Assessment of the condition of the Swan-Canning Estuary in 2012, based on the Fish Community Indices of estuarine condition.

Final report

January 2013

Hallett, C.S.

Centre for Fish, Fisheries and Aquatic Ecosystems Research,
Murdoch University

Centre for Fish, Fisheries and Aquatic Ecosystems Research

Murdoch UNIVERSITY

Prepared for the Swan River Trust

Disclaimer

The authors have prepared this report in accordance with the usual care and thoroughness of the Centre for Fish, Fisheries and Aquatic Ecosystems Research (CFFAER), for use by the Swan River Trust (SRT) and only those third parties who have been authorised in writing by the CFFAER to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose required by the SRT. The methodology adopted and sources of information used by the authors are outlined in this report. The authors have made no independent verification of this information beyond the agreed scope of works, and they assume no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to the authors was false. This report was prepared between July and September 2012 and revised between November 2012 and January 2013, and is based on the information reviewed at the time of preparation. The authors disclaim any responsibility for changes that may have occurred after this time. This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Executive summary

This report, commissioned by the Swan River Trust, describes the monitoring and evaluation of fish communities in the Swan-Canning Riverpark during 2012 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 zones of the estuary during summer and autumn 2012, with as many fish as possible returned to the water alive following their identification. 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 scoring thresholds to determine condition grades (A-E) for each zone and for the estuary as a whole, based on the fish community.

The composition of nearshore fish communities for the Swan-Canning Estuary in summer and autumn was dominated by small bodied, schooling species. Most notable of these were the tropical, marine hardyhead C*raterocephalus mugiloides* in the lower zones of the estuary and the freshwater/estuarine hardyhead *Leptatherina wallacei* in the upper reaches of the system. The number of species recorded in nearshore waters zones was greatest in the lower reaches of the estuary (24 species) and declined upstream.

Overall, the index scores derived from fish communities in the nearshore waters of the Swan-Canning Riverpark suggest the estuary was in generally good to fair ecological condition across summer and autumn 2012. Average nearshore index scores of between 64 and 71 were recorded for three zones, and for the estuary as a whole, in each season. In comparison to historic data, the 2012 assessment was consistent with good to fair (B to C) condition assessments for nearshore waters in recent years, following an apparent improvement in the condition of the estuary as a whole between 2005/06 and 2008/09, based on the fish community data.

Two zones displayed comparatively lower index scores for nearshore waters in 2012. In summer, the Upper Swan Estuary (USE) scored relatively poor ecological condition (D) based on the fish communities in that zone. The result may be explained by the fact that the zone was recovering from a low dissolved oxygen and fish kill event (22 January 2012) influencing the abundance of estuarine spawners and benthic species.

Fewer fish species (particularly benthic and specialist feeders) were evident in the nearshore areas of the Lower Swan-Canning Estuary (LSCE) zone in autumn, resulting in a poor-fair condition (D/C) at that time. These results may reflect a more modest immigration of marine species into the estuary than might typically be expected during this season.

The composition of offshore fish communities was also fairly typical for the Swan-Canning Estuary in summer and autumn, being dominated by Perth herring, with notable catches of Tailor in the LSCE and of Black bream in the USE.

Offshore waters consistently exhibited good to fair (B to C) ecological condition based on fish communities across summer and autumn 2012, with average offshore index scores of 60-70 for most zones and for the estuary as a whole. The lowest fish community index scores in any zone in 2012 were in the Canning Estuary (CE), recording 51 and 54 in summer and autumn, respectively. The fair

to fair-poor ecological condition assessments, based on these scores, were driven by relatively low numbers and diversity of species and by a high proportion of species that feed on detritus (decomposing organic material).

Background

The Swan River Trust 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 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 program

Through a collaborative project between the Trust, Murdoch University, Department of Fisheries and Department of Water, Fish Community Indices have been developed for assessing the ecological condition of the Swan-Canning Estuary (Hallett et al. 2012, Hallett and Valesini 2012). These 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-based indices therefore provide a means to assess an important component of the ecology of the system and how it responds to changes in estuarine condition.

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

In response to increasing degradation of estuarine ecosystems, fish species with specific habitat, feeding or other environmental requirements will become less abundant and diverse, whilst a few species with more general requirements become more abundant, ultimately leading to an overall reduction in the diversity of fish species. 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.* Perth herring and Yellow-tail grunter) will decrease, as will the overall number and diversity of species. In contrast, generalist feeders (*e.g.* Banded toadfish or blowfish) and species called 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 undegraded system which is subjected to fewer human stressors (right side of Fig. 1; noting that this conceptual diagram represents a continuum of ecological condition from poor to good).

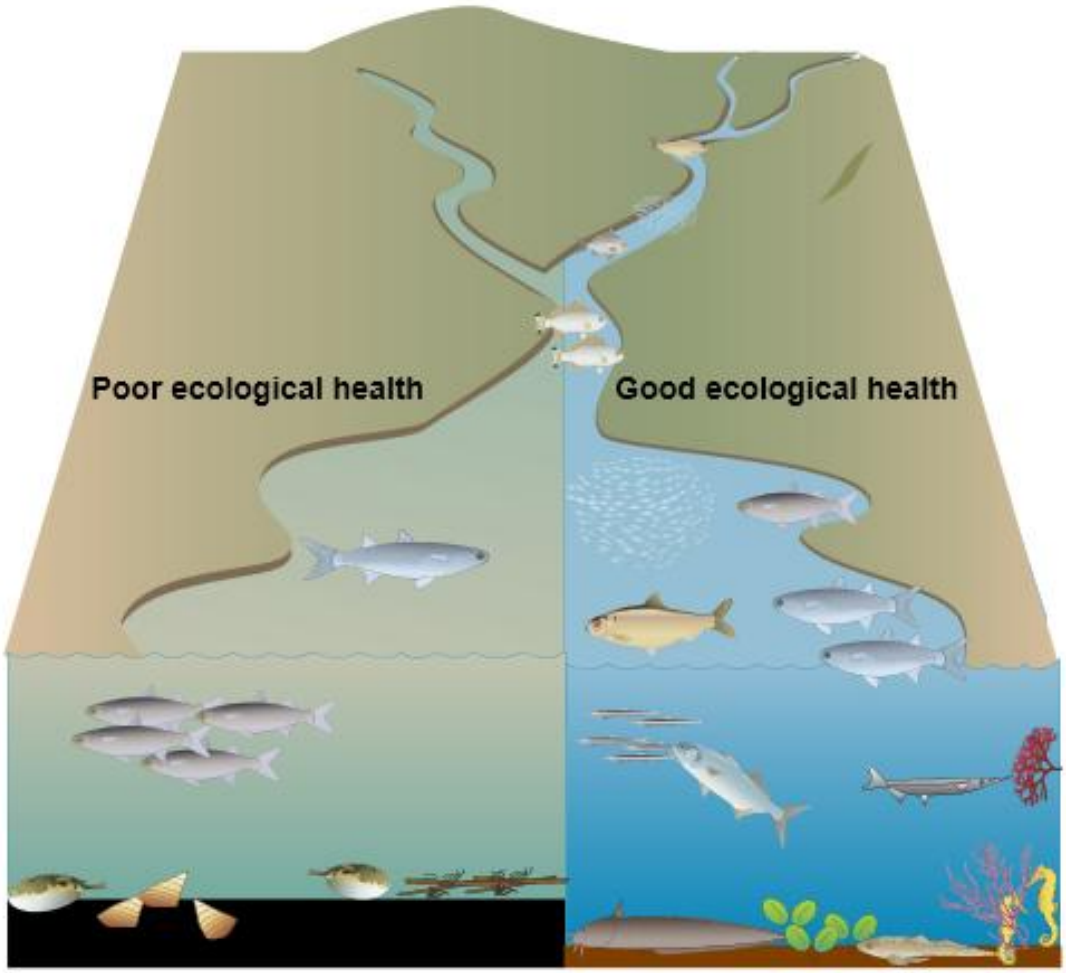


Figure 1. Conceptual diagram illustrating the predicted responses of the estuarine fish community to situations of poor and good ecological condition. (Images courtesy of the Integration and Application Network [ian.umces.edu/symbols/].)

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 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 2012 for the purposes of applying the Fish Community Indices and thus enabling the reporting of biological information towards a report card framework for the Riverpark. 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, qualitative condition grades 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 can feed into an estuarine reporting framework.

Methods

Fish communities were sampled at six nearshore and six offshore sites in each of four zones of the Swan-Canning Estuary (Fig. 2) during both summer (6-20 February) and autumn (2 April-14 May) 2012[1], using a 21.5 m seine net (Fig. 3a) and sunken, multimesh gill nets (Fig. 3b), 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 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, euthanized 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 bagged and frozen until their identification in the laboratory. See appendix 1 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, which were 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 simply summarised 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 group.

[1] Note that the system-wide sampling of fish communities described in this report was supplemented by additional sampling of the Upper Swan Estuary (USE) zone during late May 2012, to determine the effect of a *Karlodinium veneficum* bloom on the estuarine fish community. Details of this bloom and its effects on estuarine condition are provided by Hallett (2012) and will not be considered in detail in the current report.

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), 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 individual metric scores, index scores and condition grades for nearshore and offshore samples collected during summer and autumn 2012 were then examined to assess the condition of the Swan-Canning Estuary during this period and compared to previous years.

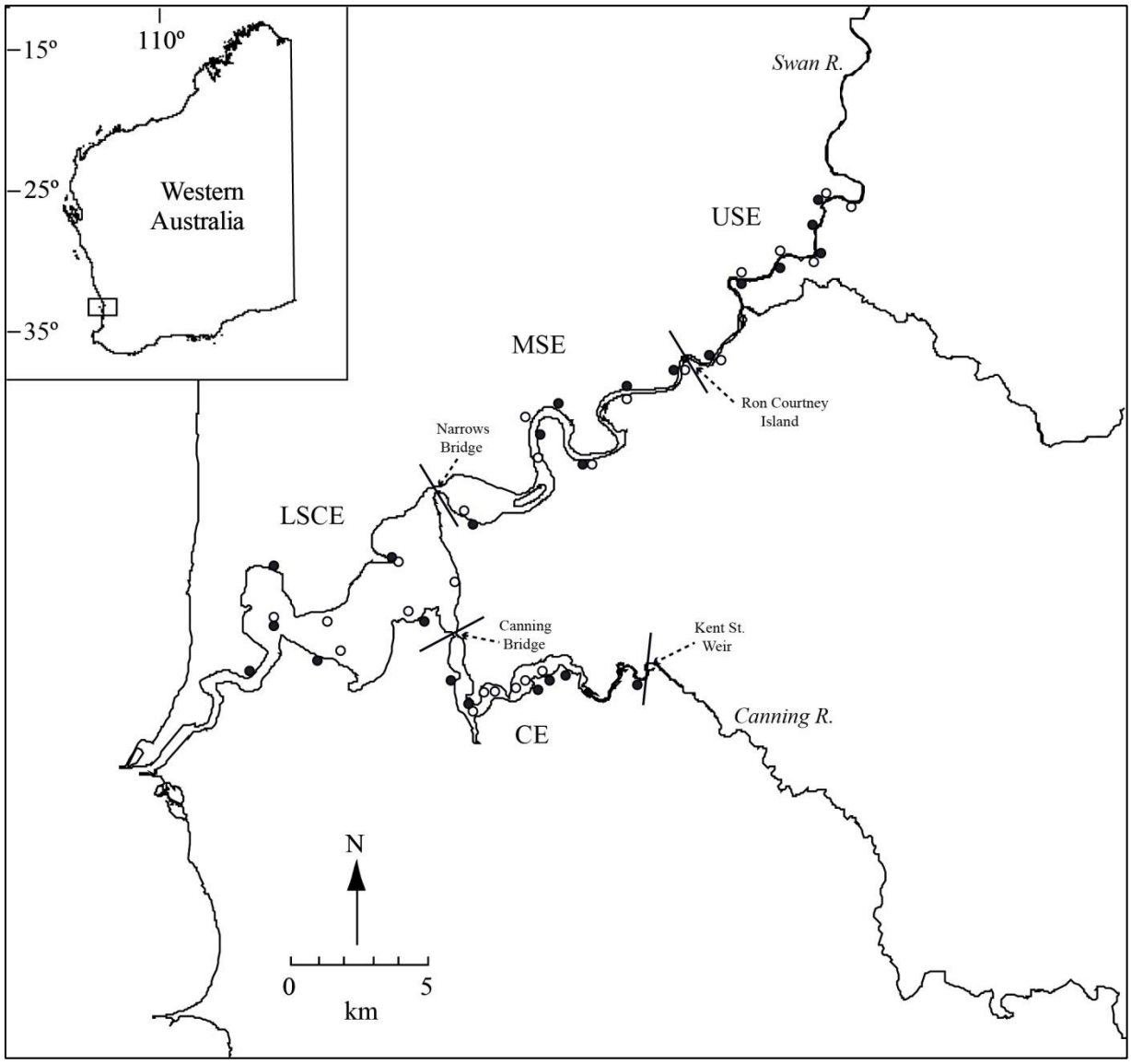


Figure 2: Locations of nearshore (black circles) and offshore (open circles) sampling sites for the Fish Community Indices of estuarine condition. LSCE, Lower Swan-Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

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 and Kerry Trayler, SRT).

Results and discussion

Description of the fish community of the Swan-Canning Estuary during 2012

An estimated total of 27,119 fish, belonging to 29 species, were caught in seine net samples collected from the nearshore waters of the Swan-Canning Riverpark during summer and autumn 2012. The vast majority of these fish belonged to small, schooling species such as hardyheads (Atherinidae) and gobies (Gobiidae). The total number of species recorded per zone was greatest in the LSCE (24) and declined upstream, to only 14 species in the USE (Table 3). Notable differences were observed between zones in the total densities of fish, with those in the CE (1,104 fish/100m^2, on average) being roughly three or four times greater than those in the other zones, although overall fish densities typically are extremely variable and provide little information about estuarine condition.

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 2012. 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	**210.6**	**63.3**	**658.4**	**59.6**	**64.5**	**28.0**	6.6	2.3
Leptatherina presbyteroides	Silverfish	**29.5**	**8.9**	**77.8**	**7.0**	11.6	5.1	-	-
Pelates octolineatus	Eight-lined trumpeter	**22.3**	**6.7**	12.9	1.2	10.8	4.7	3.7	1.3
Torquigener pleurogramma	Blowfish	16.8	5.0	4.3	0.4	1.2	0.5	-	-
Atherinosoma elongata	Elongate hardyhead	13.7	4.1	1.5	0.1	0.1	<0.1	-	-
Aldrichetta forsteri	Yellow-eye mullet	11.7	3.5	9.5	0.9	12.3	5.3	-	-
Apogon rueppelli	Gobbleguts	6.5	2.0	0.9	<0.1	7.4	3.2	-	-
Favonigobius lateralis	Long-finned goby	4.5	1.4	0.1	<0.1	-	-	-	-
Papillogobius punctatus	Red-spot goby	4.3	1.3	18.0	1.6	**34.2**	**14.9**	12.6	4.5
Sillago burrus	Trumpeter whiting	3.7	1.1	0.6	<0.1	1.0	0.4	-	-
Atherinomorus vaigiensis	Ogilby's hardyhead	2.4	0.7	3.2	0.3	0.4	0.2	3.4	1.2
Acanthopagrus butcheri	Black bream	1.4	0.4	6.8	0.6	5.7	2.5	0.9	0.3
Gerres subfasciatus	Roach	1.3	0.4	9.1	0.8	10.1	4.4	14.5	5.2
Rhabdosargus sarba	Tarwhine	0.8	0.2	-	-	-	-	-	-
Amniataba caudavittata	Yellowtail grunter	0.7	0.2	10.1	0.9	4.2	1.8	1.7	0.6
Sillago schomburgkii	Yellow-fin whiting	0.5	0.2	<0.1	<0.1	0.5	0.2	-	-
Pseudogobius olorum	Blue-spot goby	0.4	0.1	4.0	0.4	2.9	1.2	13.1	4.6
Leptatherina wallacei	Wallace's hardyhead	0.2	<0.1	**263.2**	**23.8**	**34.1**	**14.8**	**77.7**	**27.6**
Mugil cephalus	Sea mullet	0.2	<0.1	13.6	1.2	14.5	6.3	**62.2**	**22.1**
Sillaginodes punctata	King George whiting	0.2	<0.1	-	-	-	-	-	-
Platycephalus endrachtensis	Bar-tailed flathead	0.1	<0.1	-	-	-	-	<0.1	<0.1
Pelsartia humeralis	Sea trumpeter	0.1	<0.1	-	-	-	-	-	-
Ammotretis elongata	Elongate flounder	0.1	<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
Haletta semifasciata	Blue weed whiting	<0.1	<0.1	-	-	-	-	-	-
Gambusia holbrooki	Mosquito fish	-	-	5.6	0.5	12.6	5.5	**73.7**	**26.2**
Nematalosa vlaminghi	Perth herring	-	-	2.4	0.2	0.9	0.4	9.3	3.3
Afurcagobius suppositus	Southwestern goby	-	-	<0.1	<0.1	0.9	0.4	2.1	0.7
Amoya bifrenatus	Bridled goby	-	-	1.4	0.1	<0.1	<0.1	-	-
Engraulis australis	Southern anchovy	-	-	0.2	<0.1	0.3	0.1	-	-
		24 Species		**23 Species**		**22 Species**		**14 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
		333	**4,629**	**1,104**	**15,365**	**230**	**3,205**	**282**	**3,920**

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 2012. 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	**15.2**	**44.9**	**25.3**	**72.0**	**27.3**	**79.0**	**26.9**	**40.5**
Pomatomus saltatrix	Tailor	**4.3**	**12.6**	1.5	4.3	0.7	1.9	0.4	0.6
Pelates octolineatus	Eight-lined trumpeter	**3.3**	**9.9**	0.8	2.4	0.2	0.5	<0.1	0.1
Platycephalus endrachtensis	Bar-tailed flathead	2.4	7.2	0.5	1.4	0.5	1.4	0.3	0.5
Rhabdosargus sarba	Tarwhine	2.2	6.4	0.2	0.5	-	-	-	-
Sillago burrus	Trumpeter whiting	1.6	4.7	-	-	-	-	-	-
Acanthopagrus butcheri	Black bream	1.4	4.2	0.6	1.7	0.7	1.9	**9.6**	**14.4**
Gerres subfasciatus	Roach	1.1	3.2	**1.8**	**5.0**	**0.8**	**2.4**	-	-
Myliobatis australis	Southern eagle ray	0.9	2.7	0.2	0.5	0.2	0.5	-	-
Torquigener pleurogramma	Blowfish	0.6	1.7	0.2	0.5	-	-	-	-
Sphyraena novaehollandiae	Snook	0.3	0.7	-	-	-	-	-	-
Amniataba caudavittata	Yellowtail grunter	0.3	0.7	1.1	3.1	**3.6**	**10.4**	**22.1**	**33.2**
Sillago schomburgkii	Yellow-fin whiting	0.2	0.5	-	-	-	-	-	-
Pseudocaranx wrightii	Sand trevally	0.2	0.5	-	-	-	-	-	-
Elops machnata	Giant herring	-	-	-	-	-	-	<0.1	0.1
Apogon rueppelli	Gobbleguts	-	-	-	-	<0.1	0.2	-	-
Cnidoglanis macrocephalus	Estuarine cobbler	-	-	0.2	0.5	-	-	-	-
Engraulis australis	Southern anchovy	-	-	0.1	0.2	0.2	0.5	-	-
Argyrosomus japonicus	Mulloway	-	-	-	-	-	-	0.3	0.5
Mugil cephalus	Sea mullet	-	-	**2.8**	**8.1**	0.4	1.2	6.7	10.0
		14 Species		**13 Species**		**11 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
		34	**405**	**35**	**421**	**35**	**415**	**67**	**798**

The small, tropical hardyhead species *Craterocephalus mugiloides* dominated the nearshore waters of the LSCE, CE and Middle Swan Estuary (MSE), comprising between 28% and 63% of the catches from these zones, but only 2% of the catches from the USE (Table 3). The opposite pattern was shown by Wallace's hardyhead (*Leptatherina wallacei*), which was highly abundant in the USE and CE zones yet rarely encountered in the LSCE. Other abundant species included another hardyhead species, the Silverfish (*L. presbyteroides*) and the Eight-lined trumpeter (*Pelates octolineatus*) in the LSCE, the hardyhead *L. presbyteroides* in the CE, the Red-spot goby (*Papillogobius punctatus*) in the MSE, and Sea mullet (*Mugil cephalus*) and the introduced Mosquitofish (*Gambusia holbrooki*) in the USE (Table 3).

Gill net samples collected in summer and autumn 2012 from offshore waters of the Riverpark returned 2,039 fish comprising 20 species (Table 4). The total number of species again declined in an upstream direction, from 14 species in the LSCE to just 9 species in the USE, this pattern being fairly typical in south-western Australian estuaries. The total catches of fishes recorded per zone were very similar for the LSCE, CE and MSE, at around 35 fish per gill net set, whilst almost twice as many fish were caught in the USE (Table 4).

The dominant species in the gill net catches from all four zones was the Perth herring (*Nematalosa vlaminghi*), which comprised just over 40% of the catches from the LSCE and USE, and >70% of those from the CE and MSE. Other abundant species included Tailor (*Pomatomus saltatrix*) in the LSCE, Yellowtail grunter (*Amniataba caudavittata*) in the MSE and USE, and Black bream (*Acanthopagrus butcheri*) in the USE (Table 4).

Ecological condition in 2012 and comparison to other periods

In general, the ecological condition (based on fish communities) of the nearshore waters of the Riverpark was consistently good (B) to fair (C) across summer and autumn 2012, with the average nearshore index scores for most zones and for the estuary as a whole lying between 64 and 71 in each season (Fig. 4). This is consistent with a pattern of good-fair (B/C) condition assessments in recent years, following an apparent improvement in the condition of the estuary (based on fish communities) as a whole between 2005/06 and 2008/09 (Fig. 5). The factors underlying this improvement are not yet clear.

However, despite the generally good to fair condition of the estuary's nearshore waters during 2012, it should also be noted that the average nearshore index score for the USE zone decreased from *ca.* 70 (B) in early/mid autumn to 56.4 (D) in late May during a bloom (max ~200,000 cells/mL) of the alga *Karlodinium veneficum* in that zone (see Hallett [2012] for a full evaluation of the impacts of this bloom). Similarly, poorer ecological condition based on fish communities was observed in the USE zone during summer (D) and in the LSCE in autumn (D/C; Fig. 4).

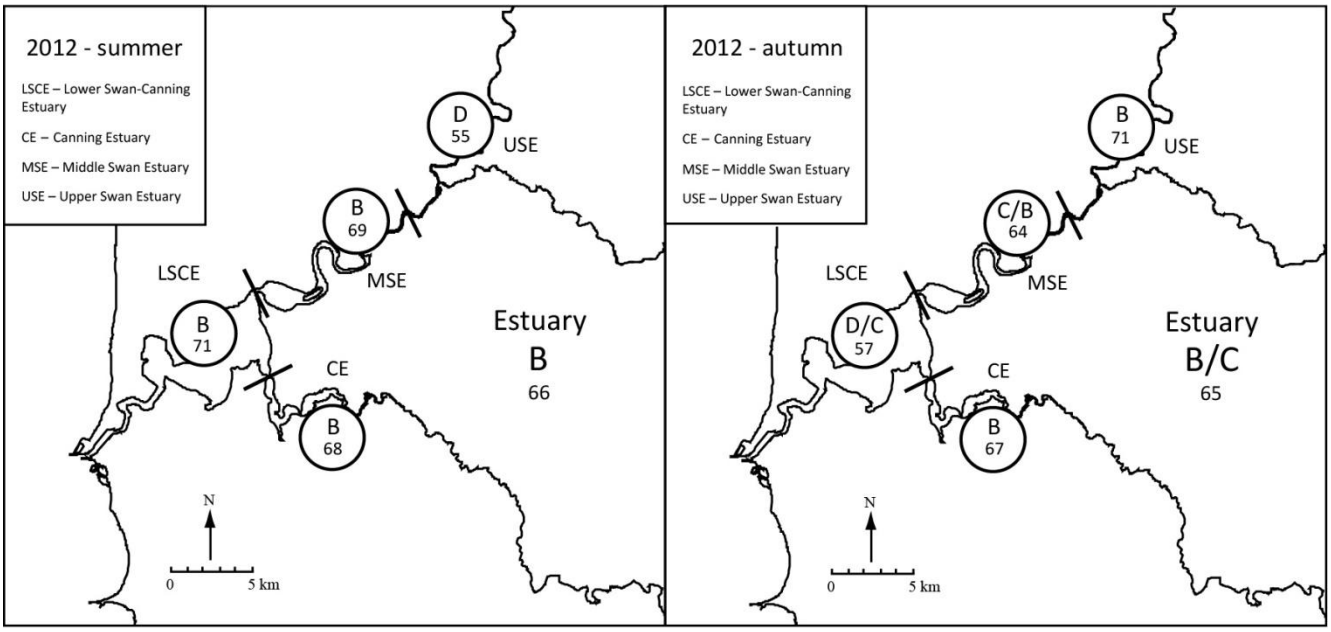


Figure 4: Average nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan-Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2012.

Examination of the radar plots of nearshore metric scores for each zone in each season reveal the assessment of poor ecological condition (D) in the USE zone in summer 2012 to have been driven by low relative abundances and small numbers of species of estuarine spawners, and by relatively low abundances of benthic (*i.e.* bottom-dwelling) species (as shown by low scores for these positive metrics; Fig. 6a). This zone is likely to have been recovering from a low dissolved oxygen event which occurred in this part of the river during January (Hallett 2012). In the case of the LSCE zone in autumn 2012, the assessment of poor-fair ecological condition (D/C) based on the fish communities was strongly influenced by low total numbers of species, few species with specialist feeding requirements and relatively few bottom-dwelling species, as indicated by average scores of <3 for the metrics for number of species, number of trophic specialist species and number of benthic associated species (Fig. 6b). Whilst the reasons for this result are not known at this time, it may reflect a more modest immigration of marine species into the estuary than might typically be expected during this season. Weekly water sampling for this region in the month preceding the fish community sampling indicated the zone was well oxygenated and relatively marine.

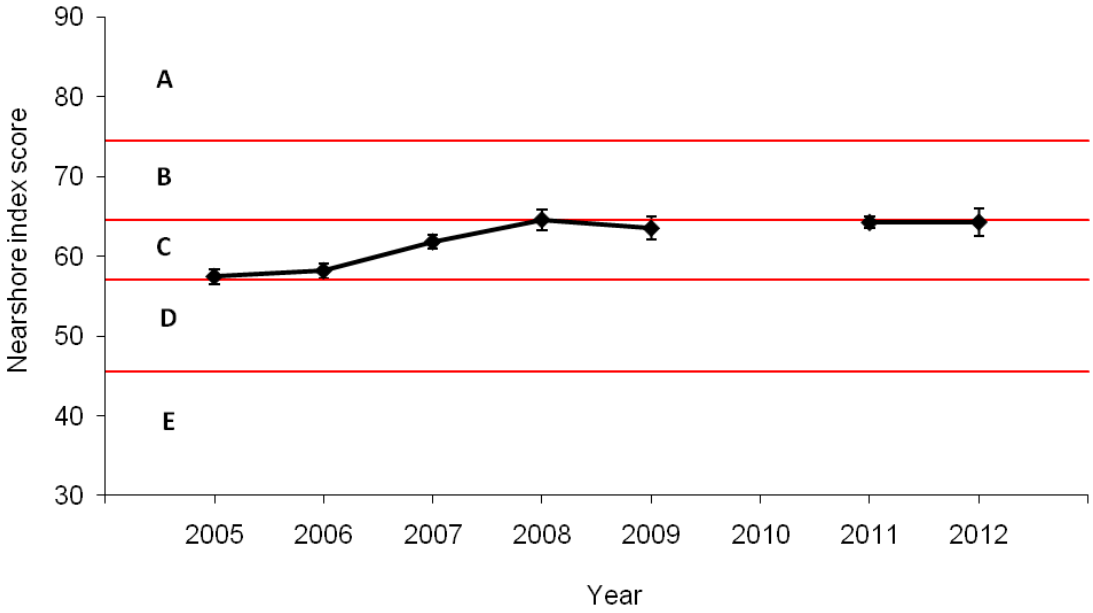
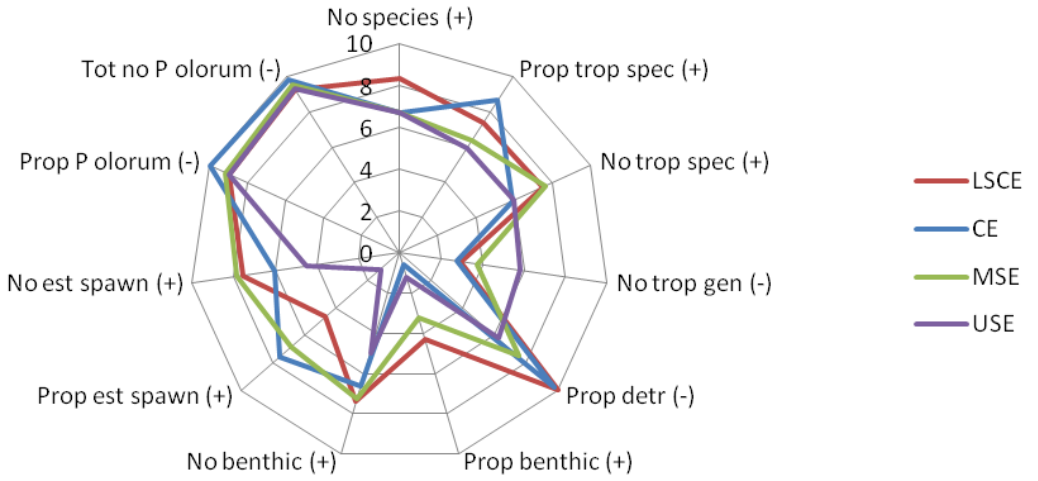


Figure 5: Trend plot of average (±SE) nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for the Swan-Canning Estuary as a whole, over recent years.

The ecological condition of the Riverpark's offshore waters based on fish communities in 2012 was generally comparable to that of the adjacent shallows, being consistently good to fair (B to C) across summer and autumn 2012. Average offshore index scores for most zones, and for the estuary as a whole, were between about 60 and 70 points (Fig. 7). This is consistent with a pattern of good-fair (B/C) condition assessments in recent years, following an apparent improvement in the condition of the offshore waters of the estuary as a whole since 2008/09 (Fig. 8). As in the case of the nearshore waters, the factors underlying this apparent improvement in the condition of the deeper, offshore waters of the Swan-Canning Estuary are currently unclear, but will be the subject of further investigation.

(a) Summer 2012



(b) Autumn 2012

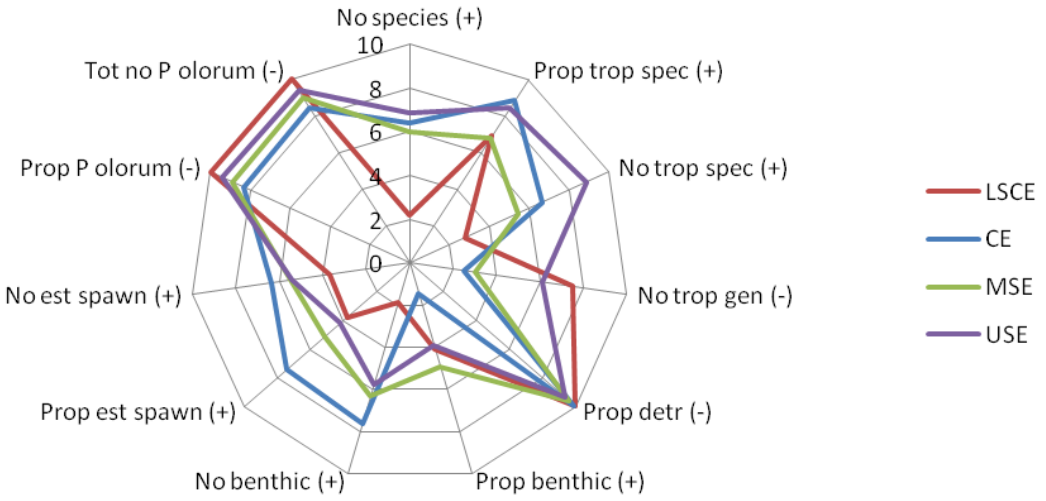


Figure 6: Average scores (0-10) for each component metric of the nearshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2012. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names).

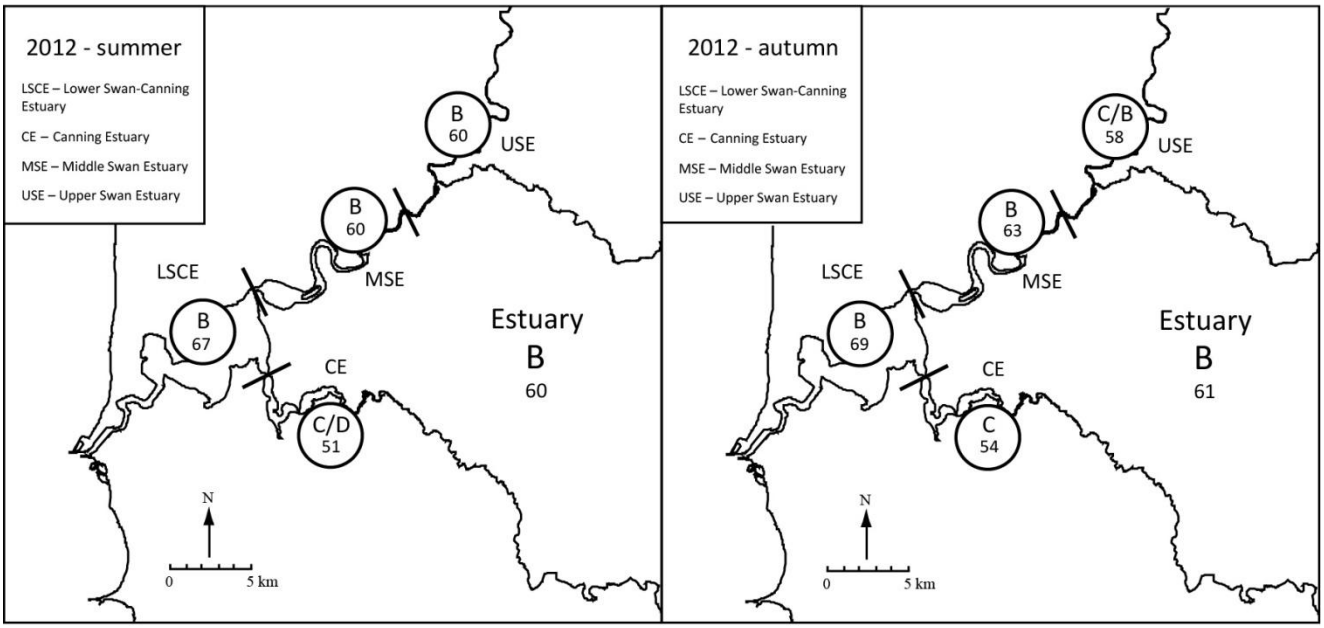


Figure 7: Average offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan-Canning Riverpark, and for the estuary as a whole, in summer and autumn of 2012.

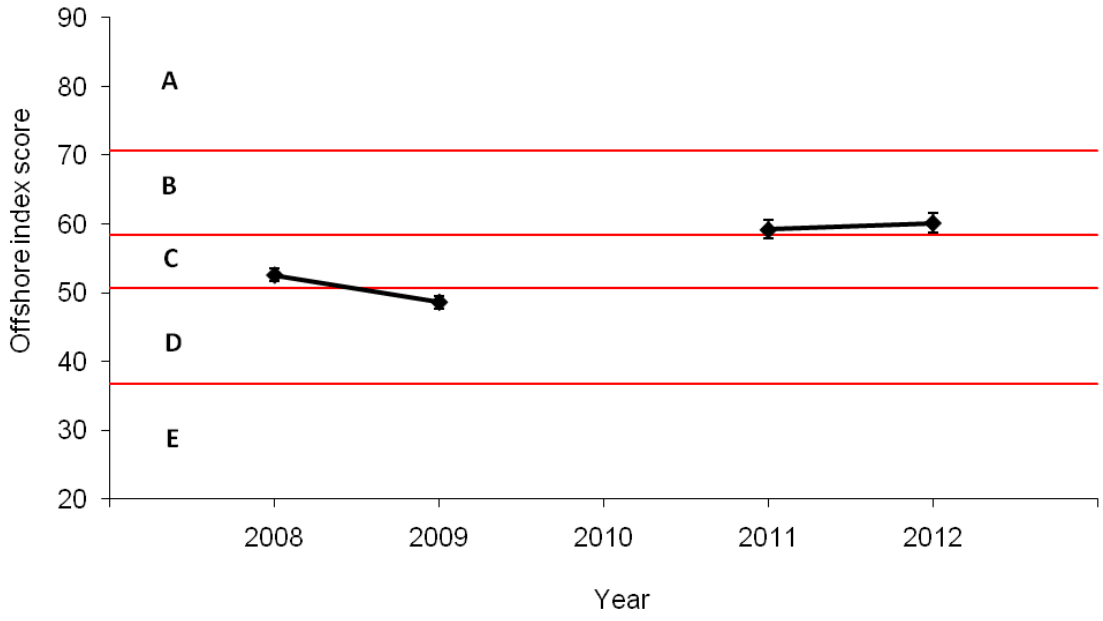


Figure 8: Trend plot of average (±SE) offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor), for the Swan-Canning Estuary as a whole, over recent years.

The offshore waters in relatively poorest condition during 2012 were located in the CE zone, which exhibited average Fish Community Index scores of 51 (C/D) and 54 (C) in summer and autumn, respectively (Fig. 7). Examination of the radar plots of metric scores for each zone in each season

reveal the fair to fair-poor ecological condition of the CE throughout 2012 to have been driven by relatively low numbers and diversity of species and by a relatively high proportion of species that feed on decomposing organic material (indicated by a low average score for the negative metric, proportion of detritivores; Figs. 9a and b).

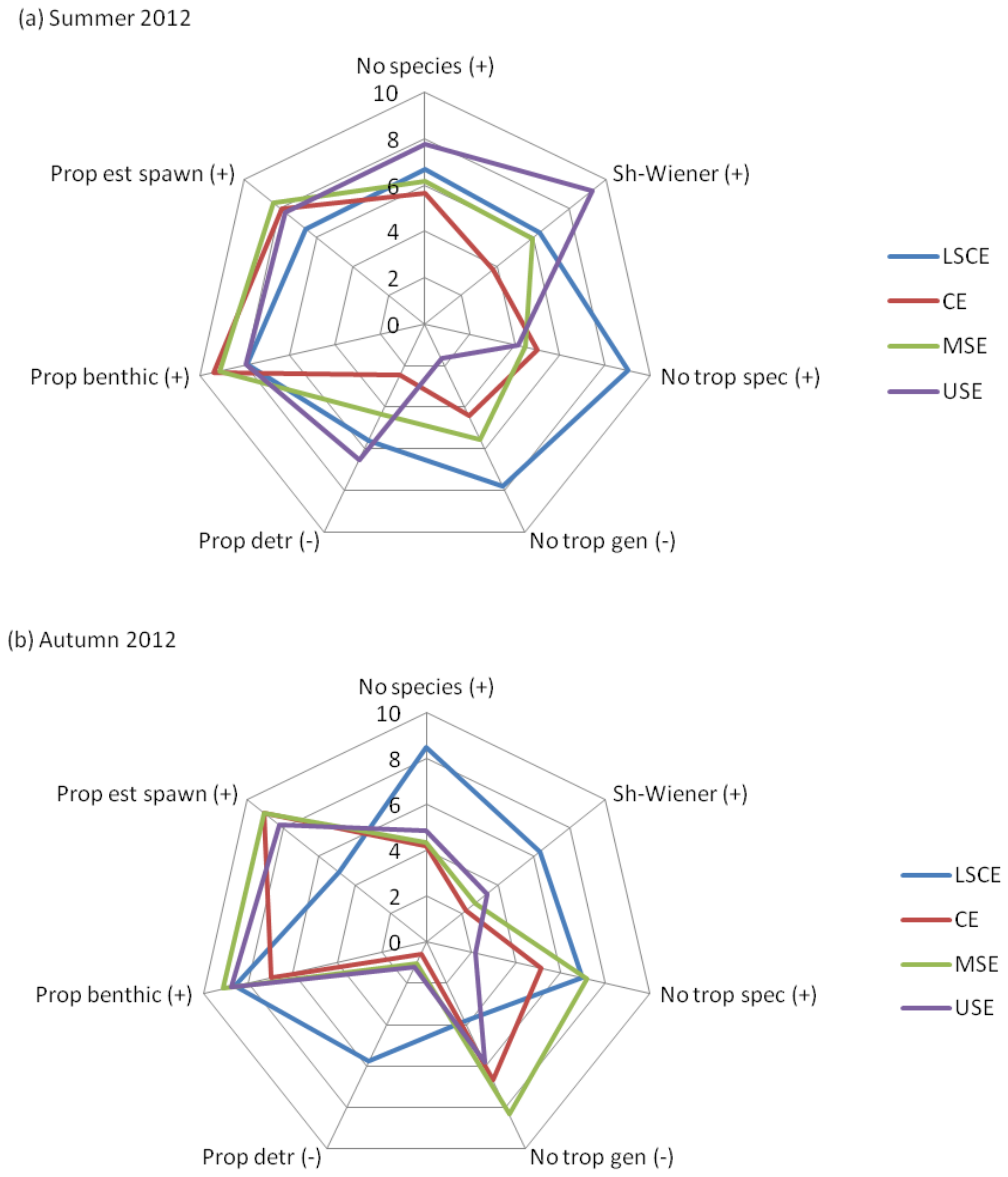


Figure 9: Average scores (0-10) for each component metric of the offshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2012. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable (see Table 1 for metric names).

References

Hallett, C.S. (2012). Brief report on fish community responses to the *Karlodinium veneficum* bloom of May 2012, including the response of the Fish Community Index of estuarine condition. Final Report to the Swan River Trust. Murdoch University.

Hallett, C.S., Valesini, F.J. (2012). Validation of the Fish Community Index of Estuarine Condition and development of a monitoring regime for the Swan-Canning Riverpark. Final Report to the Swan River Trust. Murdoch University.

Hallett, C.S., Valesini, F.J., Clarke, K.R., Hesp, S.A., Hoeksema, S.D. (2012). Development and validation of a fish-based, multimetric index for assessing the ecological health of Western Australian estuaries. *Estuarine, Coastal and Shelf Science* **104-105:** 102-113, doi: 10.1016/j.ecss.2012.03.006.

Valesini, F.J., Hallett, C.S., Cottingham, A., Hesp, S.A., Hoeksema, S.D., Hall, N.G., Linke, T.E., Buckland, A.J. (2011). Development of biotic indices for establishing and monitoring ecosystem health of the Swan-Canning Estuary. Final Report to the Swan River Trust, Department of Water, Department of Fisheries. Murdoch University.

Appendix: **(i) Descriptions of (a) nearshore and (b) offshore sampling sites under proposed future monitoring regime. 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, 1.5 m deep and 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).
- 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 to be 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 being 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 identified, counted and returned to the water alive.
- All other fish caught in the nets are placed into zip-lock polythene bags, euthanized in 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 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 such 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 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.

Rees, A.J.J., Yearsley, G.K., Gowlett-Holmes, K. (2006). Codes for Australian Aquatic Biota (on-line version). Available at http://www.cmar.csiro.au/caab/. [Last accessed February 2011].