Assessment of the condition of the Swan Canning Estuary in 2016, based on the Fish Community Index of estuarine condition

Final report

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Executive summary

This report, commissioned by the Department of Parks and Wildlife, describes the monitoring and evaluation of fish communities in the Swan Canning Riverpark during 2016 and applies the Fish Community Index (FCI) that has been developed in recent years 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, integrate information on various biological variables (metrics), each of which quantifies an aspect of the structure and/or function of estuarine fish communities and responds 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 2016. As many fish as possible were returned to the water alive after they had been identified and counted. The resulting data on the abundances of each fish species from each sample were used to calculate a Fish Community Index score (0–100). These index scores were then compared to established scoring thresholds to determine ecological condition grades (A–E) for each zone and for the estuary as a whole, based on the composition of the fish community.

Nearshore Fish Communities

The nearshore waters of the estuary as a whole were in good condition (B) during 2016, consistent with a trend of good to fair (B/C) condition assessments in recent years. This result probably reflects the relatively high salinities and well oxygenated conditions that were present throughout the estuary during summer, which would have encouraged a greater number and diversity of marine species to enter the estuary and penetrate further upstream.

The average nearshore FCI scores for each of the zones of the Swan Canning Estuary show that these were also generally in good (B) to fair (C) ecological condition during 2016. The USE was a notable exception, whose fish communities indicated very good condition (A) throughout the monitoring period (mean FCI scores ≥76). The high FCI scores for the USE zone in autumn are probably attributable in part to fish moving into the nearshore waters of the USE from the offshore waters of the USE and particularly the MSE, which experienced severe and extensive hypoxic (low oxygen) conditions throughout April.

The composition of nearshore fish communities in the Swan Canning Estuary in 2016 was similar to those observed in 2012–2014, and again dominated by small-bodied, schooling species of hardyheads (atherinids) and gobies. The tropical hardyhead *Craterocephalus mugiloides* was again the most abundant fish species overall, comprising 19%–48% of all fish recorded from the middle to upper estuary. Wallace's hardyhead (*Leptatherina wallacei*) was also highly abundant, most notably in the CE and USE where it comprised 30% and 46% of the respective overall catches, as were *Leptatherina presbyteroides* and *Atherinosoma elongata* in the LSCE (35% and 26%, respectively). Other abundant species included Gobbleguts (*Ostorhinchus rueppellii*) in the LSCE, Black bream (*Acanthopagrus butcheri*) in the CE, and Red-spot goby (*Favonigobius punctatus*) in the MSE and USE.

As is typical for this and similar estuaries in south-western Australia, the total number of species recorded in each zone declined in an upstream direction, from 29 species in the LSCE and 24 in the CE, to 17 species in the USE. The total number of species caught from nearshore waters during 2016 was considerably greater than the 25 species caught during 2015, and closer to the total of 35 species caught during 2014. As was the case in 2014, the relatively high number of species encountered during 2016 likely reflects a greater influx and penetration of marine species into the estuary in response to relatively high summer salinities.

Offshore fish communities

The offshore waters of each individual zone of the estuary were all assessed as being in fair condition (C) or better during summer, based on their fish communities, and the mean offshore FCI scores for the LSCE and CE zones changed by 5 points or less from summer to autumn. In contrast, the ecological condition of the offshore waters of the MSE and USE declined markedly from summer to autumn. The mean offshore FCI score for the USE declined from 70 (good/very good) to 55 (fair), whilst that for the MSE decreased by 17 points, from good (B) to poor (D) condition. These declines reflect the effects of the severely hypoxic conditions that became established across much of the Swan Estuary, and particularly the MSE, during autumn as freshwater flows caused the water column to become stratified. This stratification coincided with periods during which either or both of the artificial oxygenation plants at Guildford and Caversham were not operational due to technical issues, and also with several algal blooms. In response to these perturbations, many of the more mobile fish species apparently moved from the deeper, offshore waters of the USE and particularly the MSE to the shallower (and presumably less hypoxic) nearshore waters of the LSCE and USE. As a result, the average FCI scores for the offshore waters of the USE and MSE declined during autumn, while that for the nearshore waters of the USE remained high (77; A; very good condition).

The effects of the hypoxic event in the Swan Estuary during autumn caused the mean offshore FCI score for the estuary as a whole in 2016 to decline to 56 (C; fair). This represents a slight decrease from the pattern of good-fair (B/C) or fair-good (C/B) condition assessments that have been recorded for offshore waters since 2011.

In general, the composition of offshore fish communities during 2016 was fairly typical for the Swan Canning Estuary, being dominated by Perth herring, which comprised 29% of the catches from the LSCE and 54–81% of those from the CE, MSE and USE. Other species that were relatively abundant in particular zones included the Southern eagle ray (*Myliobatis australis*), Western striped grunter (*Pelates octolineatus*), Tarwhine (*Rhabdosargus sarba*), Tailor (*Pomatomus saltatrix*), Yellowtail grunter (*Amniataba caudavittata*) and Black bream (*Acanthopagrus butcheri*).

Overall

In summary, and across the estuary as a whole, the ecological condition of nearshore waters in 2016 was assessed as good (B), while that of the offshore waters was fair (C), based on fish communities. This difference between the ecological condition of nearshore and offshore waters in 2016 primarily reflects the responses of the fish community of the MSE and USE to a sustained period of severe hypoxia (low dissolved oxygen conditions) that affected the Swan Estuary during autumn.

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1. Background

The Department of Parks and Wildlife work closely 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 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 2012b, Hallett et al. 2012, 2016).

2. Rationale

Versions of the Fish Community Index were developed for the shallow, nearshore waters of the estuary and also for its deeper, offshore waters, as the composition of the fish communities living in these different environments tends to differ, as do the methods used to sample them. These indices integrate information on various biological variables ('metrics'; Table 1), each of which quantifies an aspect of the structure and/or function of estuarine fish communities and responds 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, ultimately leading 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 which 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 poor to good).

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

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

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

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).

3. Study objectives

This report describes the monitoring and evaluation of fish communities in the Swan Canning Riverpark during 2016 for the purposes of applying the Fish Community Index as a measure of ecological condition. The objectives of this study were to:

1. Undertake monitoring of fish communities in mid-summer and mid-autumn periods, following an established approach as detailed in Hallett and Valesini (2012), including six nearshore and six offshore sampling sites in each estuarine management zone.
2. Analyse the information collected so that the Fish Community Index is calculated for nearshore and offshore waters in each management zone and for the estuary overall. The information shall be presented as quantitative FCI scores (0–100), qualitative condition

grades (A–E) and descriptions of the fish communities. Radar plots shall also be used to demonstrate the patterns of fish metric scores for each zone.

3. Provide a report that summarizes the approach and results and that could feed into a broader estuarine reporting framework.

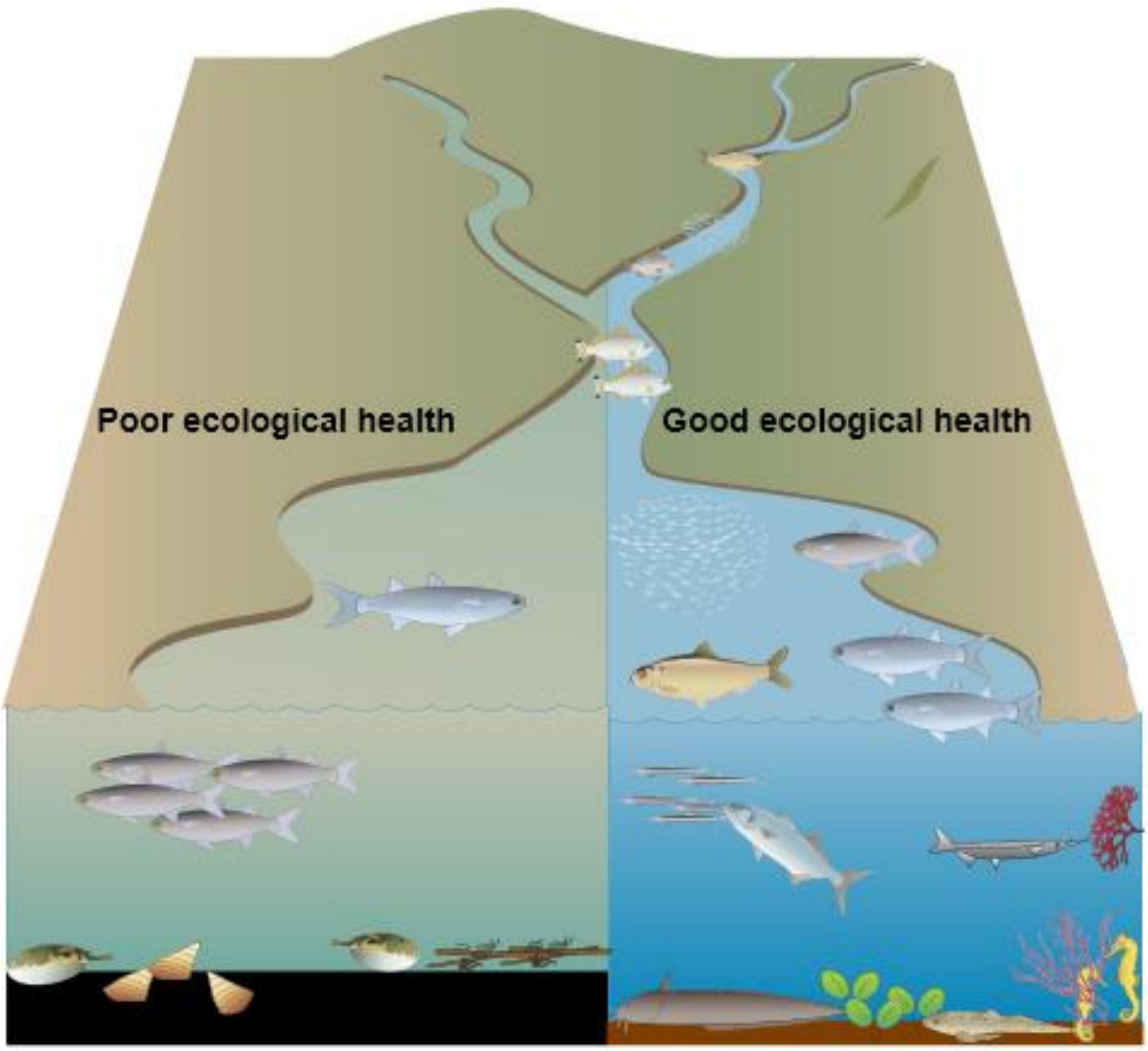


Figure 1. Conceptual diagram illustrating the predicted responses of the estuarine fish community to situations of poor and good ecological condition. (Images courtesy of the Integration and Application Network [ian.umces.edu/symbols/].)

4. Methods

Fish communities were sampled at six nearshore and six offshore sites in each of four management zones of the Swan Canning Estuary (LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary; Fig. 2) during both summer (12 January – 3 February) and autumn (5 April – 5 May) 2016, using a 21.5 m seine net and 160 m sunken, multimesh gill nets (Fig. 3), respectively. The seine net 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. The gill nets, consisting of eight 20 m-long panels with stretched mesh sizes of 35, 51, 63, 76, 89, 102, 115 and 127 mm, were deployed (*i.e.* laid parallel to the bank at a depth of 2–8 m, depending on the site) from a boat immediately before sunset and retrieved after three hours.

Once a sample had been collected, any fish that could immediately be identified to species (*e.g.* those larger species which 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 in eskies in the field for subsequent identification and counting, except in cases where large catches (*e.g.* thousands) of small fish were obtained. In such instances, an appropriate sub-sample (*e.g.* one-half to one-eighth of the catch) was retained for identification and estimation of the numbers of each species, and the remaining fish were returned alive to the water to minimise the impact on fish populations. All retained fish were then frozen until their identification in the laboratory. See appendices (i and ii) for full details of the sampling locations and methods employed.

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

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

The FCI scores and condition grades for nearshore and offshore samples collected during summer and autumn 2016 were then examined to assess the condition of the Swan Canning Estuary during this period and compared to previous years.

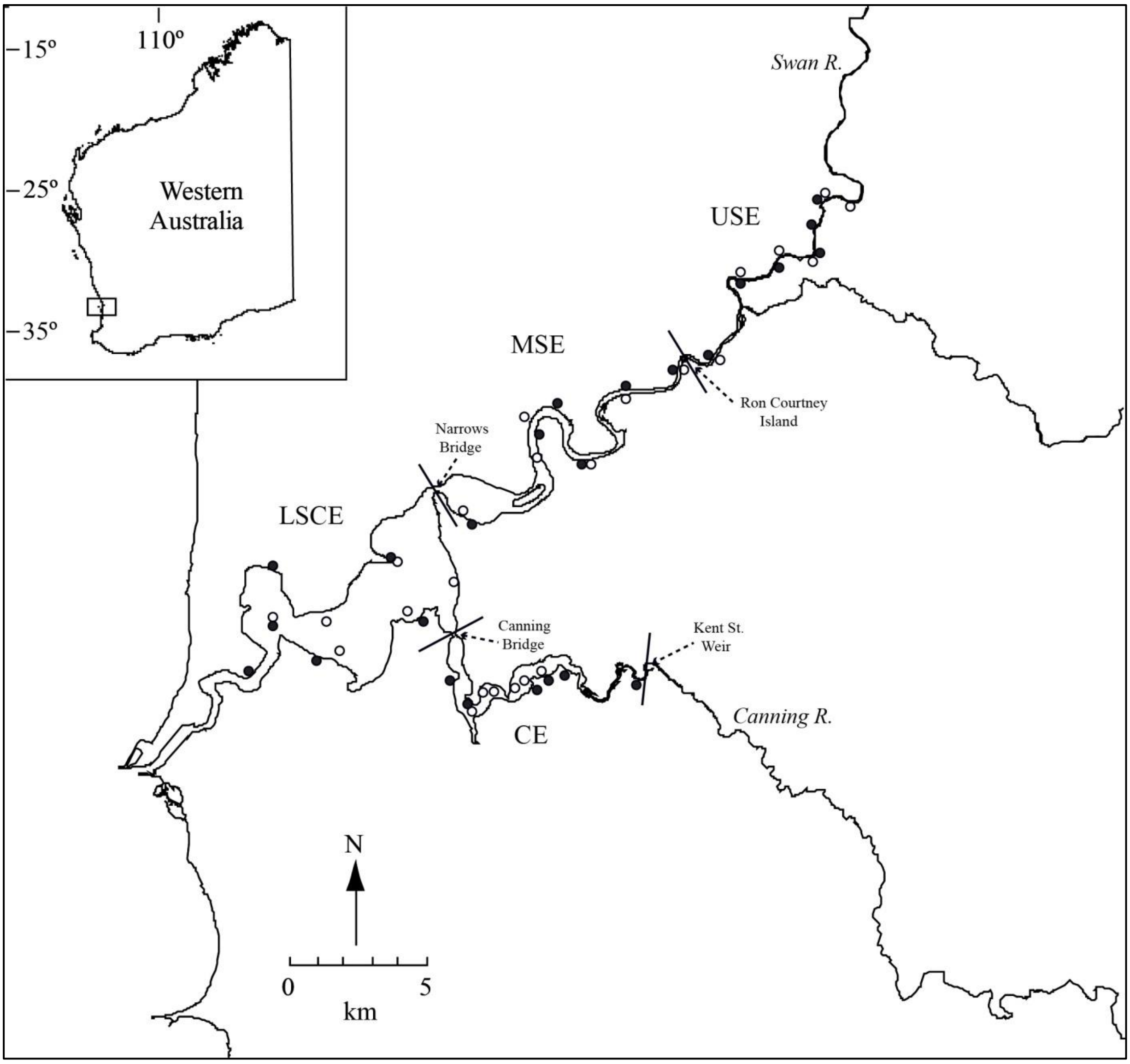


Figure 2: Locations of nearshore (black circles) and offshore (open circles) sampling sites for the Fish Community Index of estuarine condition. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

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

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

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

5. Results and discussion

5.1 Context: water quality and environmental conditions during the 2016 monitoring period

In general, average salinities measured throughout the estuary during summer sampling in 2016 (~29–30) were higher than those recorded during the summers of previous years, with the exception of 2013 (Appendix iv). Salinities during autumn of 2016 (~27–30) were, on average, lower than those observed during autumn of 2012, 2013 and 2014, reflecting the influence of freshwater flows in early April (see below).

Vertical contour plots (Appendix v), of interpolated (day-time) salinity and dissolved oxygen (DO) concentrations measured at routine monitoring stations along the length of the Swan Canning Estuary, provide more detail of the environmental conditions present throughout the system during the monitoring period. In the CE zone, conditions were generally relatively well-mixed and adequately oxygenated during the summer monitoring period (Appendix v). During autumn of 2016, rainfall in early to mid-April caused the water column of the upper reaches of the CE to become stratified. This stratification, which persisted into early May, was associated with pockets of hypoxia in the deeper parts of the CE.

Conditions throughout the Swan Estuary during summer of 2016 were similar to those of the previous year, with quite brackish conditions in the USE zone, yet relatively good levels of oxygenation and little stratification throughout (Appendix v). However, unpublished data from the Department of Parks and Wildlife indicate that parts of the Swan Estuary experienced high concentrations of particular phytoplankton species at times during the summer FCI monitoring period. Very high levels of chlorophyll were noted at water quality monitoring sites upstream of the uppermost FCI sampling site on 8 February, attributable to a bloom of the nuisance dinoflagellate *Heterocapsa horiguchii* (67,300 – 184,800 cells/mL). The Caversham oxygenation plant was not operational at that time (6 – 12 February) and while DO levels were not particularly low during the day, very low DO levels may have occurred at night, especially in the lower half of the water column (Dr Kerry Trayler, Department of Parks and Wildlife, personal communication).

In contrast to the conditions observed during summer, increased freshwater flows associated with rainfall in late March and early April of 2016 caused significant stratification of the water column of the Swan Estuary during the autumn FCI monitoring period. This stratification coincided with periods during which either or both of the artificial oxygenation plants at Guildford (29 April – 3 May) and Caversham (27 March – 13 April; 16 April – 18 April) were not operational due to technical issues. Furthermore, unpublished data show that parts of the MSE and/or USE experienced notable phytoplankton blooms during April and into early May. For example, high levels of haptophytes (*Chrysochromulina* spp.), dinoflagellates (*Heterocapsa* spp.) and diatoms (*Chaetoceros* sp.) were recorded from the USE on 15 April, 26 April and 2 May, respectively, and high levels of the dinoflagellate *Prorocentrum dentatum* were present in the MSE on 2 May. This combination of factors resulted in hypoxic (DO <2 mg/L) to near anoxic conditions (DO <0.5 mg/L) becoming established in the bottom waters of most of the MSE and USE during April (Appendix v).

5.2 Description of the fish community of the Swan Canning Estuary during 2016

An estimated total of 18,714 fish, belonging to 37 species, were caught in seine net samples collected from the nearshore waters of the Swan Canning Estuary during summer and autumn 2016. As is typical for this and similar estuaries in south-western Australia, the total number of species recorded in each zone declined in an upstream direction, from 29 species in the LSCE and 24 in the CE, to 17 species in the USE (Table 3). The total number of species caught from nearshore waters during 2016 was considerably greater than the 25 species caught during 2015, and closer to the total of 35 species caught during 2014. As in 2014, the relatively high number of species encountered during 2016 likely reflects a greater influx and penetration of marine species into the estuary in response to relatively high summer salinities (appendix iv). Examples of these species included weed whiting (family Odacidae), leatherjackets (Monacanthidae) and pipefish (Syngnathidae).

The hardyheads (Atherinidae) once again dominated catches from the nearshore waters of the estuary in 2016, with the four most abundant nearshore species overall belonging to this family. The tropical hardyhead *Craterocephalus mugiloides* was again the most abundant species overall, comprising 19% to 48% of all fish recorded from the middle to upper estuary (*i.e.* the CE, MSE and USE zones; Table 3). Wallace's hardyhead (*Leptatherina wallacei*) was also highly abundant, most notably in the CE and USE where it comprised 30% and 46% of the respective overall catches, as were *Leptatherina presbyteroides* and *Atherinosoma elongata* in the LSCE (35% and 26%, respectively). Other abundant species included Gobbleguts (*Ostorhinchus rueppellii*) in the LSCE, Black bream (*Acanthopagrus butcheri*) in the CE, and Red-spot goby (*Favonigobius punctatus*) in the MSE and USE (15% of the total catch in each zone).

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 2016. 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.

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
Craterocephalus mugiloides	Mugil's hardyhead	24.3	5.1	**63.9**	**19.4**	**112.0**	**47.7**	**63.3**	**20.9**
Leptatherina wallacei	Wallace's hardyhead	0.4	0.1	**97.6**	**29.6**	**24.3**	**10.4**	**140.3**	**46.3**
Leptatherina presbyteroides	Presbyter's hardyhead/ silverfish	**164.4**	**34.5**	2.9	0.9	-	-	-	-
Atherinosoma elongata	Elongate hardyhead	**121.8**	**25.5**	20.2	6.1	4.5	1.9	4.4	1.4
Favonigobius punctatus	Red-spot goby	0.5	0.1	7.5	2.3	**36.0**	**15.3**	**45.9**	**15.2**
Acanthopagrus butcheri	Black bream	11.1	2.3	**41.5**	**12.6**	12.6	5.4	8.8	2.9
Ostorhinchus rueppellii	Gobbleguts	**70.3**	**14.7**	1.6	0.5	1.3	0.6	-	-
Nematalosa vlaminghi	Perth herring	-	-	34.9	10.6	0.8	0.3	20.5	6.8
Pelates octolineatus	Western striped grunter	51.4	10.8	3.6	1.1	-	-	0.1	<0.1
Engraulis australis	Southern anchovy	1.9	0.4	22.7	6.9	8.8	3.7	1.8	0.6
Amniataba caudavittata	Yellowtail grunter	5.7	1.2	10.5	3.2	7.0	3.0	3.0	1.0
Torquigener pleurogramma	Blowfish/Banded toadfish	15.7	3.3	0.4	0.1	8.0	3.4	-	-
Pseudogobius olorum	Blue-spot goby	0.1	<0.1	7.2	2.2	2.7	1.2	1.7	0.5
Atherinomorus vaigensis	Ogilby's hardyhead	2.8	0.6	0.4	0.1	3.5	1.5	3.9	1.3
Aldrichetta forsteri	Yellow-eye mullet	-	-	2.2	0.7	6.8	2.9	1.1	0.4
Gambusia holbrooki	Mosquito fish	-	-	6.1	1.9	0.1	<0.1	2.9	0.9
Mugil cephalus	Sea mullet	-	-	1.2	0.4	5.0	2.1	0.2	0.1
Gerres subfasciatus	Roach	-	-	2.2	0.7	0.8	0.3	1.5	0.5
Amoya bifrenatus	Bridled goby	-	-	1.6	0.5	0.3	0.1	1.9	0.6
Afurcagobius suppositus	Southwestern goby	-	-	0.1	<0.1	-	-	1.6	0.5
Haletta semifasciata	Blue weed whiting	1.5	0.3	-	-	-	-	-	-
Favonigobius lateralis	Long-finned goby	1.1	0.2	0.4	0.1	-	-	-	-
Sillago burrus	Western trumpeter whiting	1.1	0.2	0.2	0.1	-	-	-	-

Species	Common name	**LSCE** (*n* = 12)		**CE** (*n* = 12)		**MSE** (*n* = 12)		**USE** (*n* = 12)	
		Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution	Average density (fish/100m^2)	% contribution
Geophagus brasiliensis	Pearl cichlid	-	-	0.9	0.3	-	-	-	-
Neoodax baltatus	Little weed whiting	0.5	0.1	-	-	-	-	-	-
Acanthaluteres spilomelanurus	Bridled leatherjacket	0.5	0.1	-	-	-	-	-	-
Stigmatophora argus	Spotted pipefish	0.4	0.1	-	-	-	-	-	-
Urocampus carinirostris	Hairy pipefish	0.4	0.1	-	-	-	-	-	-
Gymnapistes marmoratus	Devilfish	0.4	0.1	-	-	-	-	-	-
Rhabdosargus sarba	Tarwhine	0.2	<0.1	0.1	<0.1	-	-	-	-
Platycephalus westraliae	Yellowtail flathead	0.1	<0.1	-	-	0.1	<0.1	-	-
Sillago schomburgkii	Yellow-finned whiting	0.1	<0.1	-	-	-	-	-	-
Cnidoglanis macrocephalus	Estuarine cobbler	0.1	<0.1	-	-	-	-	-	-
Arripis georgianus	Australian herring	0.1	<0.1	-	-	-	-	-	-
Ammotretis rostratus	Longsnout flounder	0.1	<0.1	-	-	-	-	-	-
Acanthaluteres brownii	Spiny-tailed leatherjacket	0.1	<0.1	-	-	-	-	-	-
Sillaginodes punctata	King George whiting	0.1	<0.1	-	-	-	-	-	-
		29 Species		**24 Species**		**18 Species**		**17 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
		477	**6,642**	**330**	**4,591**	**235**	**3,265**	**303**	**4,216**

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 2016. 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.

		LSCE (*n* = 12)		**CE** (*n* = 12)		**MSE** (*n* = 12)		**USE** (*n* = 12)	
Species	**Common name**	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	**4.8**	**29.4**	**56.4**	**80.6**	**24.8**	**61.1**	**16.5**	**54.6**
Amniataba caudavittata	Yellowtail grunter	-	-	2.7	3.8	**6.0**	**14.8**	**8.6**	**28.5**
Gerres subfasciatus	Roach	0.7	4.1	1.1	1.5	**5.9**	**14.6**	0.1	0.3
Rhabdosargus sarba	Tarwhine	1.2	7.2	**3.5**	**5.0**	-	-	-	-
Myliobatis australis	Southern eagle ray	**3.9**	**24.2**	0.3	0.4	0.2	0.4	-	-
Pomatomus saltatrix	Tailor	0.9	5.7	**2.8**	**3.9**	0.3	0.8	-	-
Acanthopagrus butcheri	Black bream	0.1	0.5	0.7	1.0	-	-	**2.4**	**7.9**
Trachurus novaezelandiae	Yellowtail scad	0.1	0.5	-	-	2.8	6.8	-	-
Pelates octolineatus	Western striped grunter	**1.8**	**11.3**	0.4	0.6	0.3	0.6	-	-
Platycephalus westraliae	Yellowtail flathead	1.1	6.7	0.3	0.4	0.2	0.4	0.9	3.0
Argyrosomus japonicus	Mulloway	-	-	-	-	-	-	1.4	4.6
Sardinella lemuru	Scaly mackerel	0.1	0.5	1.0	1.4	-	-	-	-
Mugil cephalus	Sea mullet	-	-	0.8	1.2	-	-	0.1	0.3
Sillago burrus	Western trumpeter whiting	0.7	4.1	-	-	-	-	-	-
Elops machnata	Giant herring	0.3	2.1	-	-	0.1	0.2	0.1	0.3
Torquigener pleurogramma	Blowfish	0.3	2.1	-	-	-	-	-	-
Engraulis australis	Southern anchovy	-	-	0.1	0.1	-	-	0.2	0.6
Cnidoglanis macrocephalus	Estuarine cobbler	0.2	1.0	0.1	0.1	-	-	-	-
Carcharinas leucas	Bull shark	-	-	-	-	0.1	0.2	-	-
Arripis georgianus	Australian herring	0.1	0.5	-	-	-	-	-	-

15 Species		**13 Species**		**10 Species**		**9 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
16	**194**	**70**	**840**	**41**	**486**	**30**	**362**

Atherinids typically dominate the nearshore fish communities of estuaries across southwestern Australia, with different species partitioned throughout an estuary according to their environmental preferences (Prince and Potter 1983). For example, *L. wallacei*, which generally prefers to inhabit less saline waters (Potter et al. 2015) was thus abundant in the CE, MSE and USE zones during 2016, but largely absent from the LSCE. In contrast, *A. elongata*, which can tolerate highly elevated salinities (Veale et al. 2014), and the marine species *L. presbyteroides*, were predominantly found in the LSCE.

Gill net samples collected in summer and autumn 2016 from offshore waters returned 1,882 fish, comprising 20 species (Table 4). As in the nearshore waters, the total number of species declined in an upstream direction, from 15 species in the LSCE to 9 species in the USE. This pattern is fairly typical in south-western Australian estuaries (Loneragan et al. 1986, 1987, 1989) and is consistent with observations from the Swan Canning Estuary in each of the last four years (Hallett 2012a, 2013, Hallett and Tweedley 2014, 2015).

As in the four previous years, the dominant species among gill net catches from all four zones was the Perth herring, which comprised 29% of the catches from the LSCE and 54–81% of those from the CE, MSE and USE. Other relatively abundant species included the Southern eagle ray (*Myliobatis australis*) and Western striped grunter (*Pelates octolineatus*) in the LSCE, Tarwhine (*Rhabdosargus sarba*) and Tailor (*Pomatomus saltatrix*) in the CE, Yellowtail grunter (*Amniataba caudavittata*) in the MSE and USE, and Black bream (*Acanthopagrus butcheri*) in the USE (Table 4).

Overall, the nearshore and offshore fish communities of the Swan Canning Estuary in 2016 were again broadly similar in species composition to those observed during equivalent monitoring conducted annually since 2012, and were dominated by similar suites of species in each year. (Hallett 2012a, 2013, Hallett and Tweedley 2014, 2015).

5.3 Ecological condition in 2016 and comparison to other periods

Nearshore waters

The ecological condition (based on fish communities) of the nearshore waters of the Riverpark was generally good (B) to fair (C) during the 2016 monitoring period (Fig. 6). The USE was a notable exception, with its fish communities indicating very good condition (A) throughout the monitoring period (mean FCI scores ≥76). The high FCI scores for the USE zone in summer may reflect the movement of some fish species into this zone from areas further upstream, which were experiencing a notable dinoflagellate bloom at the time (see section 5.1). Similarly, the very good condition of the USE zone in autumn is probably attributable to fish moving into the nearshore waters of the USE from the offshore waters of the USE and particularly the MSE, which experienced severe and extensive hypoxic conditions and several algal blooms during April (see below). The mean nearshore FCI scores and condition grades for each zone exhibited relatively little change from summer to autumn (*i.e.* <5 points; Fig. 6).

Results indicated that the nearshore waters of the estuary as a whole were in good condition (B) during 2016, consistent with a trend of good to fair (B/C) condition assessments in recent years (Fig. 7). The good nearshore condition in 2016 represents an increase from that observed during the previous year, and is probably reflective of the relatively high salinities and well oxygenated conditions that were present throughout the estuary during summer (see subsection 5.1), which would have encouraged a greater number and diversity of marine species to enter the estuary and penetrate further upstream during this season. The good nearshore condition in 2016 is probably also partly attributable to the very good nearshore condition of the USE during 2016, which, as noted above and further discussed below, reflects the response of the fish community to declining condition in the offshore waters of the MSE and USE during autumn.

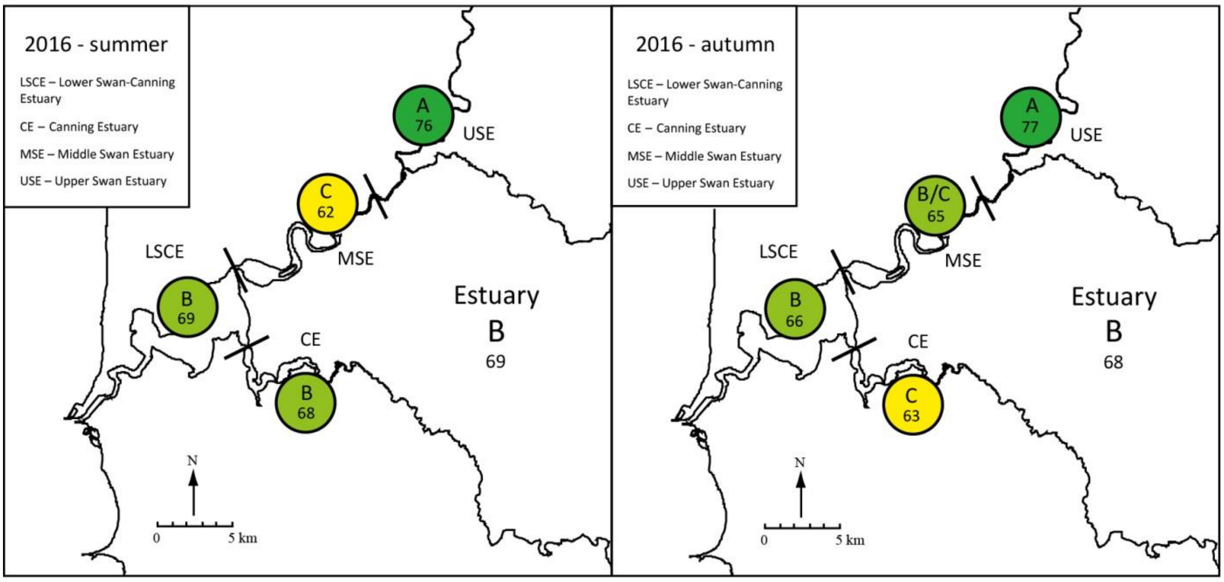


Figure 6: Average nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2016.

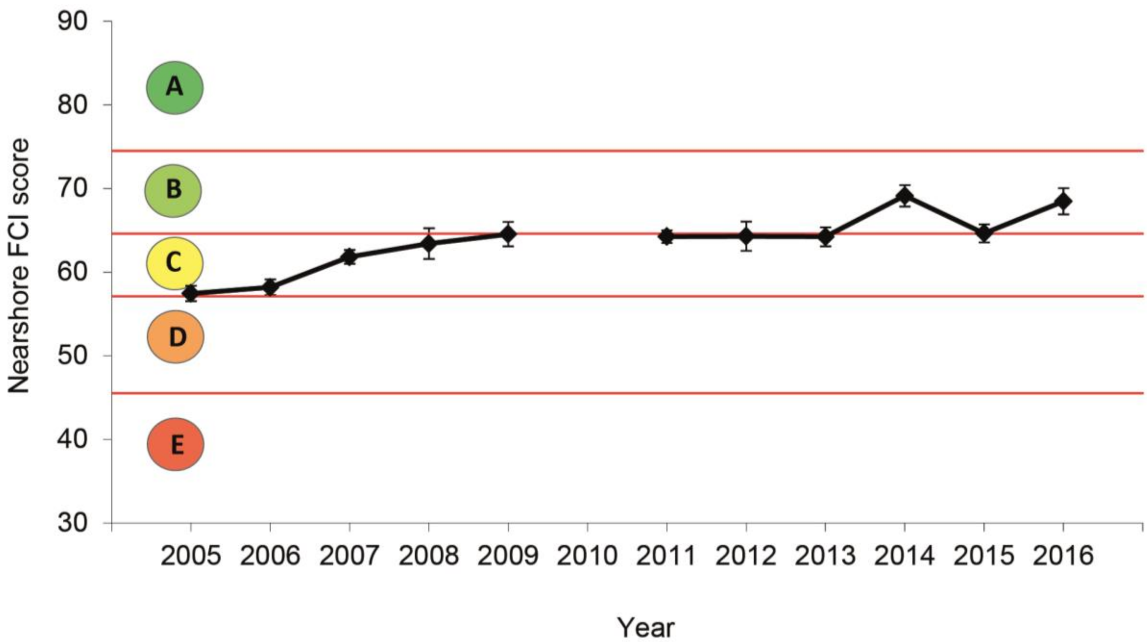
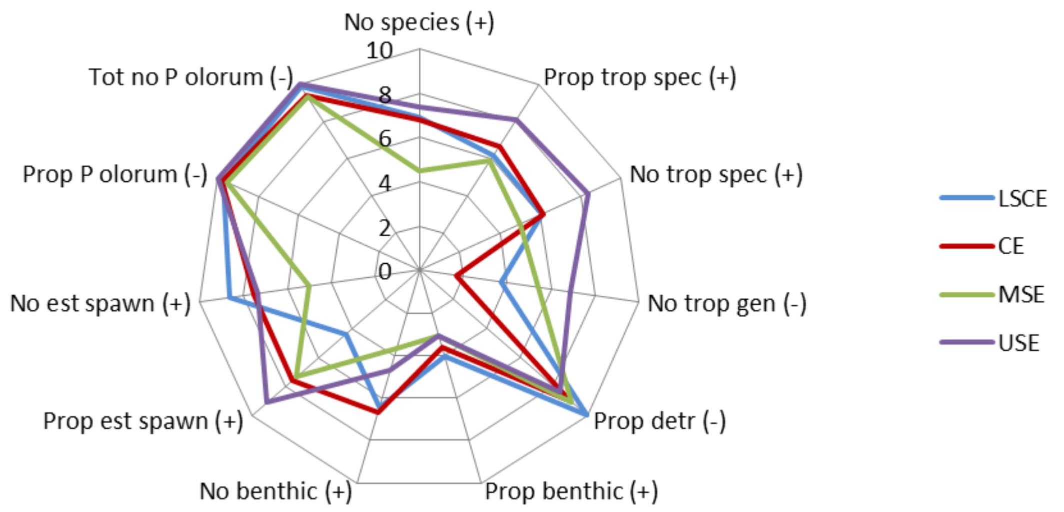


Figure 7: Trend plot of average (±SE) nearshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

Radar plots of the nearshore metric scores for each zone in each season confirm that the very good condition of the nearshore waters of the USE during 2016 was largely driven by relatively high numbers of species, and particularly of those that spawn in the estuary and feed on specific prey types, and by high proportions of fishes that spawn in the estuary and low proportions of detritivores (i.e. species that feed on decaying organic matter). This is shown by consistent scores of ~8 or more for the relevant metrics (Fig. 8).

(a) Summer 2016



(b) Autumn 2016

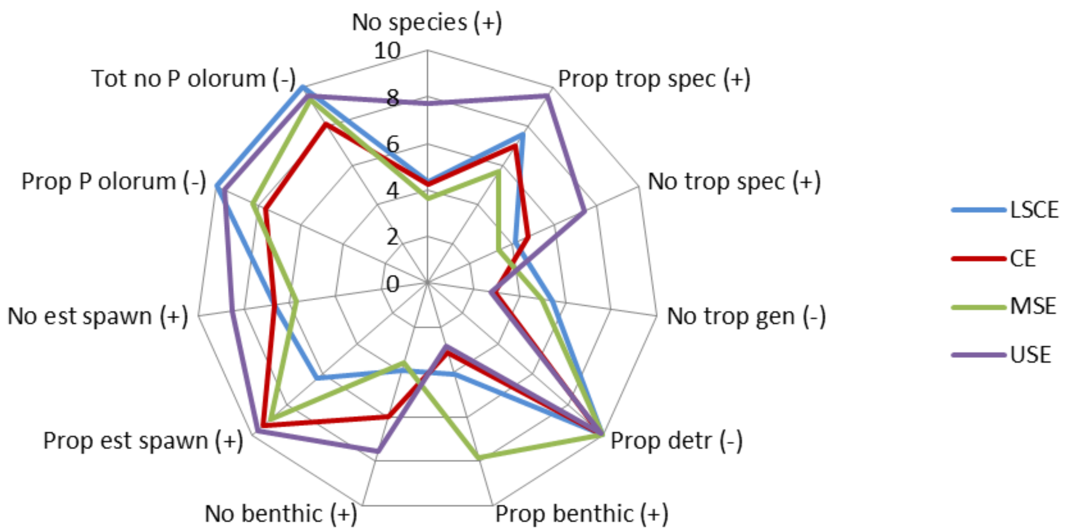


Figure 8: Average scores (0–10) for each component metric of the nearshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2016. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names).

Offshore waters

The ecological condition of the Riverpark's offshore waters during summer of 2016 was generally poorer than that of the nearshore waters, though broadly similar to that observed in previous years, with the offshore waters of the LSCE, MSE and USE assessed as being in fair condition (C) or better (Fig. 9), based on their fish communities.

Whilst the mean offshore FCI scores for the LSCE and CE zones changed by 5 points or less from summer to autumn, the ecological condition of the offshore waters of the MSE and USE declined markedly from summer to autumn. The mean offshore FCI score for the USE declined from 70 (good/very good) to 55 (fair), whilst that for the MSE decreased by 17 points, from good (B) to poor (D) condition (Fig. 9). These patterns reflect the effects of the severely hypoxic conditions that became established across much of the Swan Estuary, and particularly the MSE, during autumn (see section 5.1 and Appendix v). Rainfall in late March and early April generated freshwater flows that caused significant stratification of the water column of the Swan Estuary throughout the FCI autumn monitoring period. This stratification coincided with several algal blooms and with periods during which either or both of the artificial oxygenation plants at Guildford and Caversham were not operational due to technical issues, doubtless exacerbating the spatial extent and severity of hypoxia. The observed patterns in FCI scores suggest that, in response to these perturbations, many of the more mobile fish species apparently moved to avoid the most severe of the hypoxic conditions. These fish are thought to have moved from the deeper, offshore waters of the USE and particularly the MSE to the shallower and presumably less hypoxic nearshore waters of the LSCE and USE. As a result, the mean FCI scores for the offshore waters of the USE and MSE declined during autumn, while that for the nearshore waters of the USE remained high (77; A; very good condition) (*cf.* Figs. 6 and 9). Similar avoidance behaviours, and their effects on FCI scores, have been documented during previous hypoxic events and also algal blooms in this system (Hallett 2013; Cottingham et al. 2014; Hallett et al. 2016).

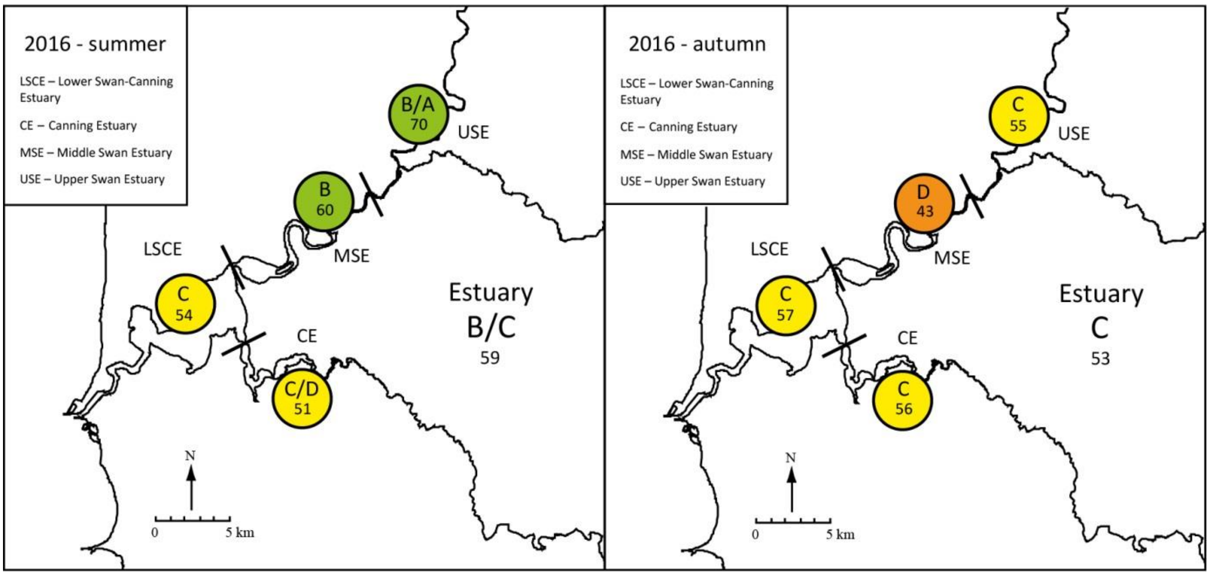


Figure 9: Average offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2016.

The effects of the hypoxic event in the Swan Estuary during autumn 2016 caused the mean offshore FCI score for the estuary as a whole to decline to 56. Overall, the ecological condition of the Swan Canning Estuary was therefore assessed as fair (C) during 2016, representing a slight decrease from the pattern of good-fair (B/C) or fair-good (C/B) condition assessments that have been recorded for offshore waters since 2011 (Fig. 10).

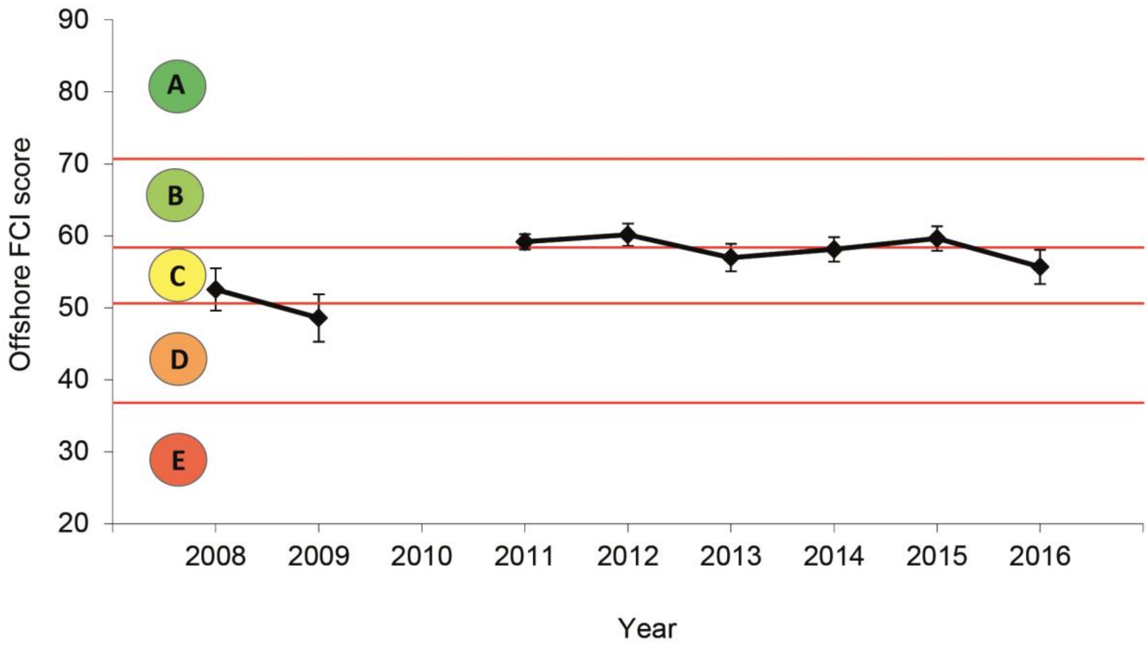
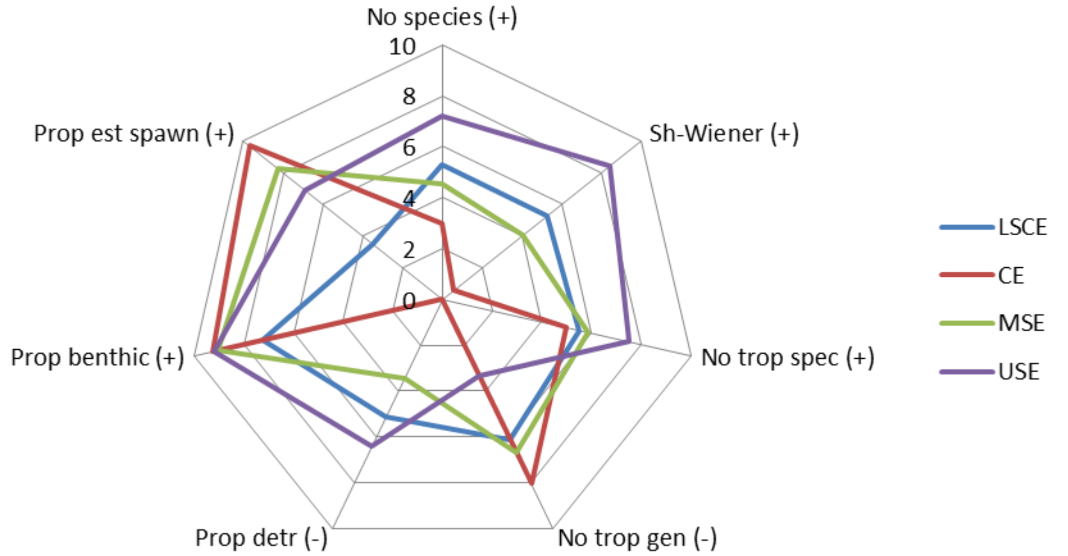


Figure 10: Trend plot of average (±SE) offshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor), for the Swan Canning Estuary as a whole, over recent years. Red lines denote boundaries between condition grades.

Radar plots of offshore metric scores for each zone in each season shed light on the responses of the fish community to the hypoxia that affected the Swan Estuary during autumn 2016. The declines in offshore FCI scores in the MSE and USE were driven by decreases in the number of species and the diversity of fishes, and an increase in the proportion of species that feed on decomposing organic material (*e.g.* Sea mullet, Perth herring). This is indicated by lower average scores for *Number of species* and *Shannon-Wiener diversity* (both positive metrics) and for the *Proportion of detritivores* (a negative metric) during autumn (Fig. 11). Decreases in the *Proportion of benthic species* and *Proportion of estuary-spawning species* (both of which are positive metrics) also contributed to the poor condition of the MSE during autumn.

(a) Summer 2016



(b) Autumn 2016

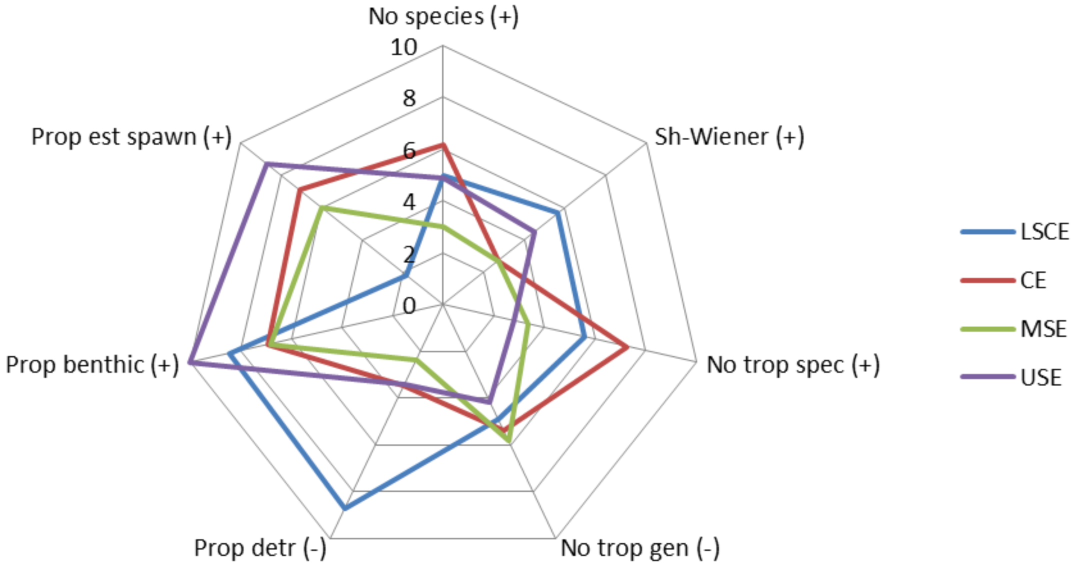


Figure 11: Average scores (0–10) for each component metric of the offshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2016. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names).

Summary

The Fish Community Index looks at 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 (*cf.* Cottingham et al. 2014).

In summary, and across the estuary as a whole, the ecological condition of nearshore waters in 2016 was assessed as good (B), while that of the offshore waters of the system was assessed as fair (C), based on fish communities. This difference between the ecological condition of nearshore and offshore waters in 2016 largely reflects the responses of the fish community of the MSE and USE to a sustained period of severe hypoxia (low dissolved oxygen conditions) that affected the Swan Estuary during autumn.

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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 29th June 2016.

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 australis	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
Stigmatophora 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
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
Sillago schomburgkii	Yellow-finned whiting	D	MM	ZB

Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
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
Chaetodermis pencilligera	Tasselled leatherjacket	D	MS	OV

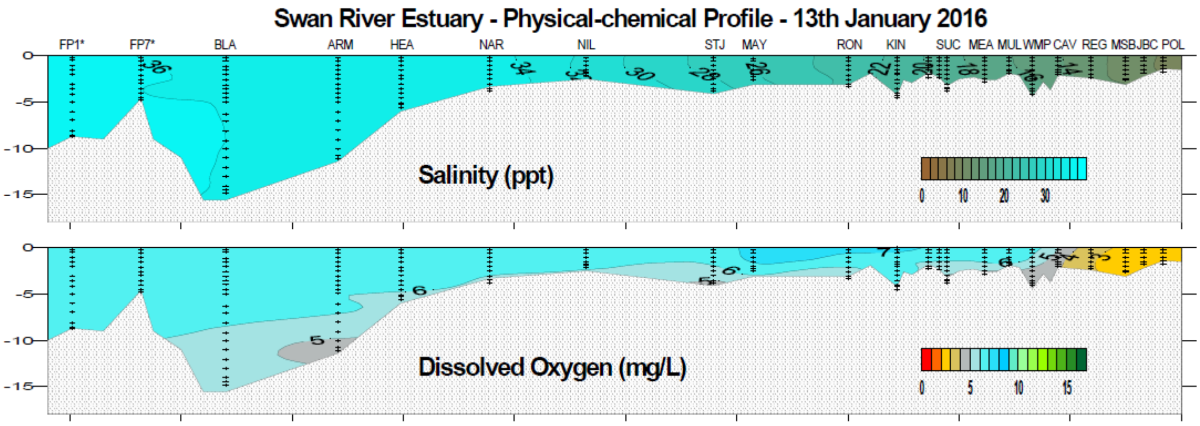
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Meuschenia freycineti	Sixspine leatherjacket	D	MM	OV
Monacanthus chinensis	Fanbellied Leatherjacket	D	MM	OV
Eubalichthys mosaicus	Mosaic leatherjacket	D	MS	OV
Acanthaluteres vittiger	Toothbrush Leatherjacket	D	MS	OV
Acanthaluteres 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

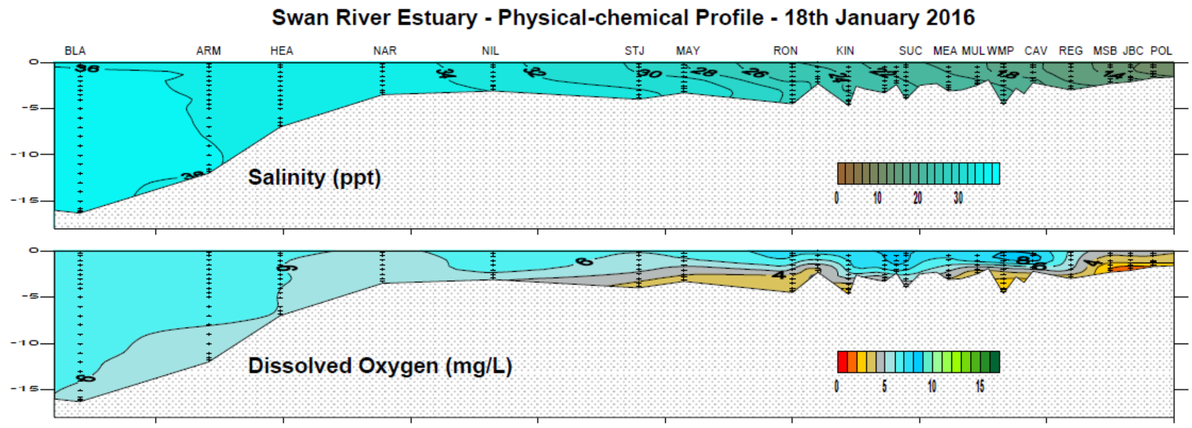
Appendix (iv): Average salinities, measured at the time of sampling, across all nearshore and offshore sampling sites during 2012–2016.

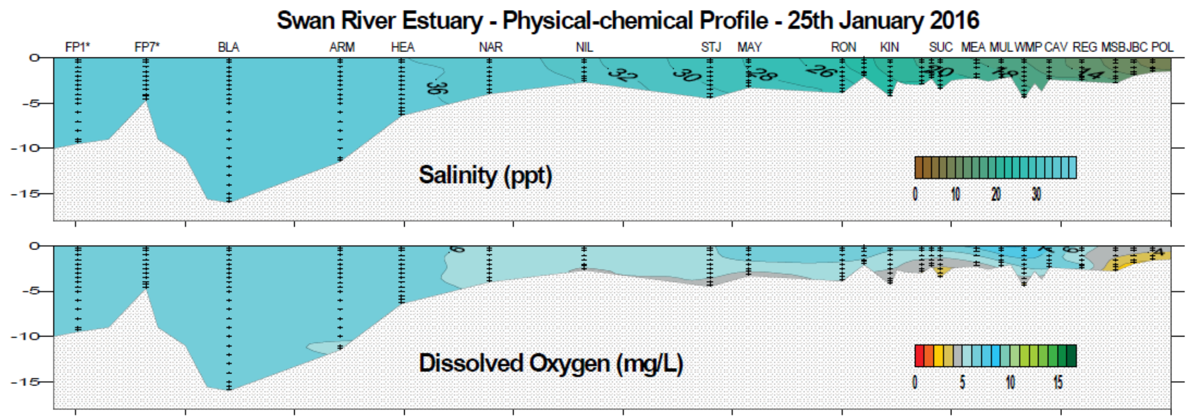
	2012		2013		2014		2015		2016	
	SU	AU	SU	AU	SU	AU	SU	AU	SU	AU
Nearshore	25.3	28.9	30.6	30.6	27.4	33.2	27.8	28.0	29.3	27.0
Offshore (surface)	26.0	30.4	30.9	30.6	27.6	33.5	28.0	28.5	29.8	28.6
Offshore (bottom)	26.4	31.7	31.5	32.5	28.7	33.9	28.6	30.0	30.3	30.4

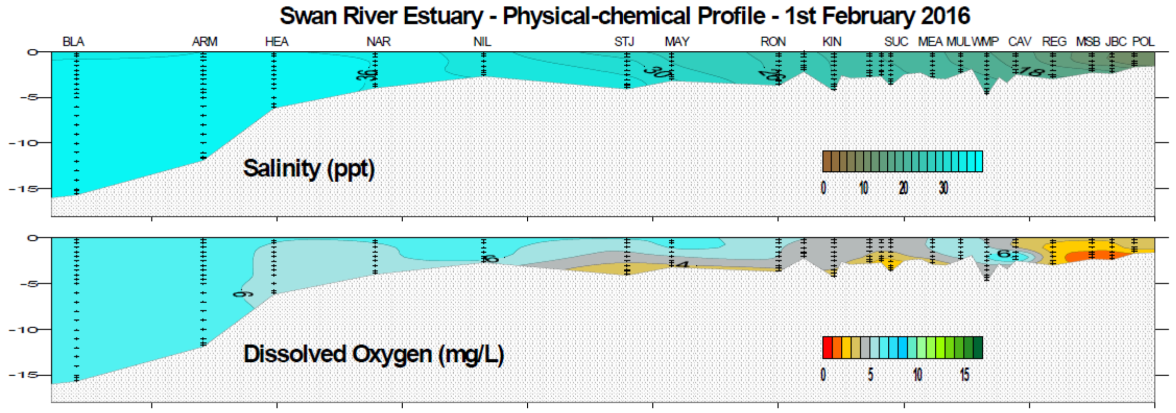
Appendix (v): Vertical contour plots of salinity and dissolved oxygen concentrations (mg/L) measured at monitoring stations along the length of the Swan Canning Estuary on occasions prior to and during the period of fish community sampling. Obtained from Department of Parks and Wildlife.

LSCE, MSE and USE zones in summer 2016.

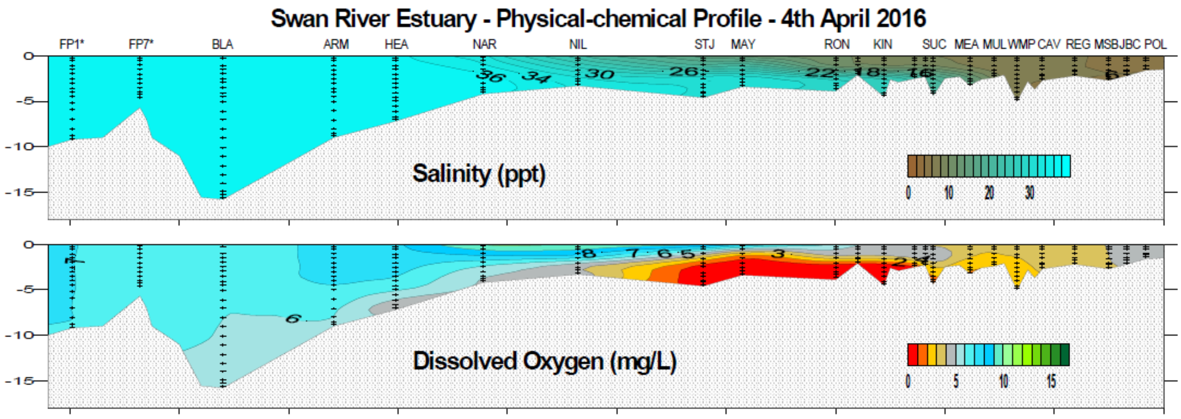


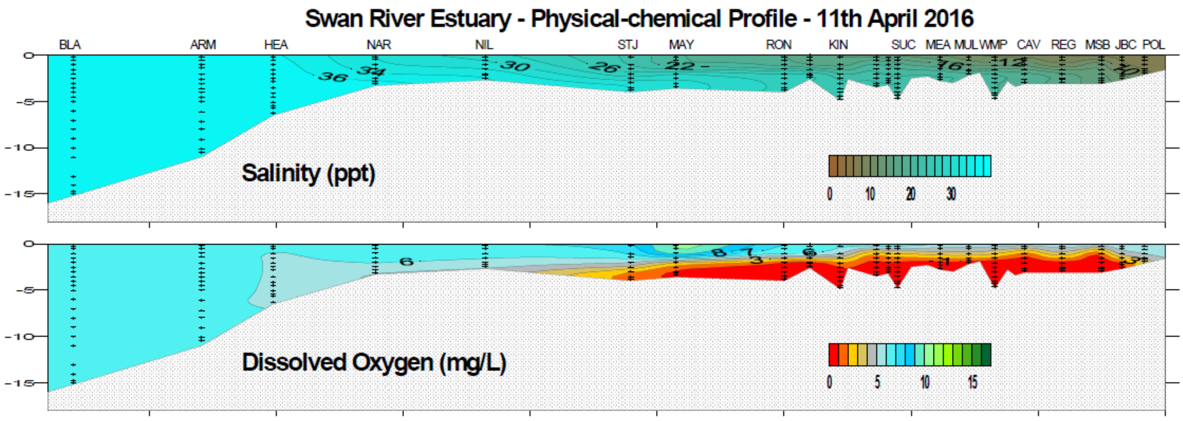




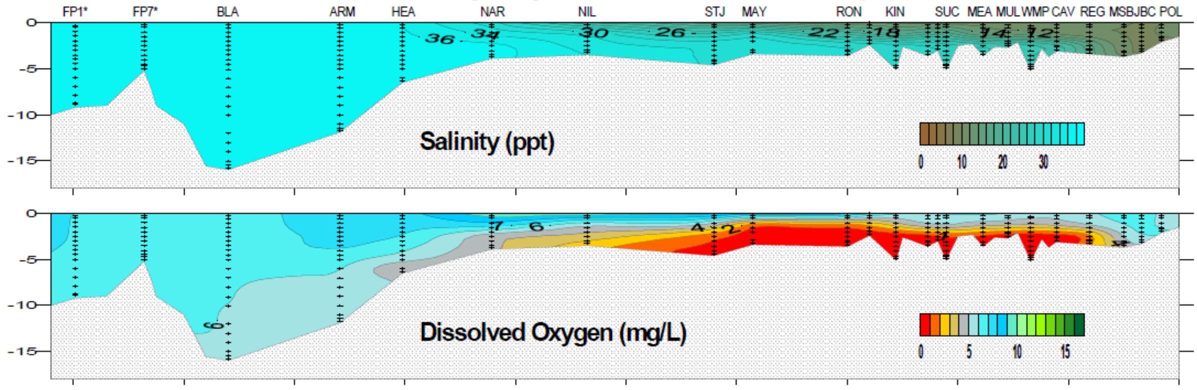


LSCE, MSE and USE zones in autumn 2016.

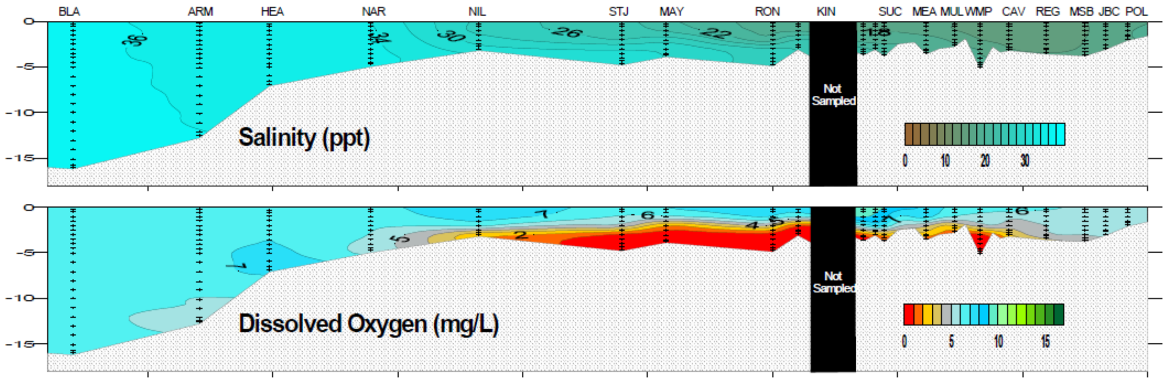




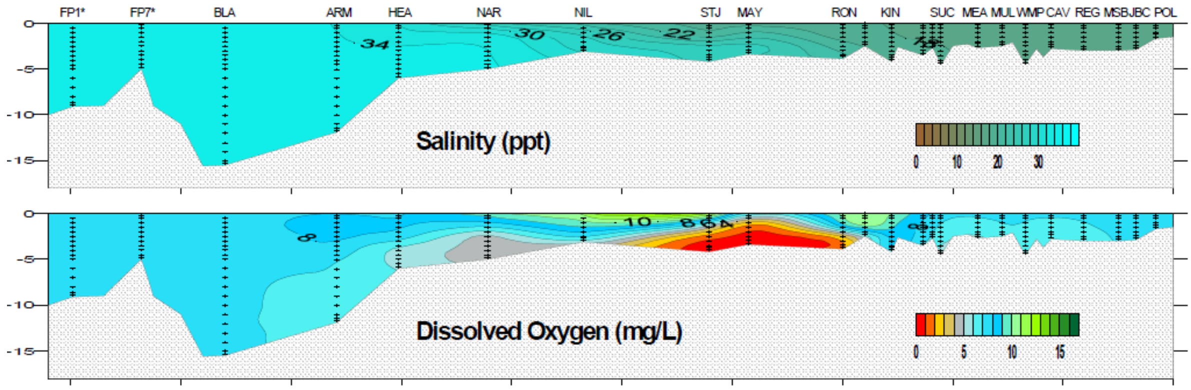
Swan River Estuary - Physical-chemical Profile - 18th April 2016



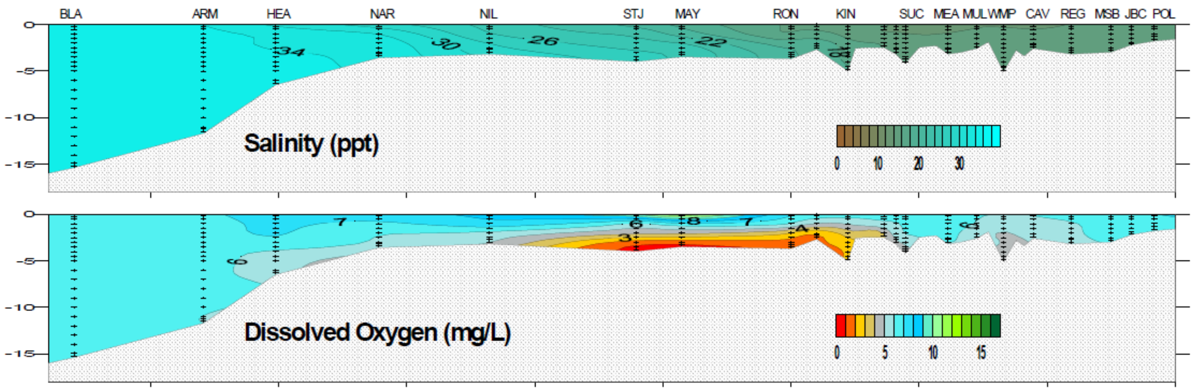
Swan River Estuary - Physical-chemical Profile - 26th April 2016



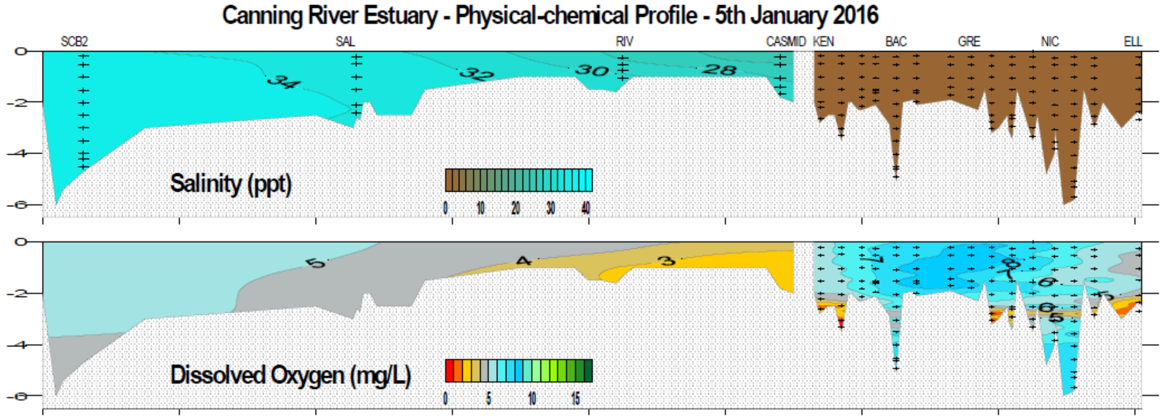
Swan River Estuary - Physical-chemical Profile - 2nd May 2016

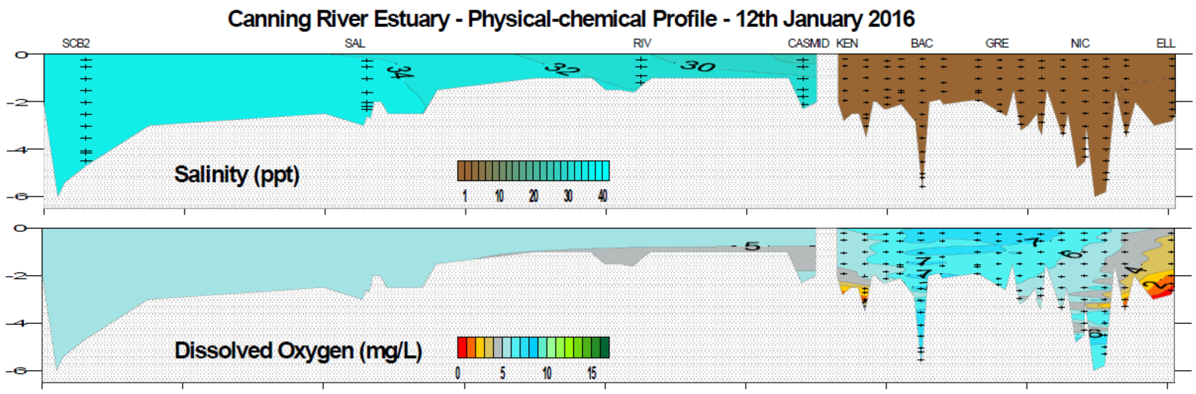


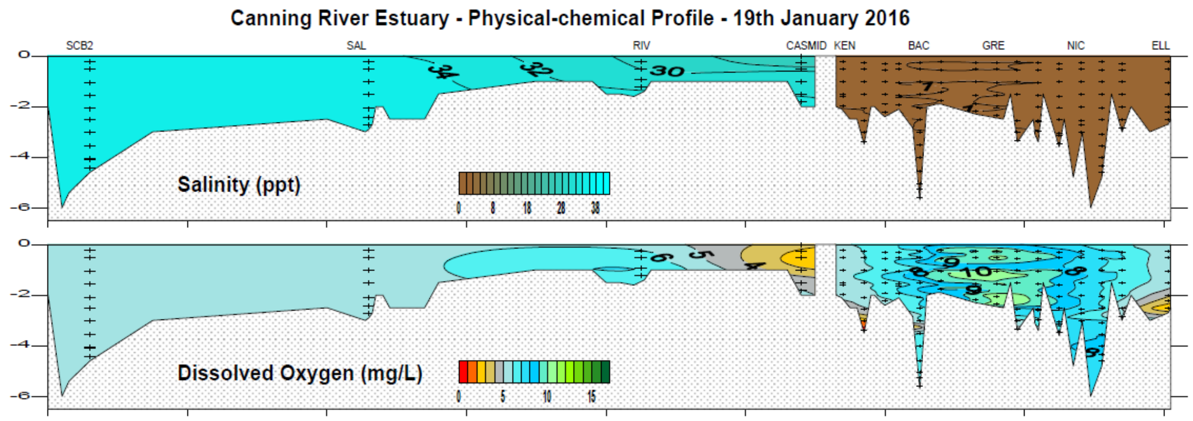
Swan River Estuary - Physical-chemical Profile - 9th May 2016

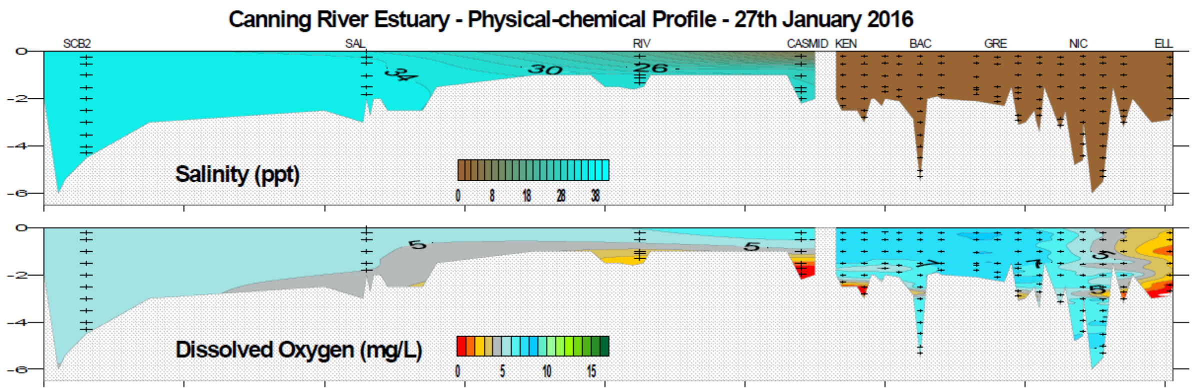


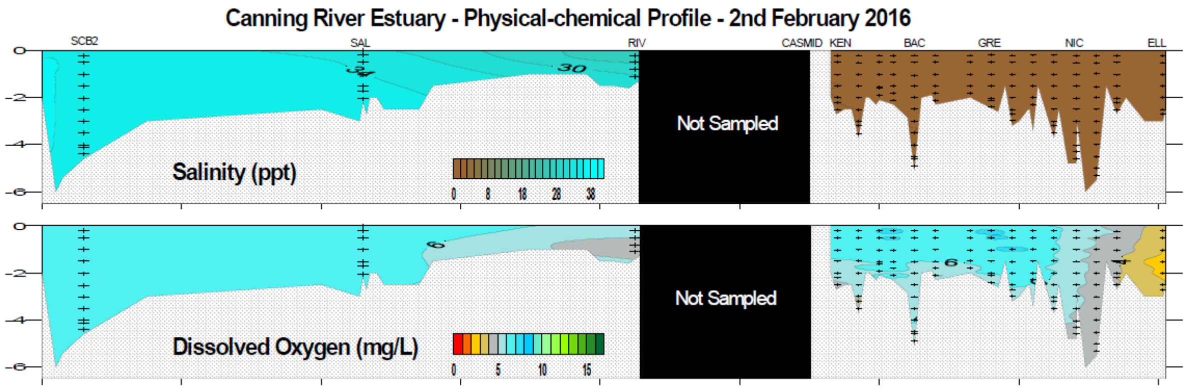
CE zone in summer 2016.

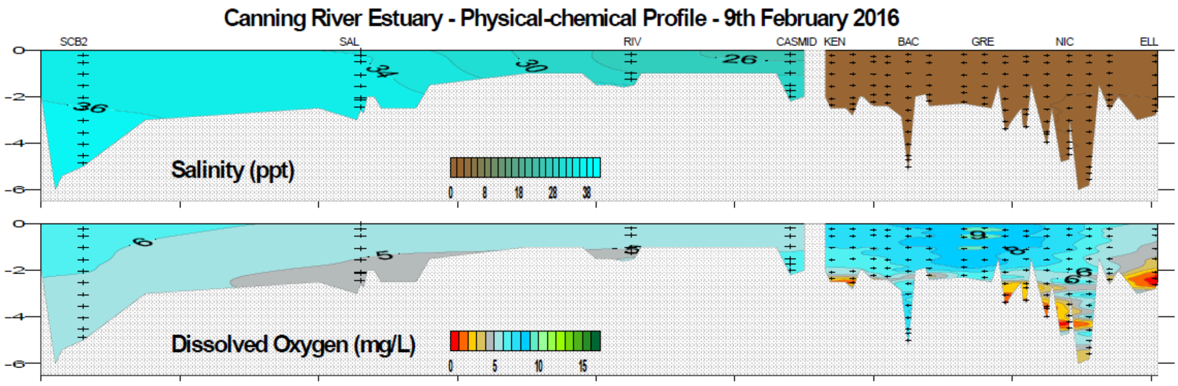




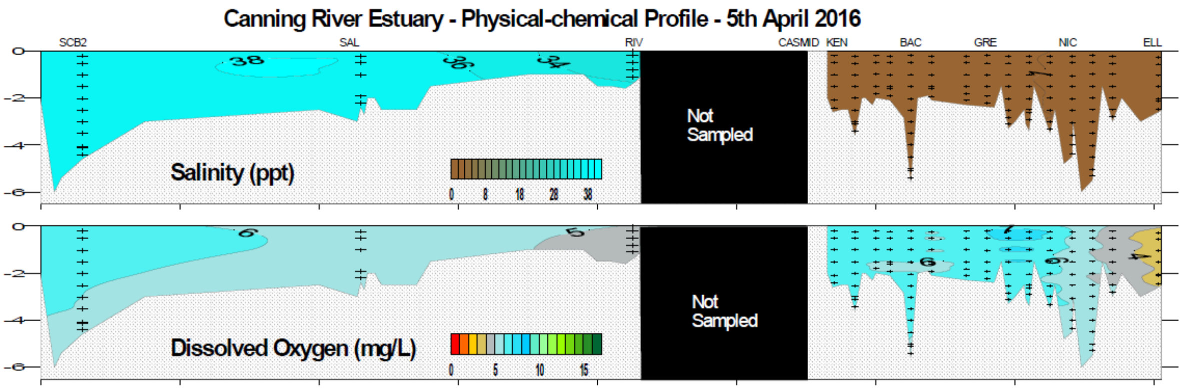




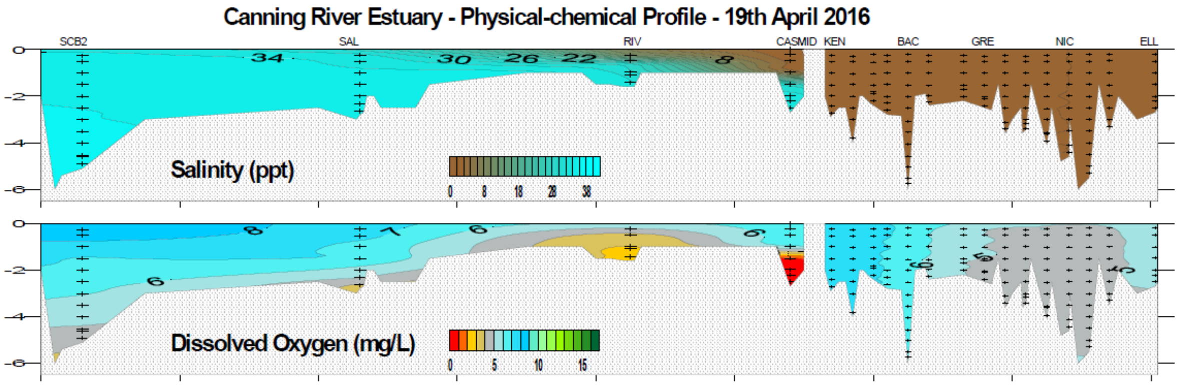


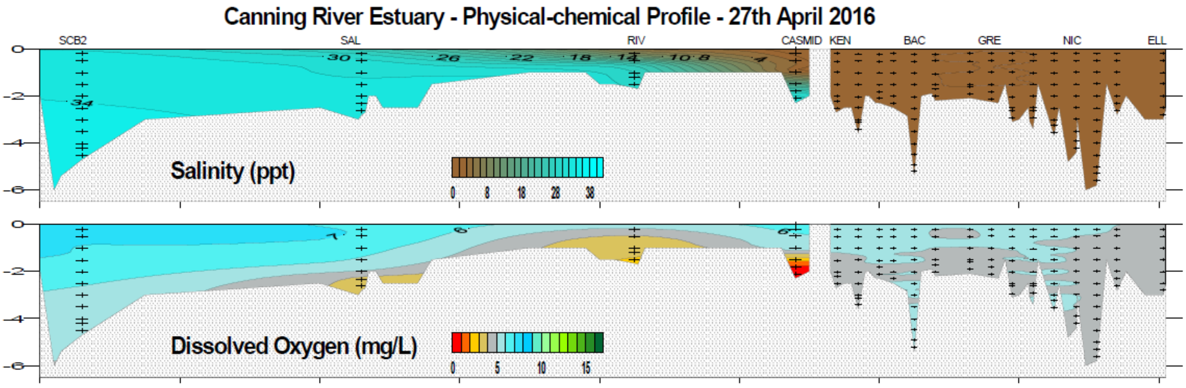


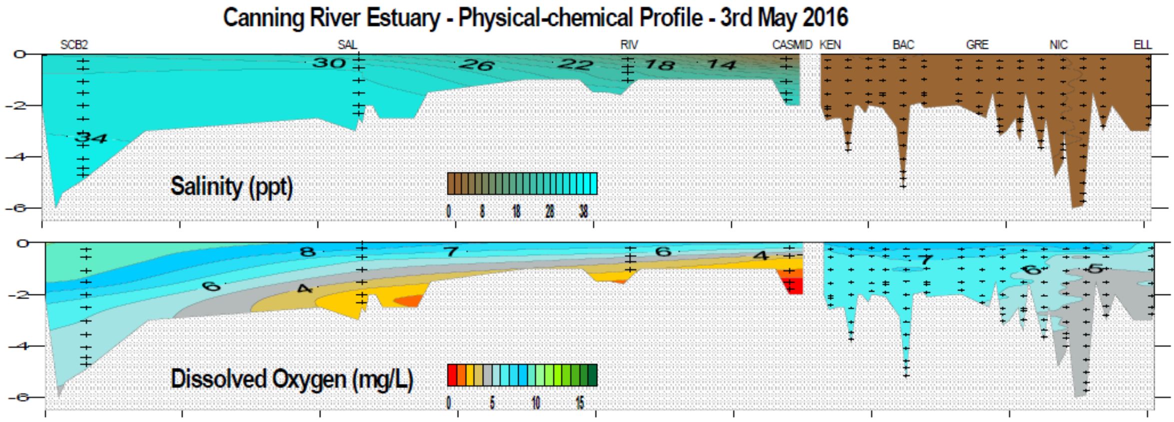
CE zone in autumn 2016.

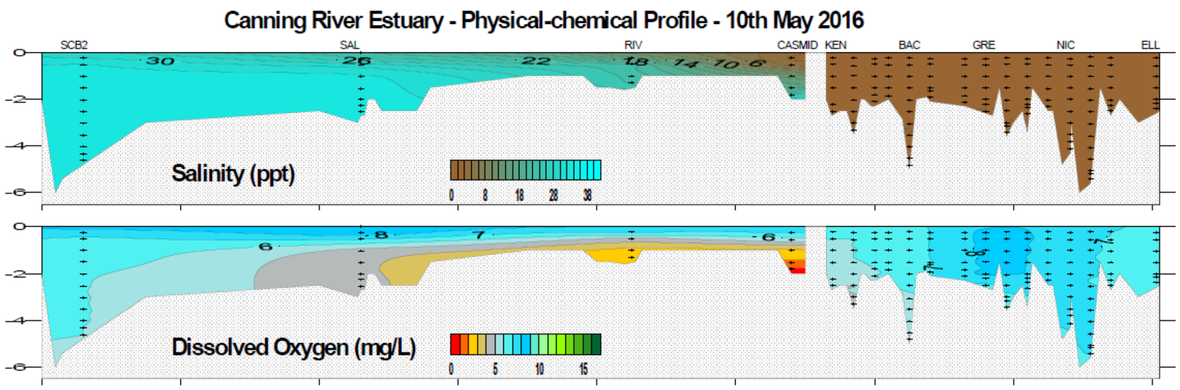


(12th April – corrupted file)


Canning River Estuary - Physical-chemical Profile - 19th April 2016
SCB2
SAL
RIV
CASMID
KEN
BAC
GRE
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)


Canning River Estuary - Physical-chemical Profile - 27th April 2016
SCB2
SAL
RIV
CASMID
KEN
BAC
GRE
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)


Canning River Estuary - Physical-chemical Profile - 3rd May 2016
SCB2
SAL
RIV
CASMID
KEN
BAC
GRE
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)


Canning River Estuary - Physical-chemical Profile - 10th May 2016
SCB2
SAL
RIV
CASMID
KEN
BAC
GRE
NIC
ELL
Salinity (ppt)
Dissolved Oxygen (mg/L)