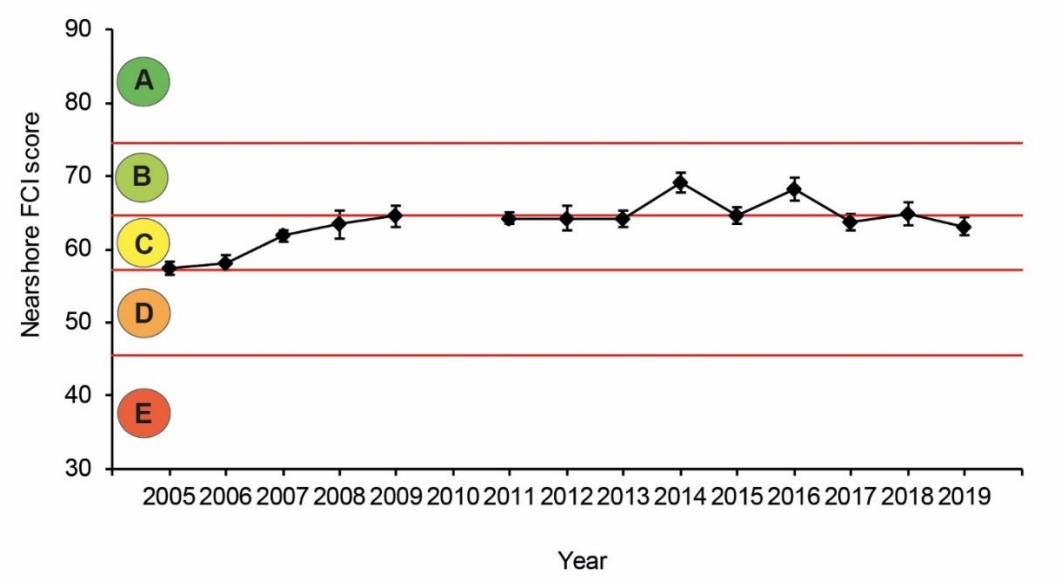


Figure 8. Trend plot of average (±SE) nearshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

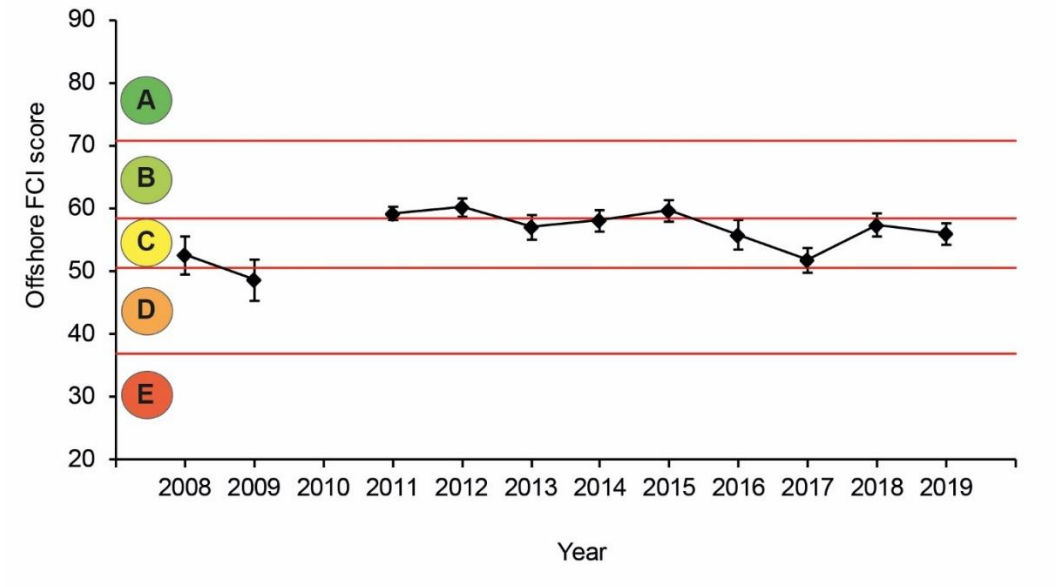


Figure 9. Trend plot of average (±SE) offshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor), for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

Summary

The Fish Community Index 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 both nearshore and offshore waters in 2019 was assessed as fair (C), based on their fish communities (Table 5). These results are consistent with the relatively stable trends in condition that have been observed since 2011.

Overall, the offshore waters of the CE exhibited the lowest scores of any zone in 2019. 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 D grade in 50% of monitored seasons), and some additional monitoring may be necessary in future 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 2019 monitoring period (mean of all summer and autumn of 2019). 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	61.1	C	62.7	B
MSE	61.2	C	52.7	C
USE	66.4	B	61.9	B
CE	63.6	C	46.8	D
Estuary	63.1	C	56.0	C

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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.

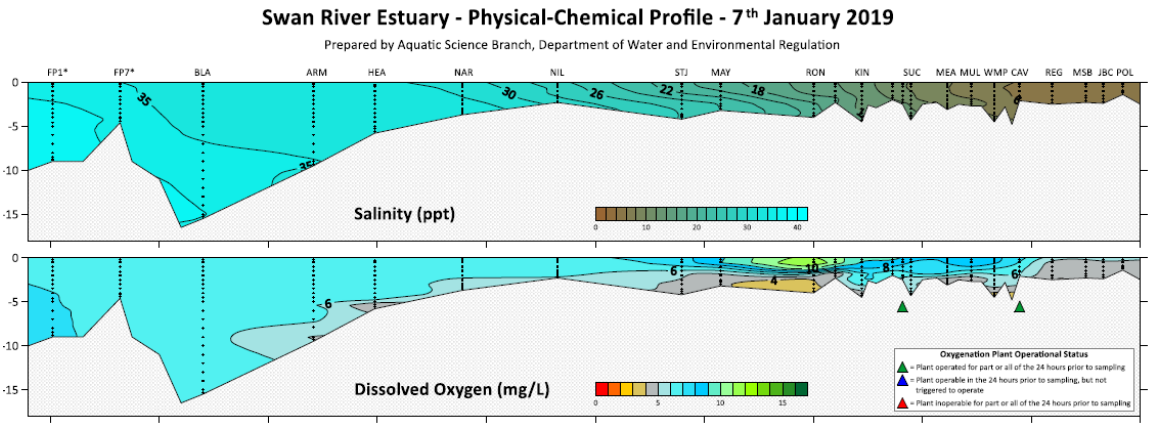
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Heterodontus portusjacksoni	Port Jackson shark	D	MS	ZB
Carcharinas leucas	Bull shark	P	MS	PV
Myliobatis tenuicaudatus	Southern Eagle ray	D	MS	ZB
Elops machnata	Giant herring	BP	MS	PV
Hyperlophus vittatus	Whitebait / sandy sprat	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

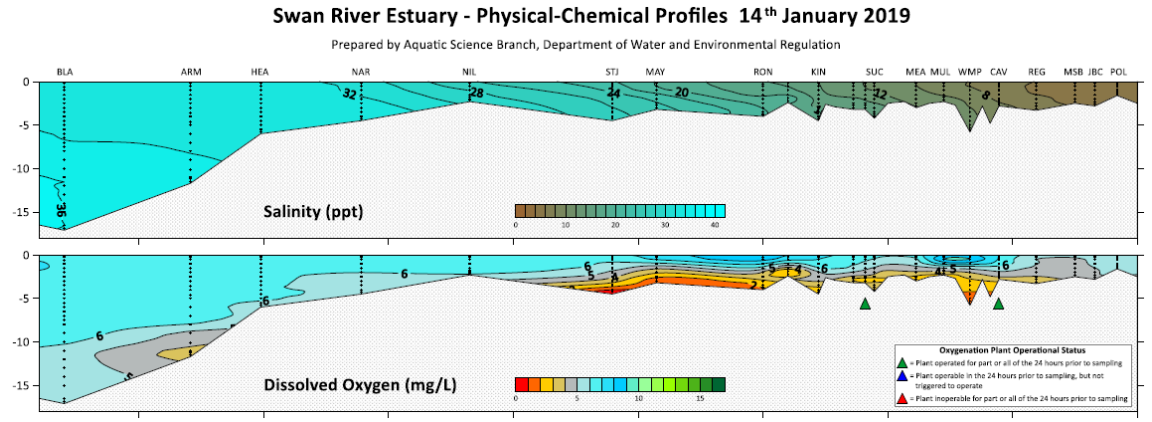
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Sillago schomburgkii	Yellow-finned whiting	D	MM	ZB
Sillago vittata	Western school whiting	D	MM	ZB
Pomatomus saltatrix	Tailor	P	MM	PV
Trachurus novaezelandiae	Yellowtail scad	P	MS	ZB
Scomeroides tol	Needleskin queenfish	P	MS	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

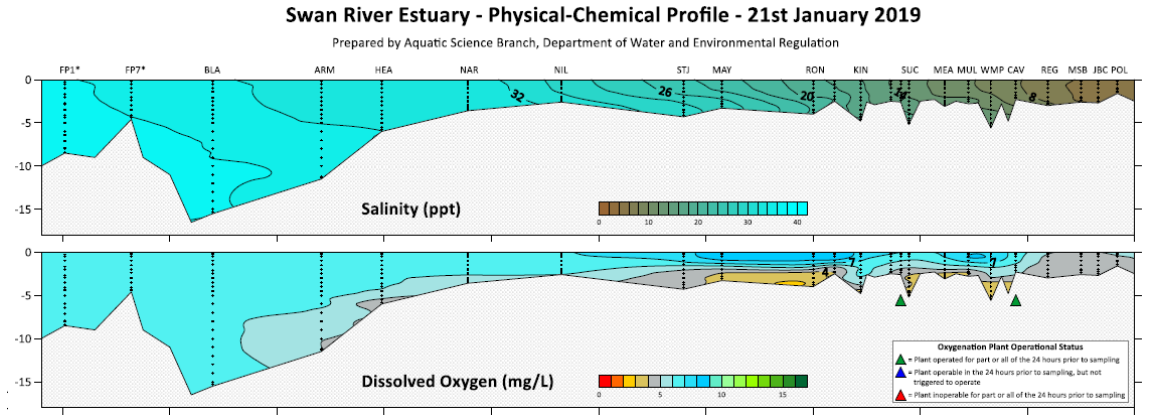
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Chaetodermis pencilligera	Tasselled leatherjacket	D	MS	OV
Meuschenia freycineti	Sixspine leatherjacket	D	MM	OV
Monacanthus chinensis	Fanbellied Leatherjacket	D	MM	OV
Eubalichthys mosaicus	Mosaic leatherjacket	D	MS	OV
Acanthaluteres 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 2019.

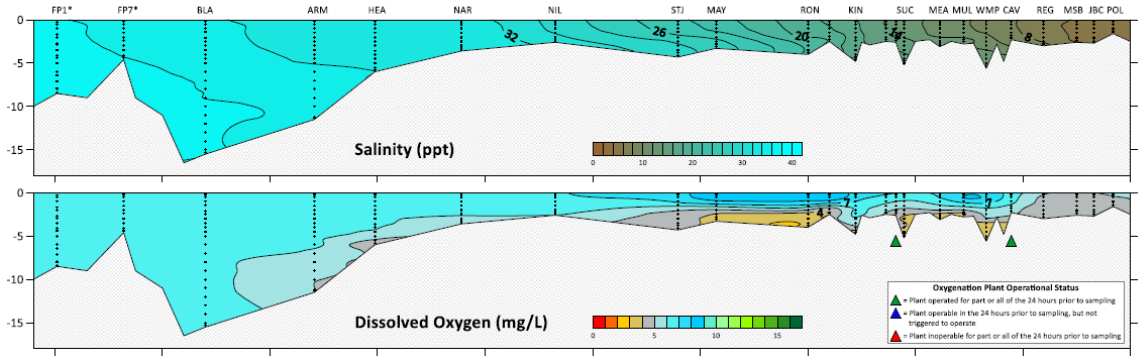






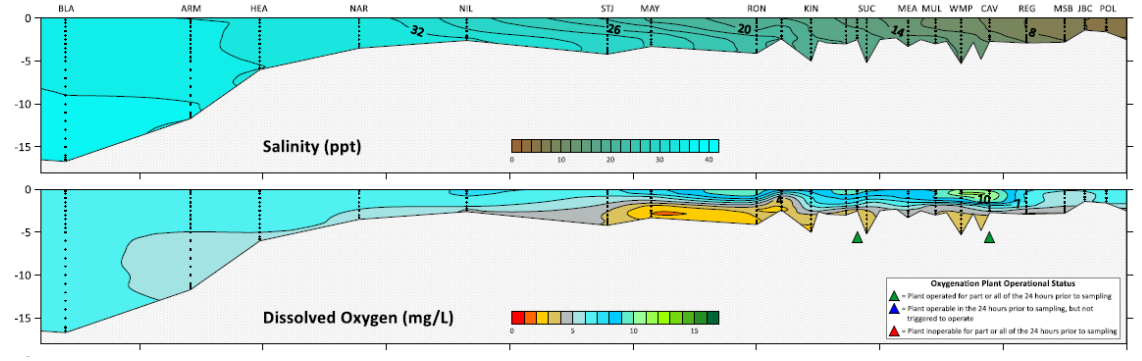
Swan River Estuary - Physical-Chemical Profile - 21st January 2019

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



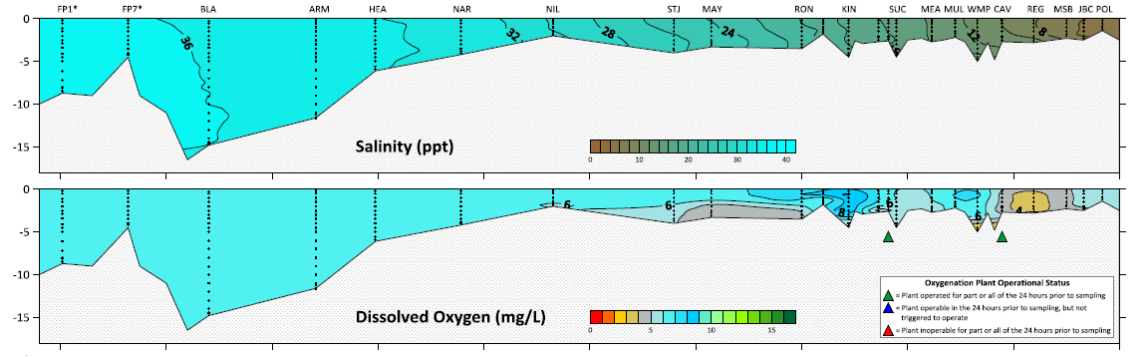
Swan River Estuary - Physical-Chemical Profiles 29th January 2019

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



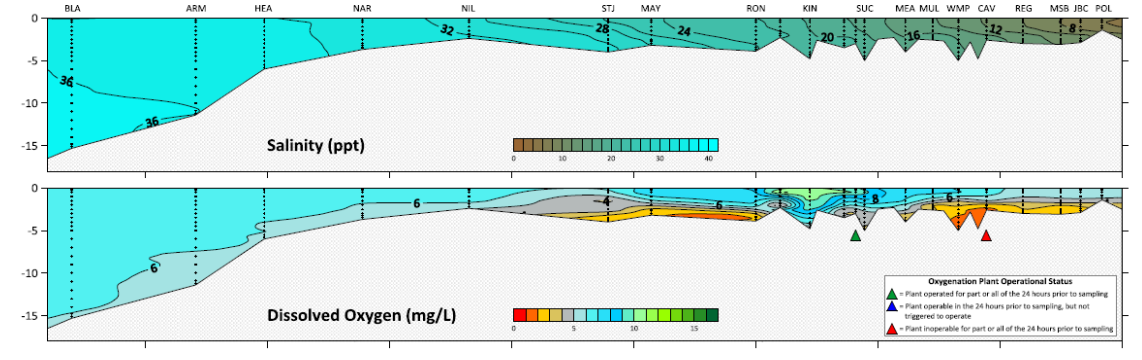
Swan River Estuary - Physical-Chemical Profile - 4th February 2019

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



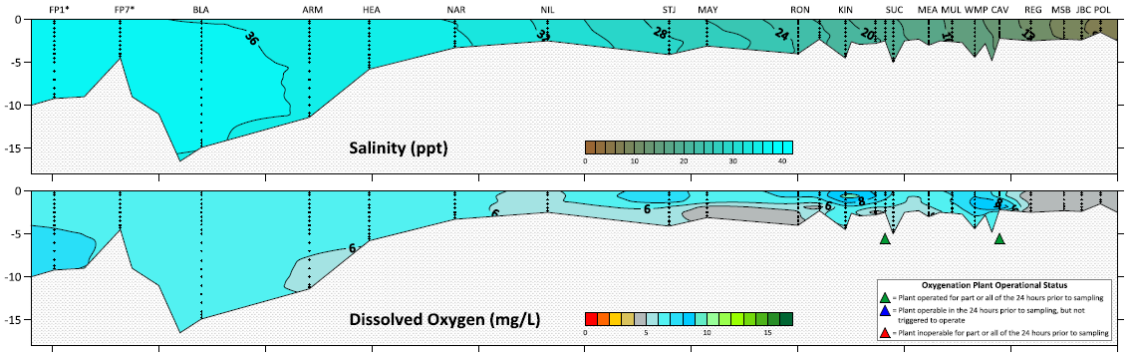
Swan River Estuary - Physical-Chemical Profiles 11th February 2019

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



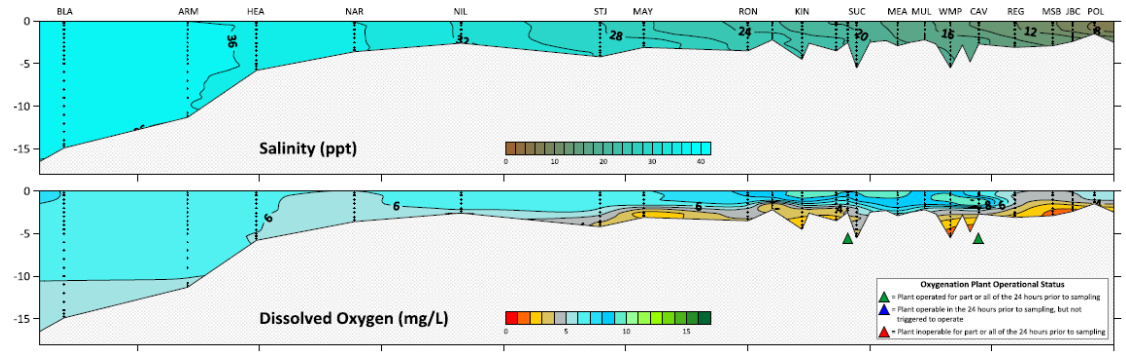
Swan River Estuary - Physical-Chemical Profile - 18th February 2019

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



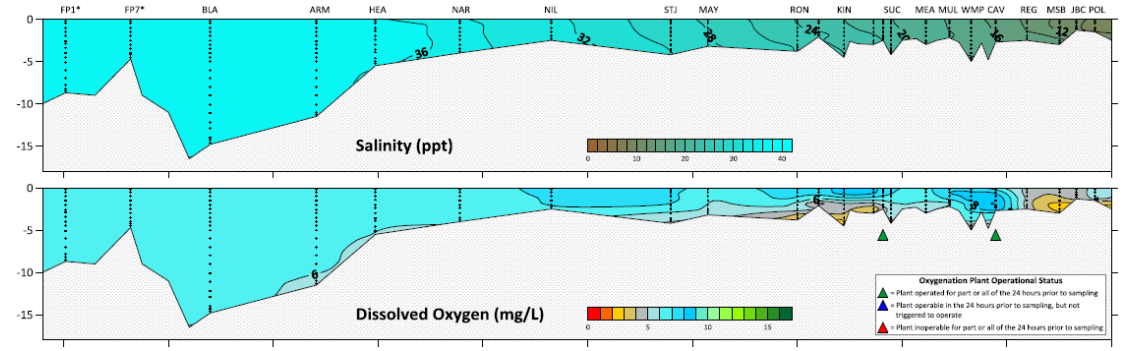
Swan River Estuary - Physical-Chemical Profiles 25th February 2019

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



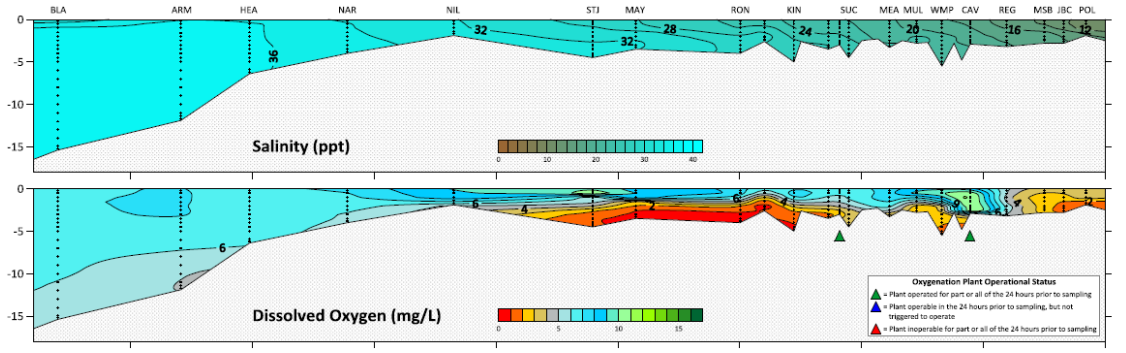
Swan River Estuary - Physical-Chemical Profile - 5th March 2019

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



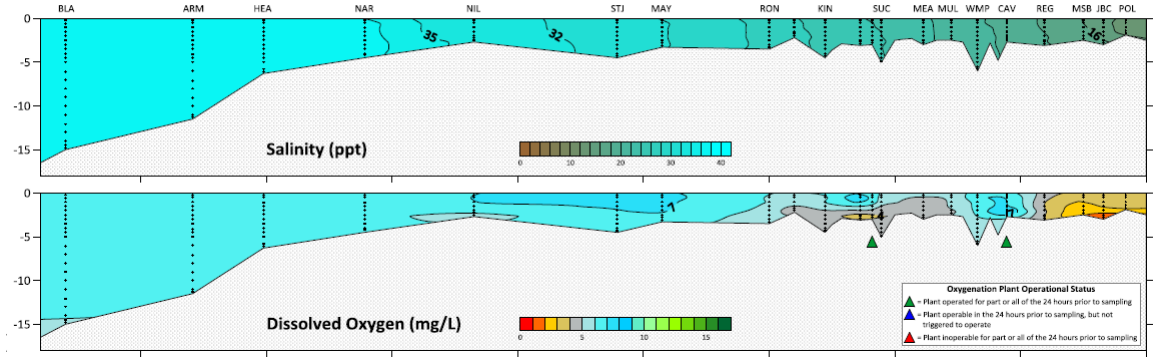
Swan River Estuary - Physical-Chemical Profiles 11th March 2019

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



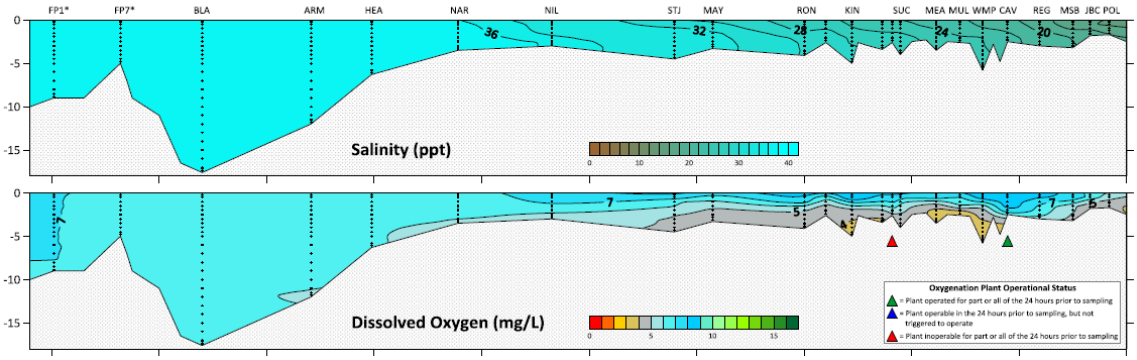
Swan River Estuary - Physical-Chemical Profiles 25th March 2019

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



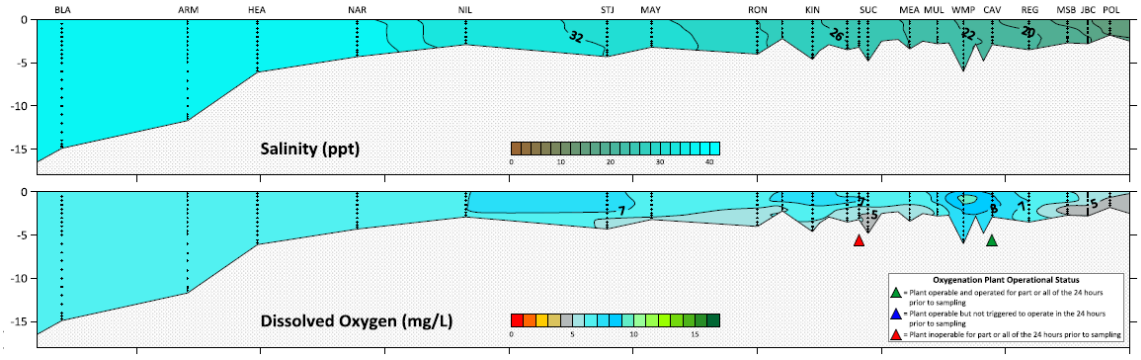
Swan River Estuary - Physical-Chemical Profile - 1st April 2019

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



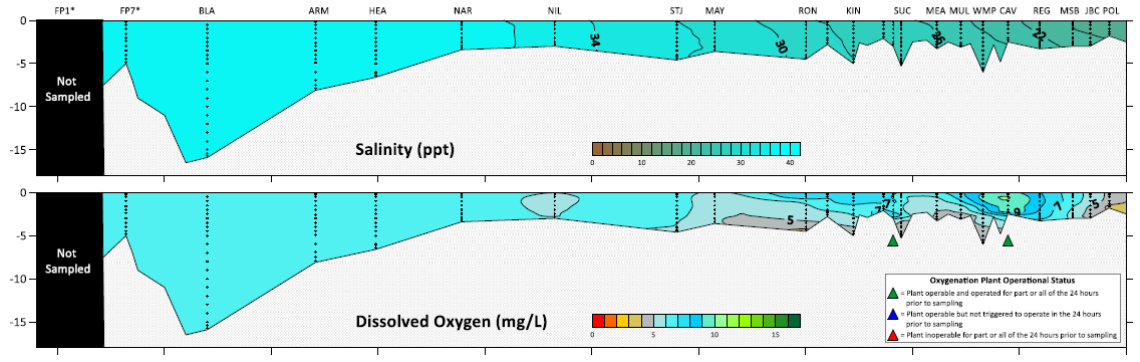
Swan River Estuary - Physical-Chemical Profiles 8th April 2019

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



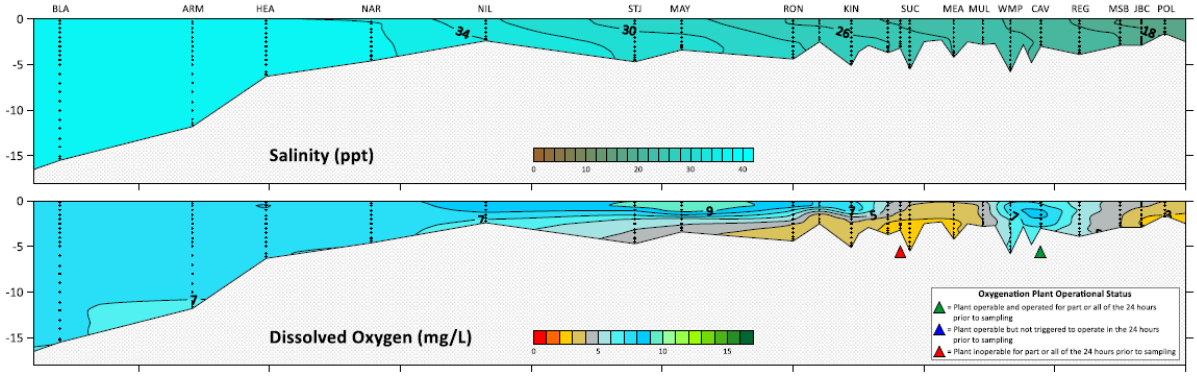
Swan River Estuary - Physical-Chemical Profile - 15th April 2019

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



Swan River Estuary - Physical-Chemical Profiles 23rd April 2019

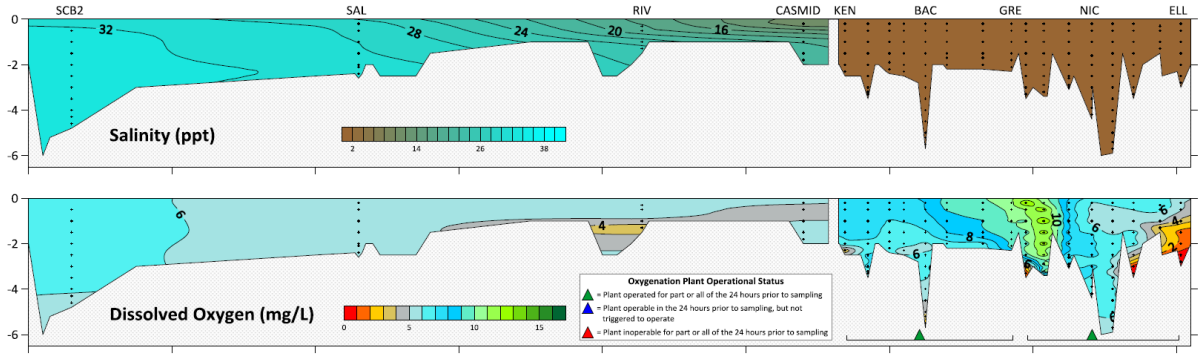
Prepared by Aquatic Science Branch, Department of Water and Environmental Regulation



CE zone in summer through autumn 2019.

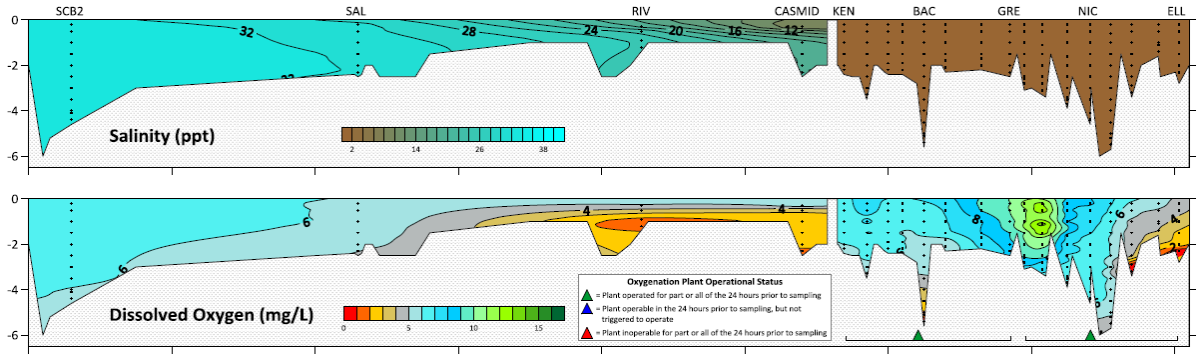
Canning River Estuary - Physical-Chemical Profile - 8th January 2018

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



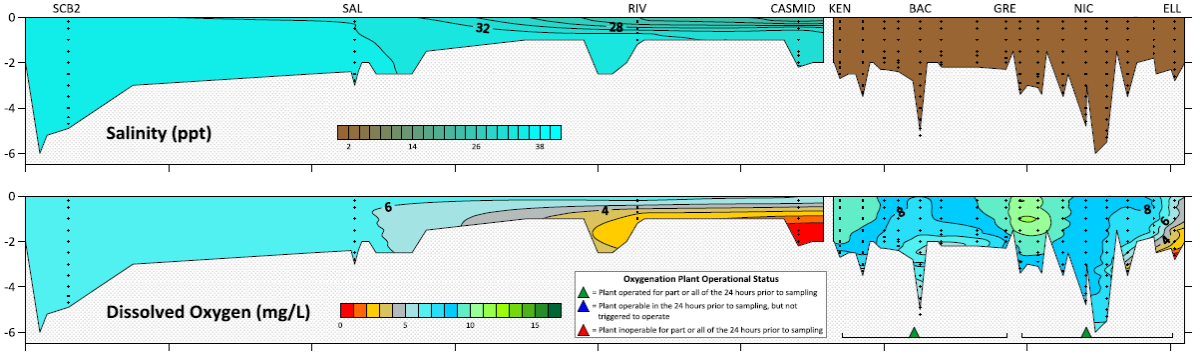
Canning River Estuary - Physical-Chemical Profile - 15th January 2019

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



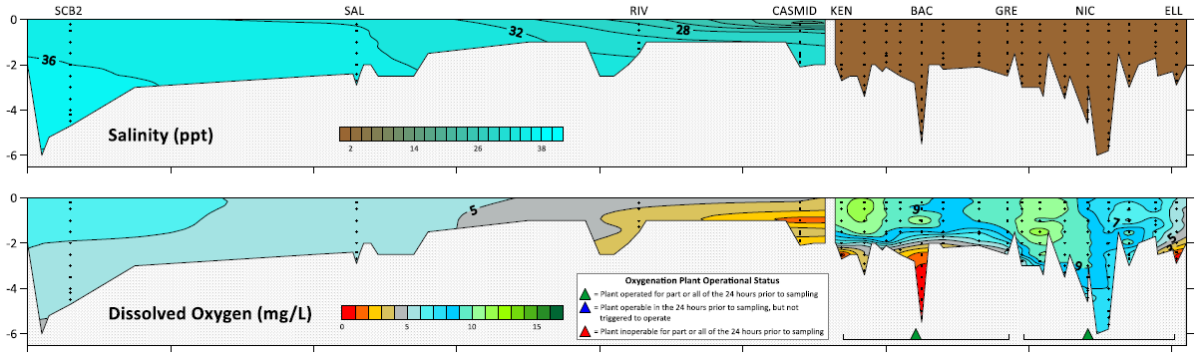
Canning River Estuary - Physical-Chemical Profile - 12th March 2019

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



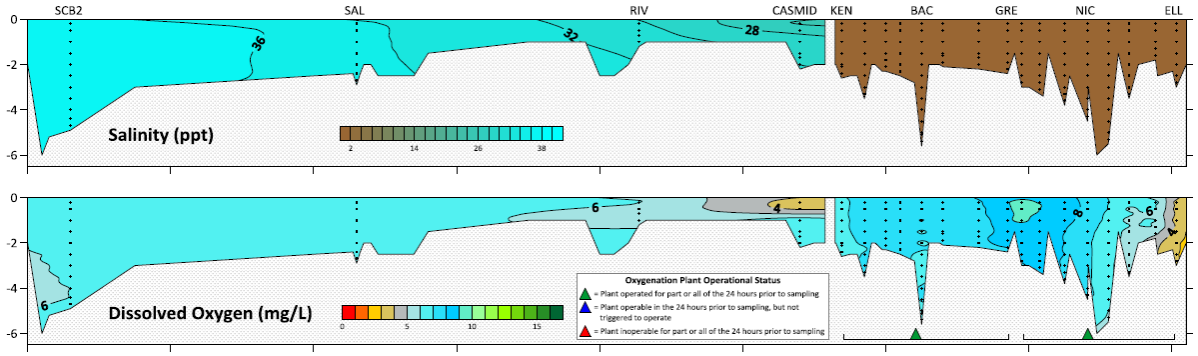
Canning River Estuary - Physical-Chemical Profile - 19th March 2019

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



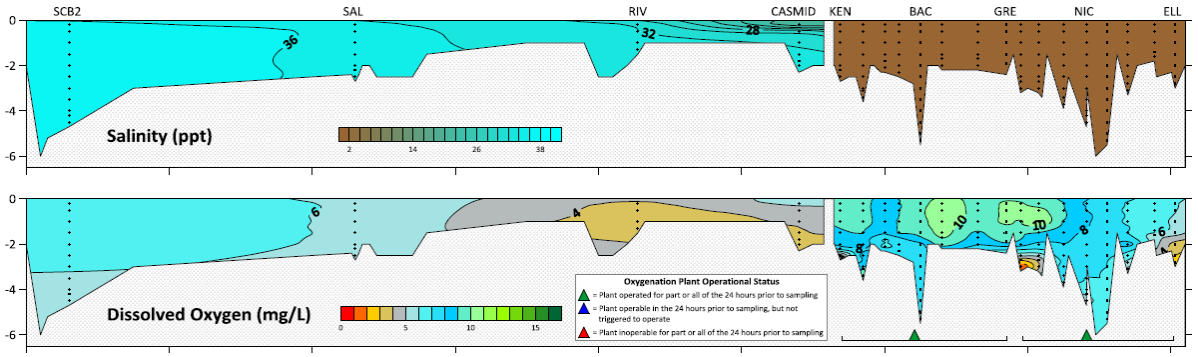
Canning River Estuary - Physical-Chemical Profile - 26th March 2019

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



Canning River Estuary - Physical-Chemical Profile - 2nd April 2019

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



Canning River Estuary - Physical-Chemical Profile - 9th April 2019

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