Assessment of the condition of the Swan Canning Estuary in 2014, based on the Fish Community Indices of estuarine condition.

Final report

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Executive summary

This report, commissioned by the Swan River Trust, describes the monitoring and evaluation of fish communities in the Swan Canning Riverpark during 2014 and applies the Fish Community Indices that have been developed in recent years as a measure of the ecological condition of the Swan Canning Estuary. These indices, developed for 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 2014, with as many fish as possible 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 fish community.

Nearshore Fish Communities

Overall, the index scores derived from fish communities in the nearshore waters of the Swan Canning Estuary show that these estuarine habitats were in generally good (B) ecological condition across both summer and autumn 2014, with the average nearshore index scores for most zones and for the estuary as a whole lying between 63 and 76 in each season. The 2014 assessment for the estuary as a whole was consistent with, and a slight improvement on, the pattern of good-fair (B/C) condition assessments observed in recent years. This reflects an increase in the overall diversity of fish species present within the estuary in recent years, and is probably related to the relatively benign environmental conditions observed in 2014, with high and stable salinities and a relatively low prevalence of hypoxic conditions (dissolved oxygen <2 mg/L) throughout much of the system during the monitoring period.

The composition of nearshore fish communities in the Swan Canning Estuary in summer and autumn was similar to those observed during 2012 and 2013, and was again dominated by small bodied, schooling species. The most notable of these was the Elongate hardyhead (*Atherinosoma elongata*), which was the most abundant species overall and comprised 71% of the catches from the Lower Swan Canning Estuary (LSCE) zone, and the tropical hardyhead species, *Craterocephalus mugiloides*, which was again among the most common species in catches from the nearshore waters of all four zones. Other abundant species included Perth herring (*Nematalosa vlaminghi*) in the Canning Estuary (CE), Blowfish (*Torquigener pleurogramma*) in the LSCE, the Red-spot goby (*Papillogobius punctatus*) and Black bream (*Acanthopagrus butcheri*) in the Middle Swan Estuary (MSE) and Wallace's hardyhead (*Leptatherina wallacei*) and the Blue-spot goby (*Pseudogobius olorum*) in the Upper Swan Estuary (USE).

Notably, six individuals of the introduced Pearl cichlid (*Geophagus brasiliensis*) were caught from nearshore waters of the USE zone in January 2014. This is the first time this species has been

encountered during monitoring for the FCI and provides further evidence of its spread through the main body of the Swan River.

As is typically observed in this estuary, the number of species recorded in the nearshore waters of each zone was greatest in the lower reaches of the system (24 species) and declined in an upstream direction. However, the 21 species recorded from nearshore catches in the USE during 2014 was again notably higher than the 14 species recorded from comparable catches in the USE during 2012. Also, the overall total of 35 species recorded from nearshore waters throughout the estuary in 2014 was substantially higher than the 29 species recorded in previous years. These findings are thought in part to reflect a greater influx and penetration of marine species into the estuary during a prolonged period of high and stable salinities in the absence of significant freshwater flows.

Offshore fish communities

The ecological condition of offshore waters in the summer and autumn of 2014 was similar to the corresponding seasons in 2013, with a good to fair (B to C) grading across most zones. Scores were, however, notably lower for the CE zone in both seasons during 2014, which exhibited poor (D) ecological condition, based on fish communities. The poor condition observed in autumn was due in part to the effects of a significant *Karlodinium veneficum* bloom that occurred in the upper reaches of this zone in mid- to late-April and coincided with the prolonged presence of low dissolved oxygen conditions in the bottom waters. Despite the poor ecological condition of the CE zone during 2014, the results for offshore waters across the estuary as a whole were consistent with the pattern of good-fair (B/C) or fair-good (C/B) condition assessments that have been recorded for offshore waters since 2011, and demonstrate a sustained improvement on the poor condition recorded during 2008/09.

In general, the composition of offshore fish communities in summer and autumn of 2014 was also fairly typical for the Swan Canning Estuary, being dominated by Perth herring, which comprised just over 20% of the catches from the LSCE, 55% of those from the USE and over 80% of those from the CE and MSE. Other relatively abundant species included Yellowtail grunter (*Amniataba caudavittata*) in the MSE and USE, Tailor (*Pomatomus saltatrix*) in the CE and MSE, and the Southern eagle ray (*Myliobatis australis*) and Scaly mackerel (*Sardinella lemuru*) in the LSCE

Overall

The ecological condition of both nearshore and offshore waters across the estuary as a whole, based on fish communities, was again assessed as generally good (B) to fair (C) during the current monitoring year. This reflects the presence of relatively stable environmental conditions across much of the estuary during the 2014 monitoring period, including high and stable salinities and an absence of widespread hypoxic conditions or extensive harmful algal blooms.

Assessment of the condition of the Swan Canning Estuary in 2014, based on the Fish Community Indices of estuarine condition

Contents

Background

The Swan River Trust (SRT) has been working closely with other government agencies, 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.

Until recently the Trust's environmental monitoring program has been focused on water quality reporting in the estuary and catchment and it has long been envisaged that reporting on ecological health will be a key component of Riverpark reporting in the future. Reporting on changes in fish communities provides insight into the biotic integrity of the system and offers one measure to complement the existing water quality monitoring program

Through a collaborative project between the SRT, Murdoch University, Department of Fisheries and Department of Water, Fish Community Indices were developed for assessing the ecological condition of the Swan Canning Estuary (Valesini et al. 2011, Hallett et al. 2012, Hallett and Valesini 2012, Hallett 2014). These indices, which have been subjected to extensive testing and validation over a period of several years (e.g. Hallett and Valesini 2012), have 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. This is exemplified by the ability of the indices to track the changes in estuarine condition that were associated with harmful algal blooms during 2004 (Hallett et al. submitted), 2011 (Hallett et al. 2012) and 2012 (Hallett 2012b). Moreover, recent refinements of the grading system for the FCI have increased its ability to communicate, simply and reliably, the degree of ecological perturbation impacting on the Swan Canning Estuary and its individual management zones (Hallett 2014).

Rationale

The Fish Community Indices 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. The 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 Fish Community Indices therefore provide 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.

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). 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 (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 Fish Community Indices are scored from 0-10 according to the numbers and proportions of the various fish species present in samples collected from the estuary using either seine or gill nets. These metric scores are summed to generate an index 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 index scores (see methods section below for more details).

Study objectives

This report describes the monitoring and evaluation of fish communities in the Swan Canning Riverpark during 2014 for the purposes of applying the Fish Community Indices 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 Indices are calculated for nearshore and offshore waters in each management zone and for the estuary overall. The information shall be presented as quantitative index 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.

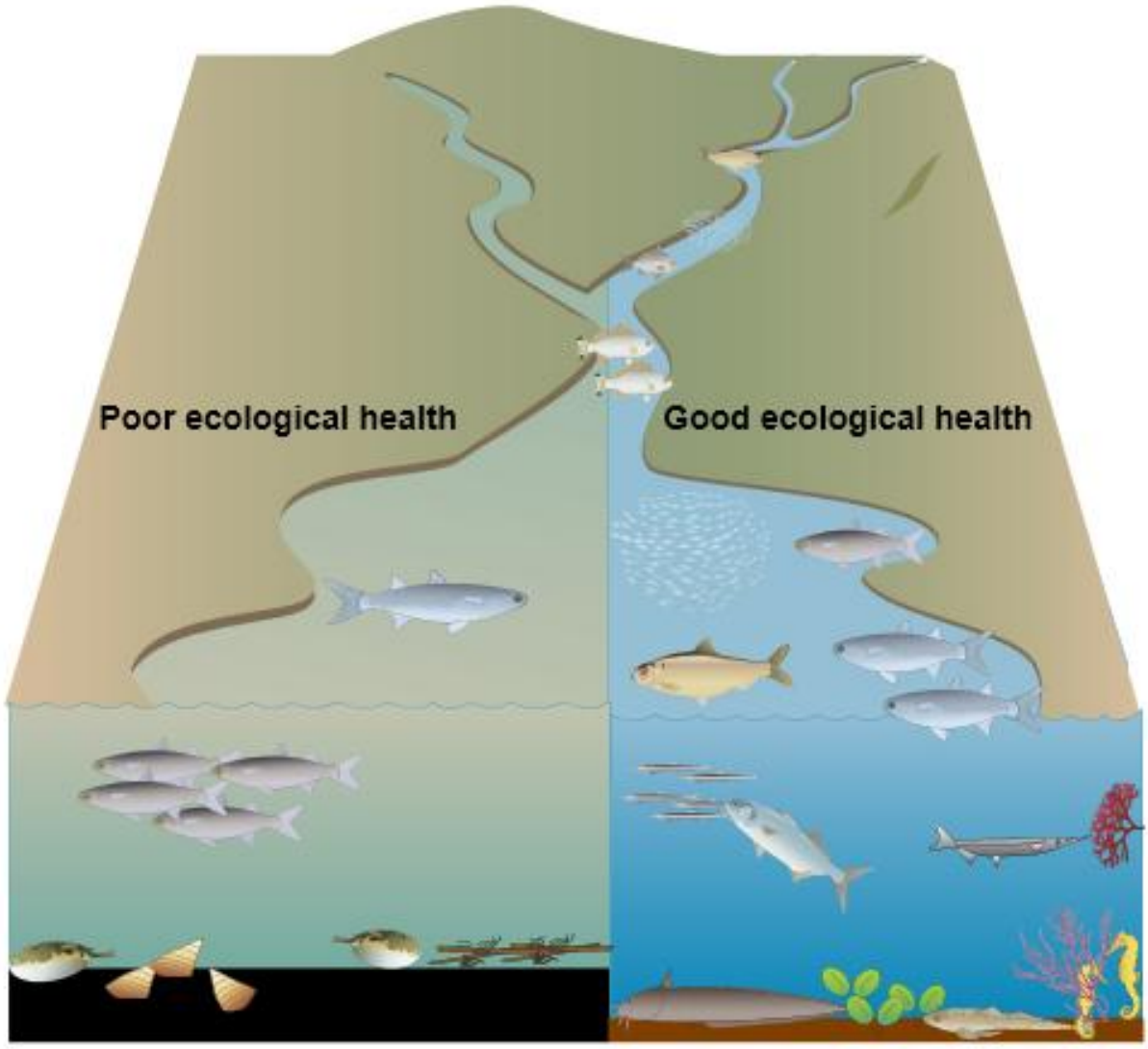


Figure 1. Conceptual diagram illustrating the predicted responses of the estuarine fish community to situations of poor and good ecological condition. (Images courtesy of the Integration and Application Network [ian.umces.edu/symbols/].)

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 (6-23 January) and autumn (7-23 April) 2014, using a 21.5 m seine net and 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 an 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 data on the abundances of each fish species from 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 index 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 index score (0-100) for each sample.
4. Compare the index 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 index scores and condition grades for nearshore and offshore samples collected during summer and autumn 2014 were then examined to assess the condition of the Swan Canning Estuary during this period and compared to previous years.

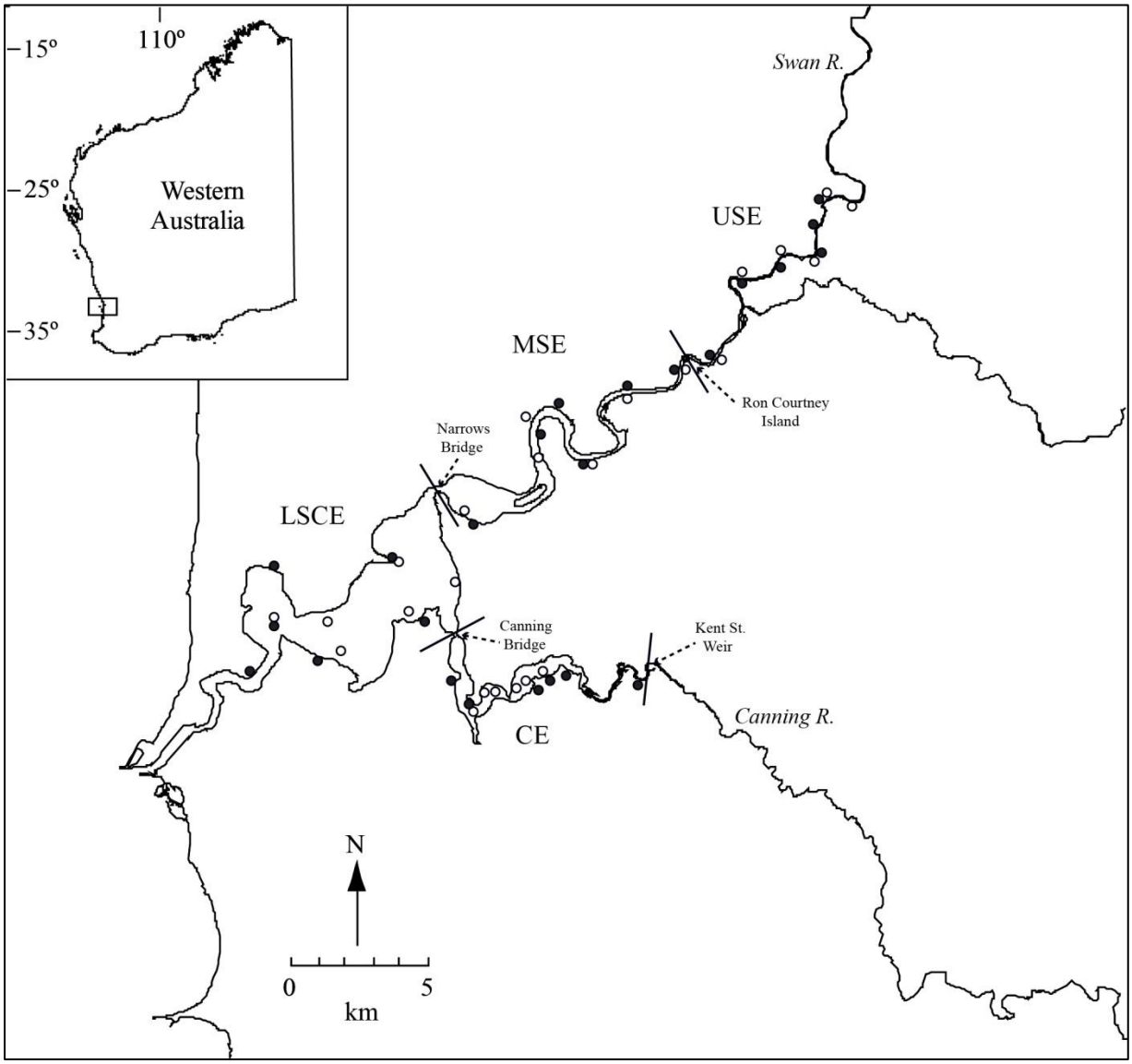


Figure 2: Locations of nearshore (black circles) and offshore (open circles) sampling sites for the Fish Community Indices of estuarine condition. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

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

Condition grade	Nearshore index scores	Offshore index 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, SRT).

Results and discussion

Description of the fish community of the Swan Canning Estuary during 2014

An estimated total of 30,825 fish, belonging to 35 species, were caught in seine net samples collected from the nearshore waters of the Swan Canning Estuary during summer and autumn 2014. The vast majority of these fish belonged to small, schooling species, most notably the hardyheads (Atherinidae). As was the case in both 2012 and 2013, the total number of species recorded per zone was greatest in the LSCE (24 species) and showed a slight decline upstream (Table 3). The total of 21 species captured from the USE is notably higher than the 14 species caught in this zone in 2012.

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 2014. 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
Atherinosoma elongata	Elongate hardyhead	**370.1**	**70.9**	**152.4**	**16.8**	26.9	6.7	17.4	4.5
Nematalosa vlaminghi	Perth herring	-	-	**315.4**	**34.8**	11.2	2.8	43.5	11.3
Craterocephalus mugiloides	Mugil's hardyhead	**21.0**	**4.0**	**180.5**	**19.9**	**46.8**	**11.6**	**60.1**	**15.7**
Leptatherina wallacei	Wallace's hardyhead	0.3	<0.1	142.0	15.6	20.5	5.1	**62.5**	**16.3**
Papillogobius punctatus	Red-spot goby	14.2	2.7	43.5	4.8	**85.8**	**21.4**	49.0	12.8
Acanthopagrus butcheri	Black bream	7.5	1.4	23.3	2.6	**39.9**	**9.9**	40.2	10.5
Pseudogobius olorum	Blue-spot goby	1.7	0.3	0.9	<0.1	12.1	3.0	**68.1**	**17.8**
Torquigener pleurogramma	Blowfish/Banded toadfish	**65.4**	**12.5**	2.4	0.3	10.3	2.6	-	-
Amniataba caudavittata	Yellowtail grunter	0.7	0.1	21.6	2.4	13.8	3.4	11.9	3.1
Engraulis australis	Southern anchovy	3.4	0.7	<0.1	<0.1	32.9	8.2	0.3	<0.1
Gerres subfasciatus	Roach	-	-	4.2	0.5	19.8	4.9	12.4	3.2
Amoya bifrenatus	Bridled goby	-	-	8.8	1.0	18.9	4.7	4.7	1.2
Aldrichetta forsteri	Yellow-eye mullet	1.3	0.2	3.7	0.4	15.6	3.8	2.2	0.6
Pelates octolineatus	Western striped grunter	13.4	2.6	0.1	<0.1	8.3	2.1	0.1	<0.1
Apogon rueppelli	Gobbleguts	6.0	1.1	-	-	15.1	3.8	-	-
Atherinomorus vaigiensis	Ogilby's hardyhead	4.5	0.9	-	-	14.2	3.5	2.0	0.5
Sillago burrus	Western trumpeter whiting	3.2	0.6	2.3	0.3	9.0	2.2	1.5	0.4
Mugil cephalus	Sea mullet	-	-	5.7	0.6	0.5	0.1	2.0	0.5
Favonigobius lateralis	Long-finned goby	8.1	1.6	-	-	-	-	-	-
Gambusia affinis	Mosquito fish	-	-	0.5	<0.1	-	-	2.2	0.6
Afurcagobius suppositus	Southwestern goby	-	-	-	-	-	-	1.9	0.5
Geophagus brasiliensis	Pearl cichlid	-	-	-	-	-	-	0.4	0.1
Elops machnata	Giant herring	-	-	-	-	-	-	0.4	<0.1
Hyperlophus vittatus	Sandy sprat	-	-	-	-	-	-	0.3	<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
(Cont'd)									
Platycephalus westraliae	Yellowtail flathead	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Haletta semifasciata	Blue weed whiting	0.2	<0.1	-	-	-	-	-	-
Pseudorhombus jenynsii	Small-toothed flounder	0.2	<0.1	-	-	-	-	-	-
Stigmatophora argus	Spotted pipefish	0.2	<0.1	-	-	-	-	-	-
Sillago schomburgkii	Yellow-fin whiting	0.1	<0.1	-	-	-	-	-	-
Rhabdosargus sarba	Tarwhine	0.1	<0.1	-	-	-	-	-	-
Myliobatis australis	Southern eagle ray	-	-	<0.1	<0.1	-	-	-	-
Lesueurina platycephala	Flathead sandfish	-	-	<0.1	<0.1	-	-	-	-
Parapercis haackei	Wavy grubfish	<0.1	<0.1	-	-	-	-	-	-
Pelsartia humeralis	Sea trumpeter	<0.1	<0.1	-	-	-	-	-	-
Pugnaso curtirostris	Pugnose pipefish	<0.1	<0.1	-	-	-	-	-	-
		24 Species		**20 Species**		**19 Species**		**21 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
		606	**7,266**	**1,053**	**12,635**	**466**	**5,591**	**444**	**5,333**

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 2014. 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 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	**4.6**	**20.8**	**24.9**	**88.2**	**44.5**	**82.4**	**15.9**	**54.6**
Amniataba caudavittata	Yellowtail grunter	<0.1	0.4	0.3	0.9	**6.8**	**12.5**	**8.7**	**29.7**
Pomatomus saltatrix	Tailor	1.4	6.4	**1.5**	**5.3**	**1.0**	**1.9**	0.5	1.7
Myliobatis australis	Southern eagle ray	**4.2**	**18.9**	<0.1	0.3	-	-	-	-
Platycephalus westraliae	Yellowtail flathead	3.1	14.0	0.3	0.9	0.3	0.6	0.3	1.1
Sardinella lemuru	Scaly mackerel	**3.3**	**14.8**	-	-	-	-	-	-
Gerres subfasciatus	Roach	1.4	6.4	**0.4**	**1.5**	0.3	0.6	0.6	2.0
Mugil cephalus	Sea mullet	-	-	0.3	1.2	-	-	**1.8**	**6.3**
Acanthopagrus butcheri	Black bream	0.4	1.9	-	-	0.2	0.3	0.7	2.3
Pelates octolineatus	Western striped grunter	1.0	4.6	0.2	0.6	-	-	-	-
Argyrosomus japonicus	Mulloway	0.3	1.1	-	-	0.3	0.5	0.4	1.4
Rhabdosargus sarba	Tarwhine	0.7	3.0	-	-	-	-	-	-
Pseudocaranx wrightii	Sand trevally	0.6	2.7	-	-	-	-	-	-
Elops machnata	Giant herring	0.2	0.8	-	-	0.3	0.5	<0.1	0.3
Sillago burrus	Western trumpeter whiting	0.5	2.3	-	-	-	-	-	-
Torquigener pleurogramma	Banded toadfish	0.2	0.8	0.3	0.9	<0.1	0.2	-	-
Engraulis australis	Southern anchovy	-	-	-	-	0.3	0.5	0.2	0.6
Cnidoglanis macrocephalus	Estuarine cobbler	0.2	0.8	-	-	-	-	-	-
Carcharinas leucas	Bull shark	-	-	-	-	<0.1	0.2	-	-
Hippocampus angustus	Western spiny seahorse	<0.1	0.4	-	-	-	-	-	-
Aldrichetta forsteri	Yelloweye mullet	-	-	<0.1	0.3	-	-	-	-
		17 Species		**10 Species**		**11 Species**		**10 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
		22	**264**	**28.3**	**339**	**54**	**648**	**29.2**	**350**

Notable differences were observed between zones in the total densities of fish, being greatest in the CE (1,053 fish/100m^2, on average) and lowest in the MSE and USE (466 and 444 fish/100m^2, respectively). However, total fish densities typically show a great degree of variability over space and time and provide little information about estuarine condition.

Consistent with sampling in the two previous years, small hardyhead species were highly abundant in catches from the nearshore waters of the estuary. The Elongate hardyhead (*Atherinosoma elongata*) was the most abundant species overall, and comprised 71% of the catches from the LSCE zone (Table 3). The tropical hardyhead species, *Craterocephalus mugiloides*, was again among the most common species in catches from the nearshore waters of all four zones, comprising 4-20% of the total catch per zone. Other abundant species included Perth herring (*Nematalosa vlaminghi*) in the CE (35% of the total catch), Blowfish (*Torquigener pleurogramma*) in the LSCE (12.5%), the Red-spot goby (*Papillogobius punctatus*) and Black bream (*Acanthopagrus butcheri*) in the MSE and Wallace's hardyhead (*Leptatherina wallacei*) and the Blue-spot goby (*Pseudogobius olorum*) in the USE.

Gill net samples collected in summer and autumn 2014 from offshore waters returned 1,601 fish comprising 21 species (Table 4). The total number of species again declined in an upstream direction, from 17 species in the LSCE to 10 species in the USE and CE. 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 2012 and 2013 (Hallett 2012a, 2013). The total catches of fishes recorded per zone were very similar for the LSCE, CE and USE, with 22-29 fish per gill net set, whilst 54 fish were caught per gill net in the MSE (Table 4). As in the two previous years, the dominant species in the gill net catches from all four zones was the Perth herring, which comprised just over 20% of the catches from the LSCE, 55% of those from the USE and over 80% of those from the CE and MSE. Other relatively abundant species included Yellowtail grunter (*Amniataba caudavittata*) in the MSE and USE, Tailor (*Pomatomus saltatrix*) in the CE and MSE, and the Southern eagle ray (*Myliobatis australis*) and Scaly mackerel (*Sardinella lemuru*) in the LSCE (Table 4).

The nearshore and offshore fish communities of the Swan Canning Estuary in 2014 were thus broadly similar in composition to those observed during equivalent monitoring conducted in 2012 and 2013 (Hallett 2012a, 2013). Catches using each of the two net types exhibited comparable total fish abundances in 2012, 2013 and 2014, and were dominated by broadly similar suites of species in each year. However, whilst the total numbers of species recorded among the offshore catches in each zone in 2014 were consistent with those in 2012 and 2013, the total of 35 species recorded from nearshore waters throughout the estuary in 2014 was notably higher than the 29 species recorded in both 2012 and 2013. Most notably, the total of 21 species recorded from nearshore catches in the USE during 2014 (Table 3) was again higher than the 14 species recorded from comparable catches in the USE during 2012. As was the case in 2013, these findings are thought in part to reflect a greater influx and penetration of marine species into the estuary during 2014 than during 2012. Salinities were found to be higher during sampling in 2014, compared with 2012 and salinities in autumn exceeded those of 2012 and 2013 (appendix iv). A wide range of marine straggler species, which enter estuaries sporadically and generally in low numbers, were thus captured from the nearshore waters of the Swan Canning Estuary during 2014. These included the Southern eagle ray, Sandy sprat (*Hyperlophus vittatus*), Flathead sandfish (*Lesueurina platycephala*), Wavy grubfish (*Parapercis haackei*) and Sea trumpeter (*Pelsartia humeralis*).

It is also important to note that the Pearl cichlid (*Geophagus brasiliensis*; Fig. 4) was encountered in 2014 for the first time during monitoring for the FCI. Six individuals of this species, which was first reported from the Swan River catchment in 2006 (Beatty et al. 2013), were captured from the nearshore waters of three sites in the USE zone during January 2014 (Fig. 5).

Figure 4: Pearl cichlid, *Geophagus brasiliensis* (Image courtesy of David Morgan, Freshwater Fish Group & Fish Health Unit, Murdoch University).

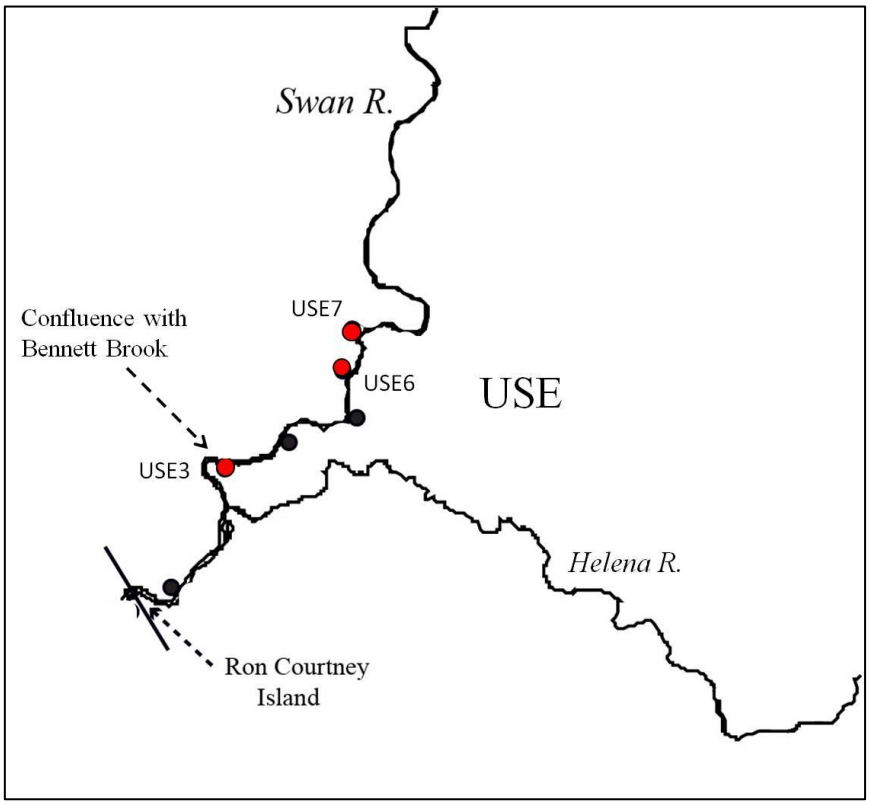


Figure 5: Map of the Upper Swan Estuary (USE) zone of the Swan Canning Riverpark, showing the sites (red circles) of Pearl cichlid captures during monitoring in summer of 2014.

The lengths of captured individuals suggest that these fish were sexually mature and thus capable of breeding (Beatty et al. 2013). Furthermore, the capture of several Pearl cichlids from sites USE6 and USE7, approximately 3-4 km upstream from the Bennett Brook confluence, provides further confirmation that this species is now colonising the main body of the Swan River. Given the brackish waters from which these individuals were captured (Table 5) and the documented ability of this species to tolerate direct exposure to high salinities (18-27) and to acclimate to full strength seawater (36; De Graaf and Coutts, 2010), it is highly likely that this species is capable of spreading throughout large parts of the system, both upstream and downstream of its current distribution.

Table 5: Capture details for Pearl cichlids encountered during sampling of the Upper Swan Estuary (USE) zone in summer of 2014.

Date	Site	Total lengths of each fish (mm)	Ambient water conditions at time of sampling		
			Temperature (°C)	Salinity	Dissolved oxygen (mg/L)
08/01/2014	USE6	142	28.6	13.5	6.5
08/01/2014	USE7	121, 123, 125	28.6	13.1	6.0
22/01/2014	USE3	146, 152	30.3	19.0	7.2

Ecological condition in 2014 and comparison to other periods

The ecological condition (based on fish communities) of the nearshore waters of the Riverpark was consistently good (B) across summer and autumn 2014, with the average nearshore index scores for most zones and for the estuary as a whole lying between 63 and 76 in each season (Fig. 6). The nearshore scores and condition grades were fairly consistent between summer and autumn of 2014 for most zones, although the nearshore condition of the CE and USE zones improved from summer to autumn, likely reflecting the movement of fish from the deeper waters of these zones into the more favourable conditions of the adjacent nearshore waters during autumn (see below).

Overall, these results are consistent with a pattern of good-fair (B/C) condition assessments in recent years, following an apparent improvement in the nearshore condition of the estuary (based on fish communities) as a whole between 2005/06 and 2008/09 (Fig. 7). The factors underlying this improvement, and the observed increase in nearshore index scores from 2013 to 2014, are not known. However, they may reflect, at least in part, observed increases in the overall diversity (i.e. numbers of species) of fish within the estuary in recent years. This, in turn, may reflect the relatively benign environmental conditions observed in 2014, with high and stable salinities and a relatively low prevalence of hypoxic conditions (dissolved oxygen <2 mg/L) throughout much of the system during the monitoring period (appendices iv and v).

Examination of the radar plots of nearshore metric scores for each zone in each season confirms that, as was the case in 2013, the USE zone harboured a relatively high number of species in both summer and autumn 2014 (as shown by high scores of >8 for this positive metric; Fig. 8). This likely reflects the effects of high and stable salinities coupled with benign environmental conditions, as outlined above. In contrast, the number of species was relatively low in the CE in summer and in

the LSCE in autumn of 2014, as shown by scores of approximately 4 or less for this positive metric (Fig. 8).

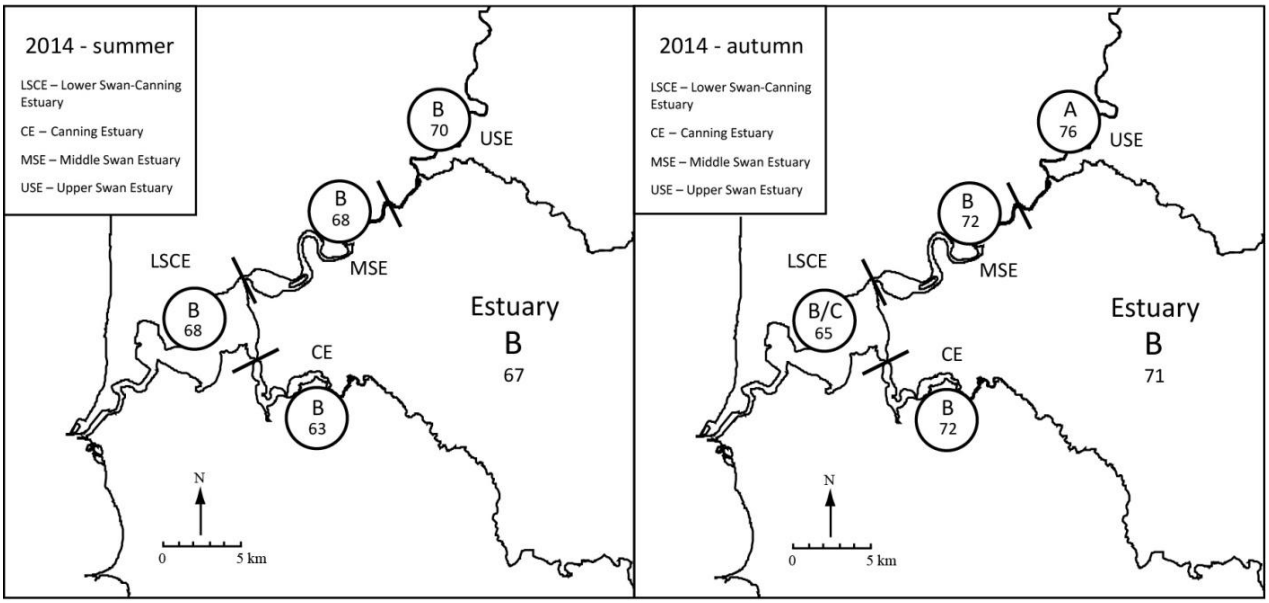


Figure 6: Average nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2014.

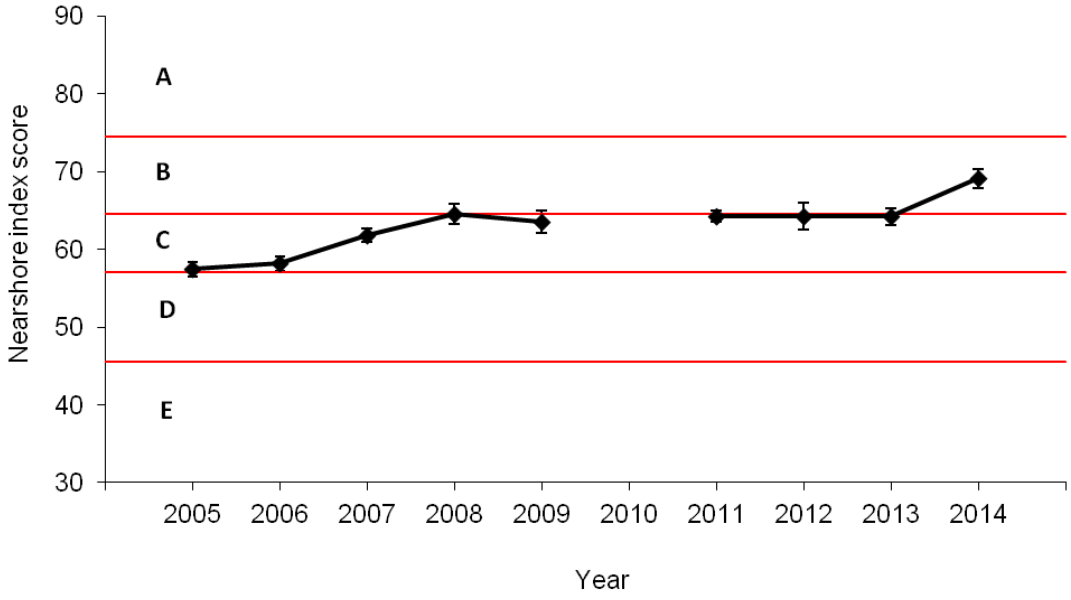
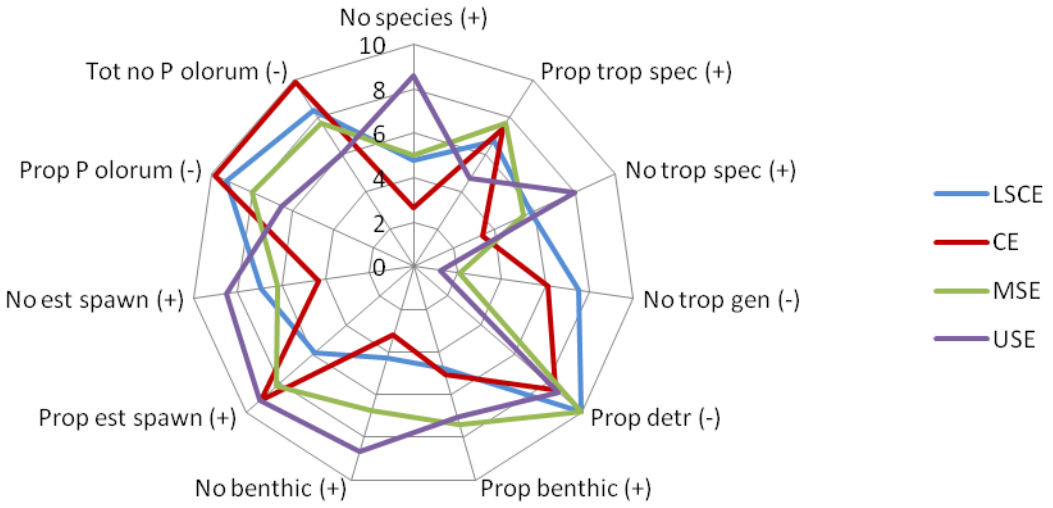


Figure 7: Trend plot of average (±SE) nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for the Swan Canning Estuary as a whole, over recent years.

(a) Summer 2014



(b) Autumn 2014

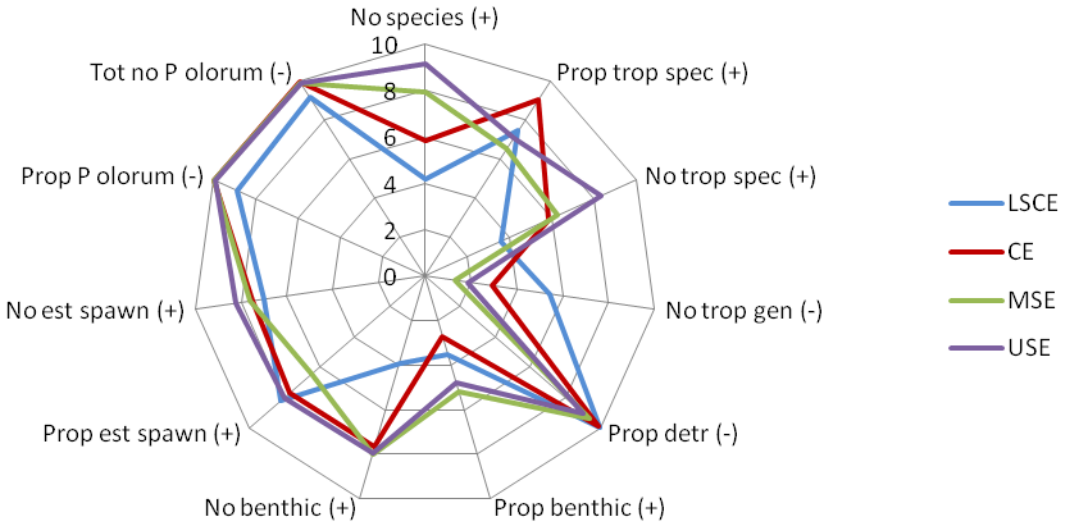


Figure 8: Average scores (0-10) for each component metric of the nearshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2014. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names).

The ecological condition of the Riverpark's offshore waters in summer and autumn of 2014 was broadly similar to that observed in the corresponding seasons of the previous year (see Hallett 2013). Offshore ecological condition was again assessed as being good to fair (B to C) across most zones, with the average FCI score for any particular zone in a given season differing by just 4 points or less between 2013 and 2014 (Fig. 9).

However, offshore index scores for the CE zone in both seasons were notably lower in 2014 than in 2013, revealing poor ecological condition based on fish communities (Fig. 9), which were dominated numerically by Perth Herring, a popular recreational species (Table 4). The reasons for the poor scores are unclear in the case of summer, though the poor condition of the CE during autumn of 2014 partly reflects the presence of a harmful algal bloom that occurred in the upper part of this zone in mid- to late-April of this year. High levels of *Karlodinium veneficum* were observed between Castledare and Kent Street Weir during this period, and were accompanied by prolonged hypoxic conditions (dissolved oxygen <2 mg/L) in the bottom waters of this stretch of the CE zone (Swan River Trust, unpublished data). The ecological impacts of the poor environmental conditions present at this time were evidenced by the collection of approximately 70 dead fish from the affected area during the bloom (Swan River Trust, unpublished data).

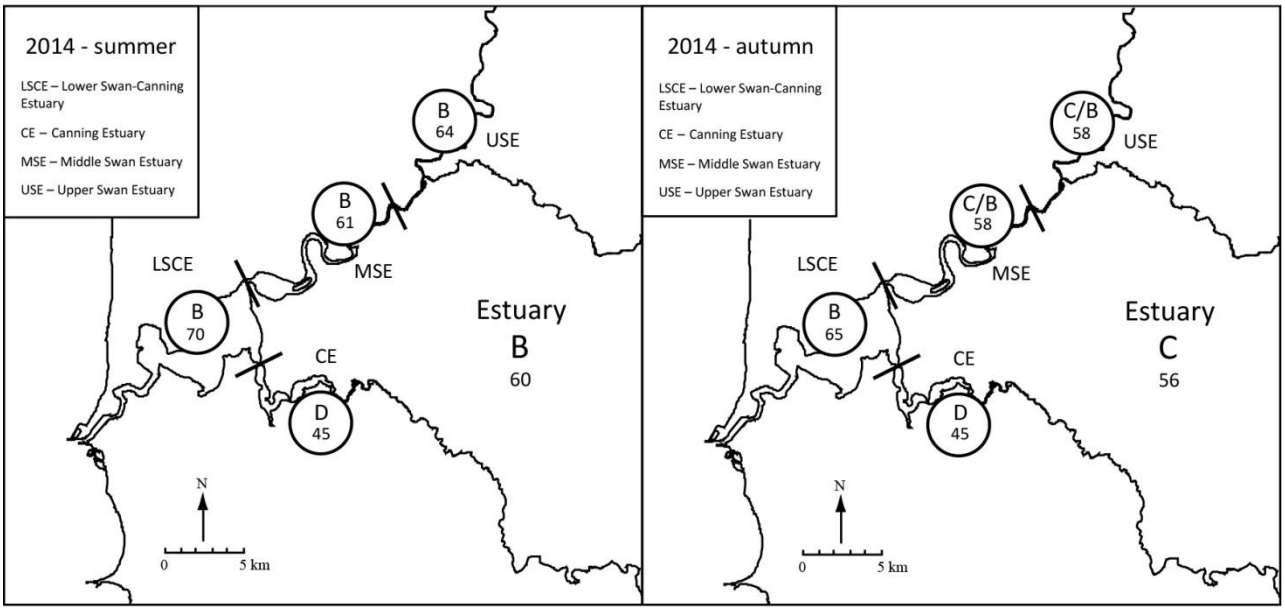


Figure 9: Average offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2014.

Despite the relatively poor ecological condition of the CE zone during 2014, the average FCI scores for offshore waters across the estuary as a whole were very similar to those recorded in 2013, i.e. 60 (B) in summer and 56 (C) in autumn (Fig. 9). These results are consistent with the pattern of good-fair (B/C) or fair-good (C/B) condition assessments that have been recorded for offshore waters since 2011, and demonstrate a sustained improvement on the poor condition recorded during 2008-09 (Fig. 10).

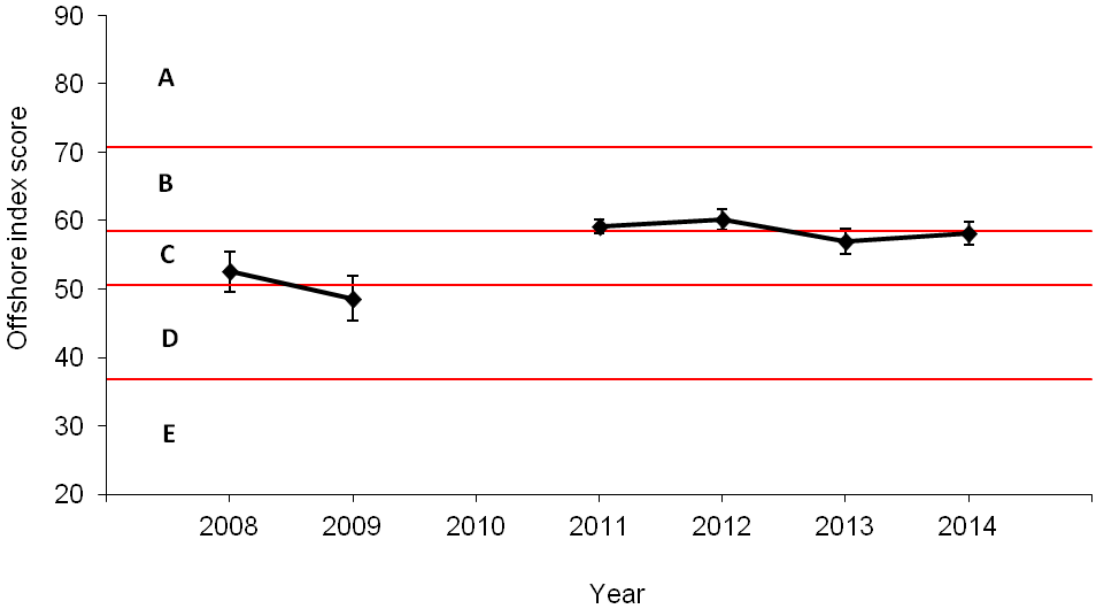


Figure 10: Trend plot of average (±SE) offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor), for the Swan Canning Estuary as a whole, over recent years.

Examination of the radar plots of offshore metric scores for each zone in each season reveal the poor ecological condition of the CE during both summer and autumn of 2014 to have been driven by relatively low numbers and diversity of fish species and by a relatively high proportion of fish species that feed on decomposing organic material (e.g. Perth Herring). This is indicated by very low average scores for Number of species and Shannon-Wiener diversity (both positive metrics) and for the Proportion of detritivores (a negative metric; Fig. 11). These findings mirror those reported in previous years for the CE zone (Hallett 2013).

In summary, the ecological condition of both nearshore and offshore waters across the estuary as a whole, based on fish communities, was again assessed as generally good (B) to fair (C) during the current monitoring year. This reflects the presence of relatively stable environmental conditions across much of the estuary during the 2014 monitoring period, including high and stable salinities and an absence of widespread hypoxic conditions or extensive harmful algal blooms. An exception to this pattern was the offshore waters of the CE, which exhibited poor ecological condition (based on fish communities) during 2014. This may be due in part to the effects of a harmful *Karlodinium veneficum* bloom that occurred in the upper stretches of this zone in mid- to late-April and coincided with the prolonged presence of hypoxic conditions in the bottom waters.

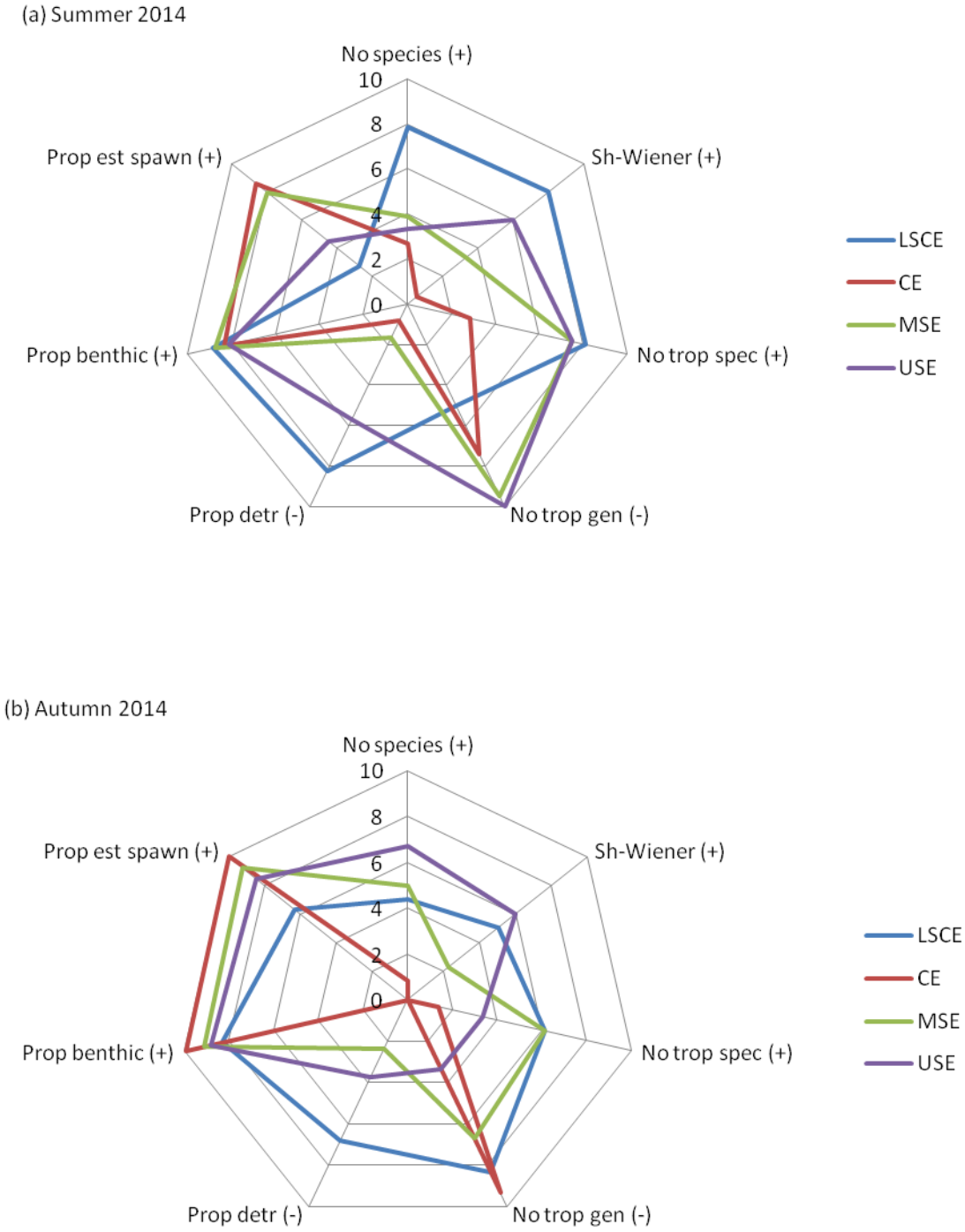


Figure 11: Average scores (0-10) for each component metric of the offshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2014. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names).

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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.* 2006), 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 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 affinis	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
Apogon rueppelli	Gobbleguts	BP	ES	ZB
Siphamia cephalotes	Woods Siphonfish	BP	MS	ZB

Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
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
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
Papillogobius 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

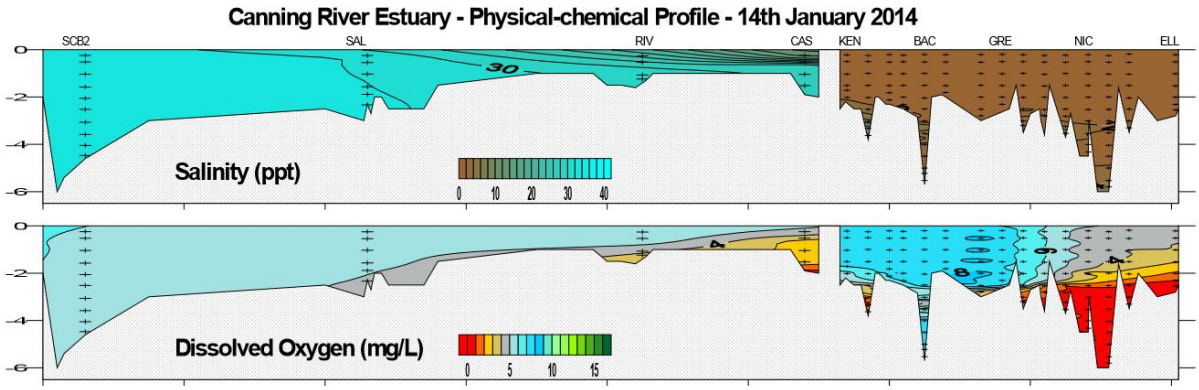
Species name	Common name	Habitat guild	Estuarine Use guild	Feeding Mode guild
Brachaluteres jacksonianus	Southern pygmy leatherjacket	D	MS	OV
Scobinichthys granulatus	Rough Leatherjacket	D	MS	OV
Chaetodermis pencilligera	Tasselled leatherjacket	D	MS	OV
Meuschenia freycineti	Sixspine leatherjacket	D	MM	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): **Average salinities, measured at the time of sampling, across all nearshore and offshore sampling sites during 2012, 2013 and 2014.**

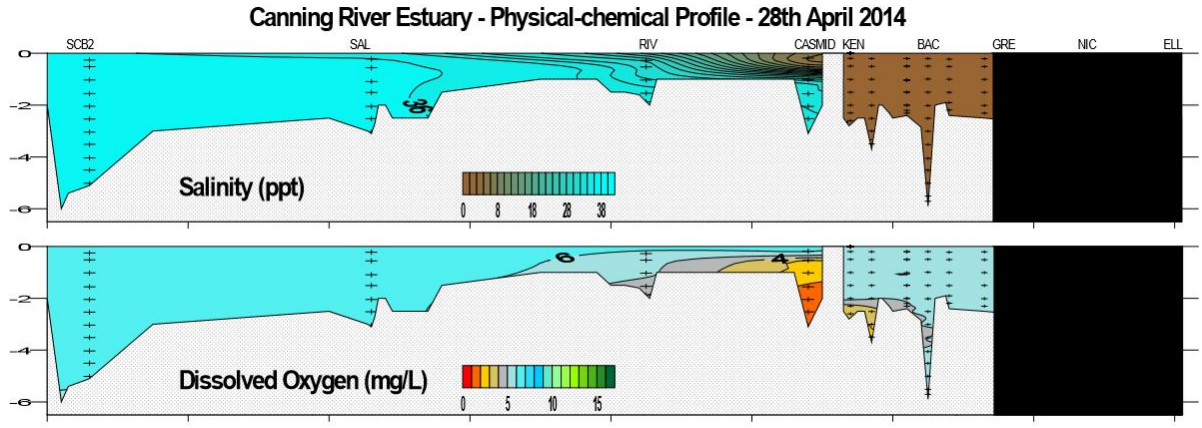
	2012		2013		2014	
	Summer	Autumn	Summer	Autumn	Summer	Autumn
Nearshore	25.3	28.9	30.6	30.6	27.4	33.2
Offshore (surface)	26.0	30.4	30.9	30.6	27.6	33.5
Offshore (bottom)	26.4	31.7	31.5	32.5	28.7	33.9

<u>Appendix (v):</u> 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 closely corresponding to fish community sampling of:

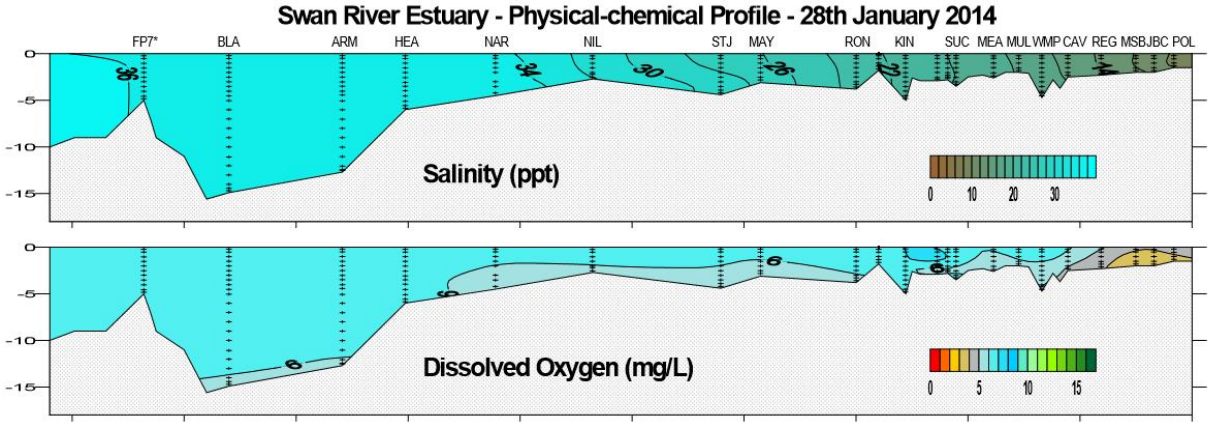
CE zone in summer 2014.



CE zone in autumn 2014.



LSCE, MSE and USE zones in summer 2014.



LSCE, MSE and USE zones in autumn 2014.