Derbal Yirragan Djarlgarro (Swan Canning Estuary) condition assessment based on fish communities - 2024

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Executive summary

This report, commissioned by the Department of Biodiversity, Conservation and Attractions (DBCA), describes the monitoring and evaluation of fish communities in Derbal Yirragan Djarlgarro (Swan Canning Estuary) during 2024 and applies the Fish Community Index (FCI) that was developed as a measure of the ecological condition of the estuary. This index, separate versions of which were developed for both the shallow (< 1.5 m), nearshore waters of the estuary and also for its deeper (> 1.5 m), offshore waters, integrates information on various biological variables (metrics). Each of these metrics quantifies an aspect of the structure and/or function of the fish community, and together they respond to a range of stressors affecting the ecosystem.

Fish communities were sampled using different types of net at six nearshore and six offshore sites in each of four management zones of the estuary (LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary) during summer and autumn of 2024. As many fish as possible were returned to the water alive after they had been identified and counted. The resulting data on the abundances of each fish species from each sample were used to calculate a Fish Community Index score (0–100). These index scores were then compared to established scoring thresholds to determine ecological condition grades (A–E) for each zone individually and for the estuary as a whole, based on the composition of the fish community.

Nearshore Fish Communities

The nearshore waters of the estuary as a whole were in fair condition (C) during both summer and autumn 2024. Although this was the lowest score since 2019, it is better than the scores before 2008 and similar to those since 2011. The average nearshore FCI scores for each zone of the estuary varied during summer, being best, i.e. good (B), in the USE, good/fair (B/C) in the MSE and lower in the CE (fair; C) and LSCE (fair/poor; C/D). The higher scores in upstream areas reflect the saline conditions that increased the occurrence of marine species and concentrated individuals of estuarine-spawning species in these zones. Moreover, these zones did not experience hypoxia, and while a potentially toxic algal bloom was present, it was upstream of the USE and so did not negatively impact the fish fauna in the area sampled. Conversely, the lower scores of the CE and LSCE reflect estuarine species moving upstream to relatively lower salinities (CE), and low tidal heights and hot water temperatures likely caused some species, particularly benthic fish, to seek shelter in deeper, waters (LSCE). Scores in autumn were similar to those in summer, and while the water temperature decreased, a lack of freshwater flow resulted in the maintenance of high salinities.

Small-bodied, schooling species of hardyheads (Atherinidae) and gobies (Gobiidae) once again dominated catches from the nearshore waters of the estuary in 2024, representing 86% of all fish recorded and constituting seven of the eight most abundant nearshore species. The marine-associated Silver Fish, rather than the estuarine-associated Wallace's Hardyhead, was the most abundant species overall, reflecting the saline conditions throughout much of the estuary during the 2024 monitoring period. Other abundant species of small, schooling fish included the Western Hardyhead, Spotted Hardyhead and Elongate Hardyhead, however, their abundances were substantially lower than recorded previously. This could reflect the movement of some of these species into deeper waters to avoid the low tides and high temperatures in the shallow, nearshore waters. It is also possible that the higher-than-usual temperatures altered the breeding season for estuarine hardyhead species, which have a one-year lifecycle and die after spawning.

Offshore fish communities

The offshore waters of the Swan Canning Estuary were in good (B) condition in both summer and autumn during 2024. The overall score was the highest ever recorded and was similar to the last two years (2023 and 2022) and in line with the generally upward trend from 2016 onwards. Scores in summer in the LSCE, MSE and USE (all B) in summer were likely driven by relatively saline and oxic conditions, the absence of toxic algal blooms and the movement of fish from nearshore to offshore areas. The score for the USE did decline from good (B) in summer to fair (C) in autumn, likely due to the presence of a protracted *Karlodinium* bloom that, while it did not result in mortalities, may have caused fish to move outside of the affected area. Unlike in previous years, there was no stratification-induced hypoxia or algal blooms in the MSE and so scores in this zone did not decline in autumn. Once again, the offshore waters of the CE in summer (fair; C) and autumn (poor/fair D/C) exhibited amongst the lowest scores of any zone, however, despite the presence of an algal bloom in the uppermost portion of this zone, scores were better than in previous years.

As in all previous years of monitoring, Perth Herring was among the dominant species in offshore waters from all four zones comprising 23–78% of the total catches. Other abundant species included the Southern Eagle Ray and Tailor in the LSCE (9 and 7%, respectively, of the catch), the Yellowtail Grunter in the MSE (12%) and USE (55%), and Sea Mullet in the USE (10%). The numbers of species and individuals recorded from the offshore waters in 2024 were amongst the greatest in any monitoring year, likely due to high salinities in 2024 and previous years of good riverine flow that enhanced the recruitment of juveniles. Catches of several species were relatively high in 2024, including the Hawaiian Giant Herring, Southern Eagle Ray, Yellowtail Grunter, and Sea Mullet. For the former two species high oceanic water temperatures and marine-like salinities likely influenced these trends.

Overall

Across the entire estuary, the ecological condition of the nearshore and offshore waters in 2024 was assessed as fair (C) and good (B), respectively, based on their fish communities. This was a relatively low score for the nearshore waters, but the highest score recorded for the offshore waters. Combined, the nearshore and offshore index scores for 2024 are the highest recorded since annual monitoring began in 2012. This reflects the high water temperatures and saline conditions in summer, which may have caused some fish to move from the nearshore waters into the deeper, cooler, offshore waters.

Derbal Yirragan Djarlgarro (Swan Canning Estuary) condition assessment based on fish communities - 2024

Contents

1. Background

The Department of Biodiversity, Conservation and Attractions (DBCA) works with other government organizations, local government authorities, community groups and research institutions to reduce nutrient and organic loading to the Derbal Yirragan Djarlgarro (Swan Canning Estuary and river system). This is a priority issue for the waterway, as it impacts water quality, ecological health, and community benefit. Environmental monitoring for the waterway includes water quality reporting in the estuary and catchment and reporting on ecological health. Reporting on changes in fish communities provides insight into the biotic integrity of the system and complements water quality reporting.

The Fish Community Index (FCI) was developed by Murdoch University, in collaboration with the Western Australian government between 2007 and 2012 (Valesini et al., 2011; Hallett et al., 2012a; Hallett et al., 2012b), and provides an assessment of the condition of the Swan Canning Estuary based on fish communities. The FCI has been subjected to extensive testing and validation over several years (e.g. Hallett et al., 2012a; Hallett, 2014). It has been shown to be a sensitive and robust tool for quantifying ecological health responses to local-scale environmental perturbations and the subsequent recovery of the system following their removal (Hallett, 2012; Hallett et al., 2012b; 2016). The development and rationale of the FCI, along with its implementation and outcomes to date, are summarized in Hallett et al. (2019).

2. Rationale

Separate versions of the FCI were developed for the shallow, nearshore waters (< 1.5 m deep) of the estuary and also for its deeper, offshore waters (> 1.5 m deep), as the composition of the fish communities living in these different environments tends to differ, as do the methods used to sample them (Chuwen, 2009; Hoeksema et al., 2009; Potter et al., 2016; Tweedley et al., 2024). These indices integrate information on various biological variables (‘metrics’; Table 1), each of which quantifies an aspect of the structure and/or function of estuarine fish communities. Together, the metrics respond to a wide array of stressors affecting the ecosystem. The FCI therefore provides a means to assess an important component of the ecology of the system and how it responds to, and thus reflects, changes in estuarine condition (Hallett et al., 2019; Tweedley et al., 2021).

The responses of estuarine fish communities to increasing ecosystem stress and degradation (i.e. declining ecosystem health or condition) may be summarised in a conceptual model (Fig. 1). In response to increasing degradation of estuarine ecosystems, fish species with specific habitat, feeding or other environmental requirements will tend to become less abundant and diverse, whilst a few species with more general requirements become more abundant. This leads ultimately to an overall reduction in the number and diversity of fish species (Gibson et al., 2000; Whitfield et al., 2002; Villéger et al., 2010; Fonseca et al., 2013; Tweedley et al., 2017). So, in a degraded estuary with poor water, sediment and habitat quality, the abundance and diversity of specialist feeders (e.g. Garfish and Tailor), bottom-living (‘benthic-associated’) species (e.g. Cobbler and Flathead) and estuarine spawning species (e.g. Black Bream, Perth Herring and Yellowtail 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 (Krispyn et al., 2021; right side of Fig. 1). The reverse will be observed in a relatively unspoiled system that is subjected to fewer human stressors (see left side of Fig. 1; noting that this conceptual diagram represents either end of a continuum of ecological condition from very poor to very good).

Each of the metrics that make up the FCI is scored from 0–10 according to the numbers and proportions of the various fish species present in samples collected from the estuary using either seine or gill nets. These metric scores are summed to generate an FCI score for the sample, which ranges from 0–100. Grades (A–E) describing the condition of the estuary and/or of particular zones are then awarded based on the FCI scores (see Section 4 for more details).

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

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

[a] A measure of biodiversity

[b] Species with specialist feeding requirements (e.g. those that only eat small invertebrates)

[c] Species that are omnivorous or opportunistic feeders

[d] Species that eat detritus (decomposing organic material)

[e] Species that live on or are closely associated with the substrate

[f] The Blue-spot or Swan River Goby, a tolerant, omnivorous species that often inhabits silty habitats (Gill et al., 1993)

3. Study objectives

This report describes the monitoring and evaluation of fish communities in the Swan Canning Estuary during 2024 to apply the FCI as a measure of ecological condition. The objectives of this study were to:

1. Undertake monitoring of fish communities in mid-summer and mid-autumn periods, following an established approach as detailed in Hallett et al. (2012a), including six nearshore and six offshore sampling sites in each estuarine management zone.
2. Analyse the information collected so that the FCI is calculated for nearshore and offshore waters in each management zone and for the estuary overall. The information shall be presented as quantitative FCI scores (0–100), qualitative condition grades (A–E) and descriptions of the fish communities. Radar plots shall also be used to demonstrate the patterns of metric scores for each zone.
3. Provide a report that summarizes the approach and results, and that could feed into the broader estuarine reporting framework of the Department of Biodiversity, Conservation and Attractions.

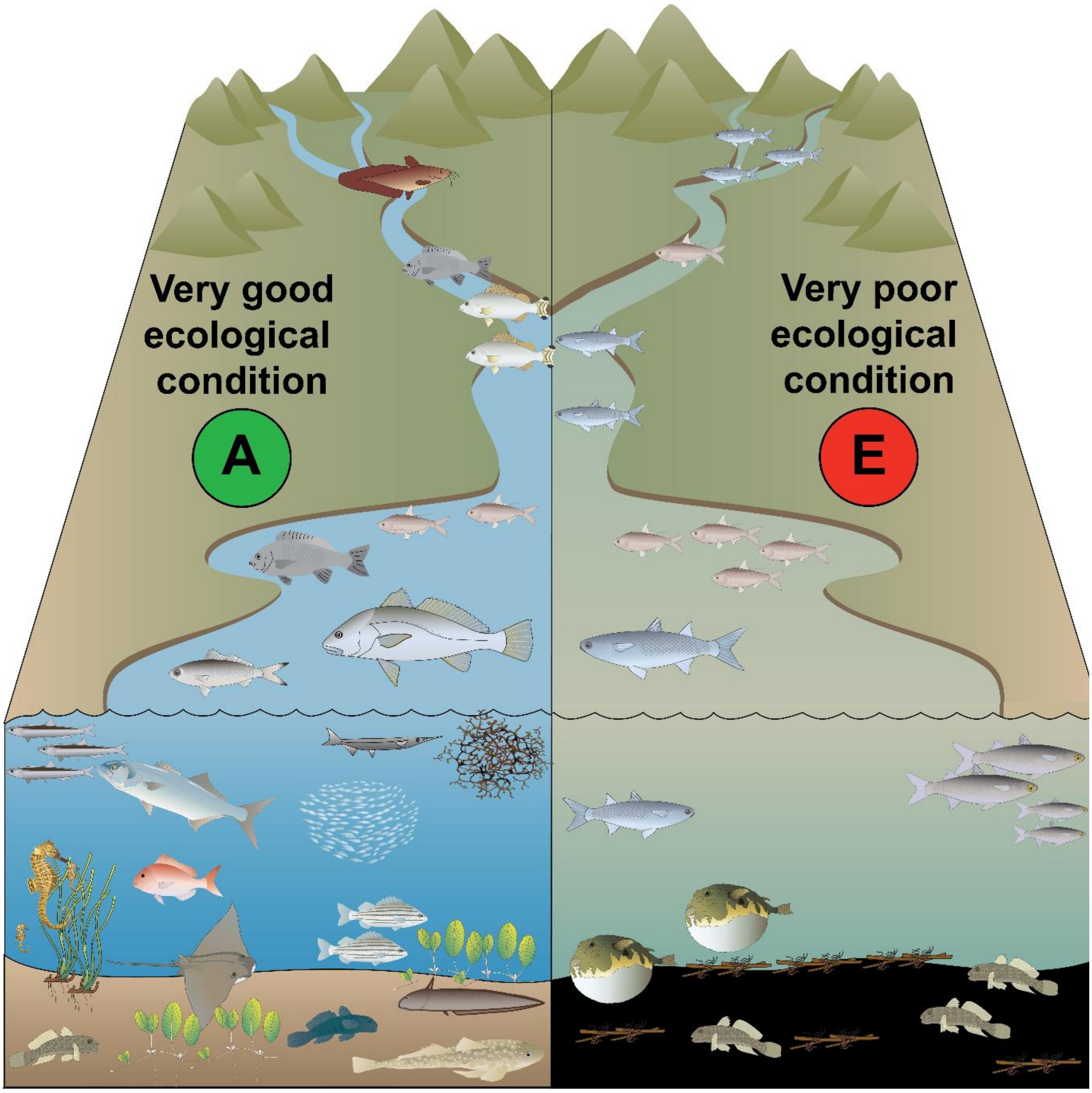


Figure 1. Conceptual diagram illustrating the predicted responses of the estuarine fish community to situations of very good (A) and very poor (E) ecological condition. Images courtesy of the Integration and Application Network [ian.umces.edu/symbols/].

4. Methods

Fish communities were sampled at six nearshore and six offshore sites in each of the four management zones of the Swan Canning Estuary (LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary; Fig. 2; Appendix i) during both summer (14 February - 7 March) and autumn (29 April – 13 May) of 2024. All sampling was conducted under permits approved by Murdoch University's Animal Ethics Committee (permit number RW3500/23), the Department of Primary Industries and Regional Development, Fisheries Division (exemption number 251151323) and the Department of Biodiversity, Conservation and Attractions (permit number FO25000254-5).

Nearshore waters were sampled using a 21.5 m seine net that was walked out from the beach to a maximum depth of ~ 1.5 m, deployed parallel to the shore, and then rapidly dragged towards and onto the shore (Fig. 3; Appendix ii). Offshore waters were sampled using 160 m-long, sunken, multimesh gill nets, each consisting of eight 20 m-long panels with stretched mesh sizes of 35, 51, 63, 76, 89, 102, 115 and 127 mm (Fig. 3). These were deployed (i.e. laid parallel to the bank at a depth of 2–8 m, depending on the depth of water at each site) from a boat immediately before sunset and retrieved after three hours.

Once a sample had been collected, any fish that could be identified immediately to species (e.g. larger species that are caught in relatively lower numbers) were identified, counted and returned to the water alive. All other fish caught in the nets were placed into zip-lock polythene bags, euthanised in ice slurry and preserved on ice for subsequent identification and counting, except in cases where large catches (e.g. thousands) of small fish were obtained. In such instances, an appropriate sub-sample (e.g. one-half to one-eighth of the catch, depending on the total size of the catch) was retained for identification and estimation of the numbers of each species, and the remaining fish were returned alive to the water to minimise the impact on fish populations. All retained fish were frozen until their identification in the laboratory by experienced fish biologists, using available keys and identification guides where required. See appendices i and ii for full details of the sampling locations and methods employed.

The abundances of each fish species in each sample were used to derive values for each of the relevant metrics comprising the nearshore and offshore indices (Hallett et al., 2012a; Hallett et al., 2012b) using bespoke code developed for the R software package. Metric scores were then calculated from these metric values, and the metric scores, in turn, combined to form the FCI scores. The method for calculating these scores is detailed in Hallett et al. (2012a), but can be summarised simply as follows:

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

The FCI scores and condition grades for nearshore and offshore samples collected during summer and autumn 2024 were then examined to assess the condition of the Swan Canning Estuary during this period and were compared to previous years through a qualitative examination of the patterns and trends in scores.

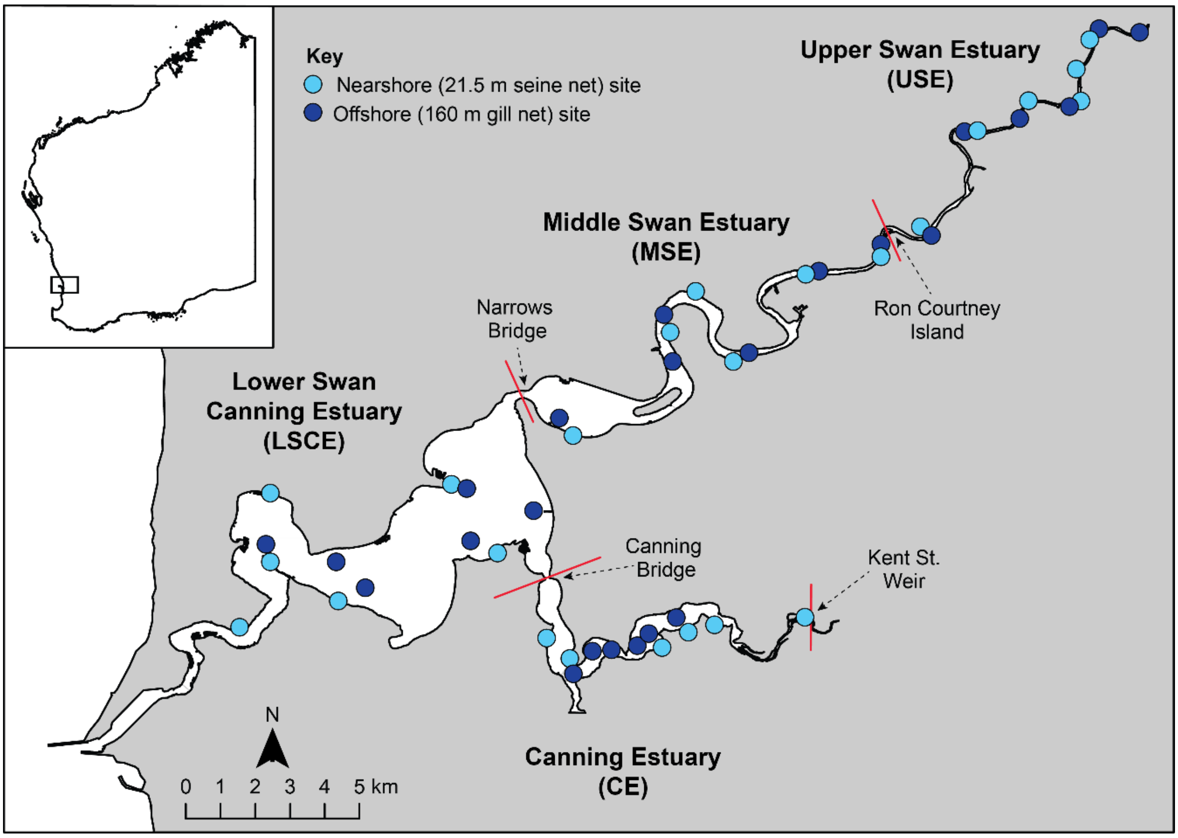


Figure 2. Locations of nearshore (light blue circles) and offshore (dark blue circles) sampling sites for the Fish Community Index of estuarine condition.

Table 2. Fish Community Index (FCI) scores comprising each of the five condition grades for both the nearshore and offshore waters of the Swan Canning Estuary. Intermediate grades, e.g. B/C (good/fair) or C/B (fair/good), are awarded if the index score lies within one point on either side of a grade threshold.

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

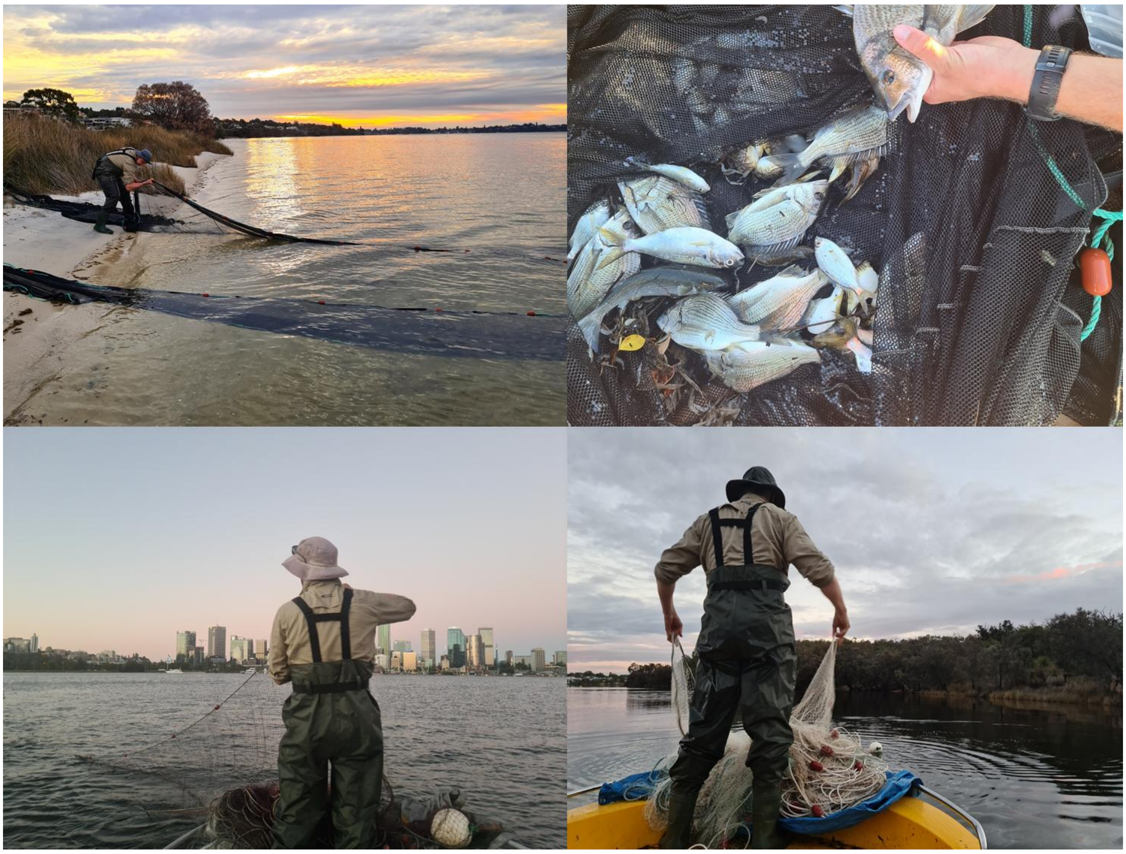


Figure 3. Photographs of the beach seine netting (upper row) used to sample the fish community in shallow, nearshore waters and the multimesh gill netting (lower row) used to sample fish communities in deeper, offshore waters of the Swan Canning Estuary. Images courtesy of Kurt Krispyn, Murdoch University.

5. Results and discussion

5.1 Water quality and environmental conditions influencing the 2024 monitoring period

The pattern of rainfall and flow in the year preceding sampling is important as it can influence fish recruitment, productivity and movement. The total annual flow at Walyunga on the Swan River was much lower (125 GL) in 2023, than the 424 and 605 GL recorded in 2022 and 2021 (Appendix vii). In 2024, no flow occurred during the Swan River until June and thus after sampling had been completed. The timing of the flow corresponded with the traditional monthly pattern in south-western Australia, where the majority occurs between May and September (Hodgkin et al., 1998; Hallett et al., 2018). In 2023, 84% of the total annual flow occurred between these months; however, in contrast to the two previous years, there were no months with particularly high values. For example, flow in August and September was 265 and 96 GL, respectively, compared to a total of 125 GL in the entirety of 2023. Total annual flow at Seaforth in the Canning River in 2023 was 6.9 GL, slightly below the median of ~8.4 GL and less than the previous two years (i.e. 10.4 and 9.7 GL, respectively; Appendix viii). Similar to the Swan River, there was no month with particularly high flow, and values were relatively high between June and September, representing 79% of the annual total.

Large spring tides during January and February resulted in water levels declining to 0.32 m above sea level at low tide (Bureau of Meteorology, 2025a). These coincided with the peak of the 18.6-year lunar nodal tides, and high atmospheric pressure systems off to west-coast which positively influenced tidal amplitude (Eliot, 2010; Peng et al., 2019) and led to subtidal banks in the LSCE becoming exposed during heat-wave conditions in February (Appendix xii).

The environmental conditions present in the Swan Canning Estuary during the monitoring period are shown as vertical contour plots of interpolated salinities, dissolved oxygen concentrations, chlorophyll levels and water temperatures (Appendix ix). The text below describes the key environmental conditions in the Swan and Canning axes of the estuary in each season. The salinity, oxygen and water temperature values recorded during sampling are also provided (Appendix x).

<u>Swan axis: physicochemical conditions</u>

Summer: The water column of the USE was brackish (salinity = 11 – 21 ppt) in early January 2024, becoming more saline into mid-February (minimum of 16 ppt) as the salt wedge dissipated due to a lack of freshwater input and vertical mixing. Salinities in the LSCE in February and March exceeded that of full-strength seawater (~35 ppt), ranging from 36 to 38 ppt, and those in the MSE were also highly saline, typically ranging from 30 to 37 ppt. No hypoxia (i.e. dissolved oxygen concentrations < 2 mg/L) was observed. However, areas of low dissolved oxygen (2 – 4 mg/L) were present in the MSE in deeper waters of the MSE in January before sampling commenced. In-situ oxygen concentrations were always > 4 mg/L (Appendix x). Both the Caversham and Guildford oxygenation plants were in operation in each week of January, February and March. Water temperatures in January increased in an upstream direction from 24 to 27 °C in the MSE and LSCE to 27 to 32 °C in the USE. Values peaked in late January, and while those in the LSCE remained similar in February, those further upstream had reduced by ~1 – 2 °C by the end of the month.

Autumn: As there was no freshwater flow until June, salinities increased during April and May, particularly in the MSE and USE. When sampling started on 29 April, salinities greater than full-strength seawater (i.e. 39 – 35 ppt) were recorded throughout the LSCE and up to Maylands in the MSE. Salinities continued to decline further upstream, ranging between 33 and 27 ppt at the lower and upper extents of the USE. By the end of autumn sampling around two weeks later, salinities had declined slightly in the LSCE by up to 2 ppt, were similar in the MSE and increased by ~1 ppt in the USE. Due to a lack of stratification, no instances of hypoxia were detected. Water temperatures were homogenous across the LSCE, MSE and USE and declined throughout autumn, being 21 – 22 °C in the first three weeks of March and 18 – 19 °C in late March and April.

<u>Canning axis: physicochemical conditions</u>

Summer: The water column of the upper part of the CE (Riverton to Castledare) was stratified by freshwater flows that diluted the surface waters to as low as 11 ppt (typically 22 – 29 ppt) overlying denser, saltier water (29 – 37 ppt) in January and February. This plume of surface brackish water did not extend past Castledare, with surface salinities of 35 to 39 ppt recorded at Salter Point and Canning Bridge. The degree of stratification decreased over time in the upper part of the CE as more of this zone became saline (Appendix ix). However, the stratification resulted in day-time hypoxia (< 2 mg/L) being detected in three of the four weeks in both January and February. Waters downstream of Riverton were always well-oxygenated (> 6 mg/L), and such conditions occurred during sampling at all sites in the CE during summer. Water temperatures in January ranged from 23 to 26 °C between Canning Bridge and Riverton, increasing in an upstream direction. Values were higher in Castledare, typically exceeding 27 °C and almost reached 33 °C. Temperatures declined slightly in February, ranging from 22 to 30 °C.

Autumn: Salinities increased in April and May, with most values exceeding full-strength seawater and the highest reaching 40 ppt. The water column throughout most of the CE was well-mixed, although stratification was present around Castledare, resulting in low oxygen or hypoxic conditions in all weeks of April and May. Oxygen concentrations during sampling were always > 6 mg/L (Appendix x). Water temperatures were far lower than in summer, ranging from 15 to 24 °C, with most being < 20 °C.

<u>Swan axis: harmful algae</u>

Before sampling: Blooms of *Karlodinium* (Place et al., 2012) occurred at levels of concern from late October 2023, with two species that breached trigger values for either investigation (15,000 cells/mL) or notification (30,000 cells/mL). The first was *Karlodinium veneficum*, which peaked at 26,000 cells/mL in Maylands (MSE) in early December and subsided by early January. A bloom of *Karlodinium* spp., dominated by *Karlodinium* cf. *armiger,* started in December 2023, subsided in late January, but returned in mid February when summer sampling commenced (DBCA, unpublished data). The non-toxic, red-tide forming *Heterocapsa rotundata* was present at densities of up to ~68,000 cells/mL in late January. *Alexandrium* spp. reached densities of 64 cells/mL but remained < 4 cells/mL between February and May.

Summer: Densities of *Karlodinium* cf. *armiger* that had occurred before sampling increased in mid February upstream of Success Hill in the lower reaches of the USE. The bloom increased, reaching a maximum density of 143,000 cells/mL several km upstream of the most upstream portion of the USE in March, and continued to exceed trigger values until 6 May, after summer sampling had been completed. No significant algal bloom activity occurred in the MSE or LSCE during the sampling period.

Autumn: The bloom *Karlodinium* cf. *armiger* present in the USE in summer occurred until 6 May, two days before sampling in this zone was completed. Cell densities reached ~76,000 and ~48,000 in mid and late April (DBCA, unpublished data). As in summer, no blooms were recorded in the MSE or LSCE.

<u>Canning axis: harmful algae</u>

Before sampling: *Alexandrium* spp. reached densities of 78 cells/mL but remained < 9 cells/mL between February and May. *Heterocapsa rotundata* was present at very high densities up to ~428,000 cells/mL) in late January, causing significant orange-brown discolouration of the water, with the potential to lower oxygen concentrations at night. *Alexandrium* spp. reached densities of 64 cells/mL but remained < 4 cells/mL between February and May.

Summer: The potential fish-killing algae, *Heterosigma akashiwo* (Mehdizadeh Allaf, 2023) exceeded investigation triggers (20,000 cells/mL) at Riverton Bridge in late January by reaching ~37,000 cells/mL. A similar density was recorded below Kent St weir on 27 February, which increased to 156,000 cells/mL on 12 March and then subsided (DBCA, unpublished data).

Autumn: A bloom of *Karlodinium* spp. breached the investigation trigger on 19 March with a maximum of 18,320 cells/mL below Kent St weir. The bloom affected the CE from the weir downstream to Castledare for several weeks before diminishing on 28 May, after autumn sampling had been completed. Maximum densities of 27,600 cells/mL were recorded at Castledare on 30 April.

<u>Comparisons to physicochemical conditions in previous years</u>

Compared to the previous 12 years, salinities at the surface of the water column in the offshore waters of all four zones of the estuary in summer were consistently relatively high, with some values being the highest ever recorded (Appendix xi). Similarly, water temperatures were elevated. For example, temperatures in the LSCE rarely exceeded 27 °C, yet in 2024 reached almost 30 °C. Temperatures were even greater in the shallow, nearshore waters with values of almost 32 °C recorded in Heathcote following low tide in February 2024 (DBCA, unpublished data). However, the most pronounced increases in surface water temperature in offshore waters compared to previous years were recorded in the MSE and USE. The warmer temperature reflects the higher residence time of water and so exposure to solar radiation in the upper reaches of the estury (MSE and USE), compared to the lower reaches (LSCE), where there is greater tidal exchange of water with the ocean (Hipsey et al., 2016). In contrast to salinity and temperature, oxygen concentrations in 2024 were similat to those that have typically occurred in the LSCE and CE and slightly higher than recorded previously in the MSE and USE.

Salinities in all zones in autumn 2024 were more elevated compared to previous years than those in summer. For example, all values in some zones in 2024 were greater than all of those in the same zone in other years, e.g. 2024 vs 2016, 2017, 2021 and 2023 in the USE. Both temperature and oxygen concentrations in 2024 were within the ranges those recorded in 2012-2023.

5.2 Fish community of the Swan Canning Estuary during 2024

Nearshore waters

An estimated total of 12,335 fish, belonging to 27 species, were caught in seine net samples collected from nearshore waters during the summer and autumn of 2024. The total number of fish recorded in 2024 was the second lowest since monitoring began in 2012, with that in only 2021 being lower. Moreover, they were around half the average from previous monitoring between 2012 and 2023 (range = 16,905 – 42,935). Similarly, the 27 species recorded in 2024 was the second lowest and well below the annual average of 32.4 (range = 25 – 36). A total of 65 fish species have been collected in seine nets as part of this annual monitoring since 2012, with the Fanbelly Leatherjacket being recorded for the first time in 2024. This species is abundant in coastal seagrass beds and has been recorded in seagrass beds around Blackwall Reach (Chubb et al., 1979) and on mussel reefs in Melville Water (Maus et al., 2024).

The greatest number of species recorded in the nearshore waters was in the MSE (21), followed by the CE (18) and least in the LSCE and USE (both 16; Table 3). This spatial pattern of species richness did not follow the traditional pattern of decline in the number of species along the longitudinal (downstream – upstream) axis that has been recorded in the nearshore waters of Swan Canning Estuary previously and in similar estuaries in south-western Australia (Veale et al., 2014; Valesini et al., 2017). This shift was due to a large decline in the number of species recorded in the LSCE and, to a lesser extent, the CE. For example, an average of 24 species have been found in the LSCE (range = 19 – 29), whereas only 16 species were recorded in this zone in 2024. Among the notably absent species were the estuarine-spawning Western Hardyhead, Black Bream and Yellowtail Flathead and the marine-spawning Tarwhine, Sea Mullet and Blue Weed Whiting. The former two species were recorded in 10 of the previous 12 years of sampling, and the remaining four in 8 of the last 12 years. Similarly, the 18 species recorded in the CE in 2024 was the lowest recorded (average = 22.7; range = 19 – 26). This was due to species like the Sea Mullet, Southwestern Goby, and Western Gobbleguts, which have been recorded in 12, 9 and 8 of the previous 12 years, all being absent in 2024. Conversely, the number of species in the MSE (21) and USE (16) were similar to the average values in previous years, i.e. 21.5 and 16.9, respectively. The total number of fish was greatest in the LSCE and similar in the other three zones (i.e. 4,707 vs 2,185 – 2,913; Table 3). The total for each region was lower than the average, particularly in the CE, where the total catch in 2024 was only 24% of the average of the previous 12 years.

Hardyheads (family = Atherinidae; five species) and gobies (family = Gobiidae; six species) once again dominated catches from the nearshore waters of the estuary in 2024, representing 86% of all fish recorded and containing the seven most abundant nearshore species and seven of the top ten. The Silver Fish was the most abundant species overall (2,139 individuals; Table 3). This was the first time this species was the most abundant, with only 98 and 243 individuals being recorded in 2023 and 2022, respectively. The Spotted Hardyhead and Western Hardyhead ranked second and third, respectively, with the latter having been the most abundant species in nearshore waters for the previous five years (2019 to 2023).

There was clear spatial partitioning of hardyheads throughout the zones of the estuary. Silverfish comprised 44% of all fish in the LSCE, accompanied by Common and Elongate hardyheads (both ~24%). While these three species were also recorded in the CE and MSE, they made small contributions to the overall catch of < 2%. Instead, the Spotted and Western hardyheads dominated the CE (37 and 47% of all fish, respectively) and, to a lesser extent, also the MSE (i.e. 24 and 5%, respectively). This reflects the salinity preferences for the various species, with the Silver Fish and Common Hardyhead occurring in coastal waters and the salty downstream reaches of estuaries (Valesini et al., 2009; 2017), whereas the Western Hardyhead prefers upstream areas where salinities are less than in other parts of the estuary (Prince et al., 1983; Potter et al., 2015b). Likewise, among the gobies, the Southern Longfin Goby was most abundant in the LSCE, the Yellowspotted Sandgoby in the CE and MSE and Bluespot Goby in the USE. This reflects the salinity preferences of these species, and the coarse sediment in the downstream zones and finer (silty/muddy) sediments found further upstream (Gill et al., 1995; Hogan-West et al., 2019). Other abundant species recorded in 2024 included the Yelloweye Mullet in the CE, the Common Silverbiddy in the MSE, and the Perth Herring and Yellowtail Grunter in the MSE and USE.

Compared to previous years, numbers of some abundant estuarine-spawning species were substantially lower in 2024, most notably the small-bodied Western Hardyhead, Spotted Hardyhead, and Elongate Hardyhead, whose abundances in 2024 were only 26, 33 and 45% of the average of the previous 12 years. Catches of juveniles of larger-bodied species, including Perth Herring, Black Bream and Yellowtail Grunter, were also lower than recorded previously. In the case of the hardyheads, this could reflect potentially poor recruitment of juveniles from spawning events in spring and early summer (Prince et al., 1983) and/or movements into deeper, cooler, offshore waters. Substantially lower numbers of juveniles of several marine-spawning species that use the estuary as a nursery area were also recorded, most notably Sea Mullet, Yelloweye Mullet, Weeping Toadfish and Western Striped Grunter. As the abundance of these marine-spawning species is influenced by factors occurring in the ocean and the estuary, and the mouth of the Swan-Canning Estuary is permanently open to the ocean, allowing recruitment at any time, the drivers of such changes are less clear. These types of species do often respond positively to high flow in preceding years (Appendix vii), as was the case in 2021 and 2022, but not in 2023 (Tweedley et al., 2022a, b; 2023). Conversely, far greater numbers of Common Hardyhead, Silver Fish, Common Silverbiddy and Yellowfin Whiting were recorded.

Two non-native fish species have been recorded regularly during this monitoring program, namely the Eastern Gambusia and the Pearl Cichlid. The former species was recorded again in 2024, albeit in relatively low numbers (i.e. a total of 72 individuals; average = 535; range = 28 – 1,633). However, this was the first year since 2014 when the Pearl Cichlid was not recorded.

Table 3. Compositions of the fish communities (D = Average density fish [100 m^{-2}] and %C = percentage composition) observed across the six nearshore sites sampled in each zone of the Swan Canning Estuary during the summer and autumn of 2024. Data for the three most abundant species in the catches from each zone are shaded in grey for emphasis. Species are ordered by total abundance throughout the estuary. LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary. * denotes non-native species.

		LSCE (*n* = 12)			**CE** (*n* = 12)			**MSE** (*n* = 12)			**USE** (*n* = 12)	
Common name	**Species**	D	%C	x	D	%C	x	D	%C	x	D	%C
Silver Fish	*Leptatherina presbyteroides*	147.63	43.66		2.95	1.41		3.09	1.97			
Spotted Hardyhead	*Craterocephalus mugiloides*	13.65	4.04		78.16	37.35		38.15	24.30		11.85	6.52
Western Hardyhead	*Leptatherina wallacei*				98.78	47.20		8.33	5.31		23.42	12.89
Common Hardyhead	*Atherinomorus vaigiensis*	81.47	24.09		0.57	0.27		0.50	0.32			
Elongate Hardyhead	*Atherinosoma elongatum*	79.17	23.41		2.23	1.06		0.50	0.32			
Bluespot Goby	*Pseudogobius olorum*				0.43	0.21		12.21	7.78		64.08	35.26
Yellowspotted Sandgoby	*Favonigobius punctatus*	0.57	0.17		11.49	5.49		29.96	19.08		17.82	9.80
Common Silverbiddy	*Gerres subfasciatus*	0.07	0.02		0.93	0.45		24.93	15.88		8.33	4.58
Perth Herring	*Nematalosa vlaminghi*				2.37	1.13		9.12	5.81		11.35	6.25
Bridled Goby	*Arenigobius bifrenatus*				0.07	0.03		3.45	2.20		18.03	9.92
Yellowtail Grunter	*Amniataba caudavittata*	0.79	0.23		0.29	0.14		7.26	4.62		6.90	3.79
Black Bream	*Acanthopagrus butcheri*				0.86	0.41		6.25	3.98		4.81	2.65
Yelloweye Mullet	*Aldrichetta forsteri*	0.79	0.23		6.18	2.95		2.73	1.74		0.07	0.04
Western Striped Grunter	*Helotes octolineatus*	0.29	0.08		0.14	0.07		6.82	4.35		0.07	0.04
Weeping Toadfish	*Torquigener pleurogramma*	6.18	1.83		0.57	0.27		0.36	0.23			
Western Trumpeter Whiting	*Sillago burrus*	2.87	0.85		2.23	1.06		1.80	1.14			
Southwestern Goby	*Afurcagobius suppositus*										6.82	3.75
Eastern Gambusia	*Gambusia holbrooki**										5.17	2.85
Southern Longfin Goby	*Favonigobius lateralis*	2.01	0.59		0.57	0.27						
Australian Anchovy	*Engraulis australis*										2.01	1.11
Western Gobbleguts	*Ostorhinchus rueppellii*	1.72	0.51					0.29	0.18			
Sea Mullet	*Mugil cephalus*							0.79	0.50		0.79	0.43
Yellowfin Whiting	*Sillago schomburgkii*	0.72	0.21		0.43	0.21		0.07	0.05			
Largemouth Goby	*Redigobius macrostoma*							0.29	0.18		0.22	0.12
Sandy Sprat	*Hyperlophus vittatus*	0.14	0.04									
Tailor	*Pomatomus saltatrix*							0.07	0.05			
Fanbelly Leatherjacket	*Monacanthus chinensis*	0.07	0.02									
	Total number of species	**16**			**18**			**21**			**16**	
	Average total fish density (fish 100 m^{-2})	**338**			**209**			**157**			**182**	
	Total number of fish	**4,707**			**2,913**			**2,185**			**2,530**	

Offshore waters

Samples collected from offshore waters in the summer and autumn of 2024 using gill nets returned 3,847 fish, comprising 22 species (Table 4). This number of fish caught was the highest ever recorded during this monitoring and follows on from relatively high catches between 2021 and 2023. Catches in the last four years (2021-2024; average = 3,063; range = 2,705 – 3,847) are substantially greater than those between 2012 and 2020 (average = 1,826; range = 1,125 – 2,235). The 22 species caught in 2024 was slightly greater than both 2023 (20) and over the entire monitoring period (average = 20.3 between 2012 and 2023), albeit less than the 23 and 24 recorded in 2021 and 2022, respectively. A total of 36 fish species have been collected in gill nets as part of this annual monitoring since 2012 and no new species were recorded in 2024.

Among the management zones, the total number of species recorded from each zone in 2024 decreased upstream from 17 species in the LSCE to 16 in the CE, 14 in the MSE and 10 in the USE. This is a trend that has occurred in most years in this monitoring program and has been recorded in other estuaries (Loneragan et al., 1987; Chuwen et al., 2009). It reflects the fact that most species of fish in the deeper waters of the estuary are marine species and, therefore, prefer higher salinities (Potter et al., 1999; Tweedley et al., 2016). The number of species in each zone was greater than in 2023 and the average from previous monitoring, except for the USE which remained the same. Catches were once again largest in the USE (1,598 fish), compared to 777, 781 and 691 fish in the LSCE, CE and MSE, respectively. The total number of fish in each zone was greater than the average of the previous 12 years. This was particularly marked in the LSCE and USE, where catches were ~140% greater than the average.

As in all previous years of monitoring, Perth Herring was the most abundant species in offshore waters in 2024, representing 50% of all fish recorded, albeit the contribution from this species was lower than the average of 58%. This species comprised 23 to 78% of the total catches in each zone, ranking first in all except the USE, where it ranked second (Table 4). The Yellowtail Grunter was the second most abundant species overall, and while found in all zones, it was particularly abundant in the MSE and in the USE, where it was the most caught species. The Southern Eagle Ray and Tailor were abundant in the LSCE (9 and 7% of the catch, respectively). The former species was also abundant in the CE, representing 12% of all fish caught. Other abundant species included the Roach and Tarwhine in the LSCE and CE, the Hawaiian Giant Herring in the MSE and Sea Mullet and Black Bream in the USE.

Catches of several species were relatively high in 2024, including Hawaiian Giant Herring, Yellowtail Grunter, Sea Mullet, Southern Eagle Ray and Perth Herring, with percentages increases of 521, 198, 170, 121 and 60, respectively, from the average between 2012 and 2023. On the other hand, there was a 60% decrease in the abundance of Western Striped Grunter. In the case of Yellowtail Grunter, Sea Mullet and Perth Herring, the increase in the offshore waters was accompanied by a corresponding decrease in nearshore waters and thus, individuals may have moved from shallower to deeper waters due to the very low tides and/or high water temperatures. Numbers of Southern Eagle Rays have increased in the Swan-Canning Estuary over the last decade, which is likely due to marinization (increasing frequency and duration of marine-like salinities) of the lower reaches of the system and that is it now being used as a nursery area by this marine species (Trayler et al., 2024). Catches of the Hawaiian Giant Herring were the highest ever recorded during this monitoring. This species is known to move southwards in Australia with warmer currents during summer months, and the summer sea surface temperature anomaly in south-western Australia during summer was 0.87 °C higher than the 1991-2020 average and the highest in any of the last 100 years (Bureau of Meteorology, 2025b).

Table 4. Compositions of the fish communities (CR = Average catch rate [fish/net set] and %C = percentage composition) observed across the six offshore sites sampled in each zone of the Swan Canning Estuary during the summer and autumn of 2024. Species ranked by total abundance. Data for the three most abundant species in the catches from each zone are shaded in grey for emphasis. Species are ordered by total abundance throughout the estuary. LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary.

		LSCE (*n* = 12)			**CE** (*n* = 12)			**MSE** (*n* = 12)			**USE** (*n* = 12)	
Common name	**Species**	CR	%C	x	CR	%C	x	CR	%C	X	CR	%C
Perth Herring	*Nematalosa vlaminghi*	41.75	64.48		41.08	63.12		45.00	78.15		31.17	23.40
Yellowtail Grunter	*Amniataba caudavittata*	0.17	0.26		1.58	2.43		6.67	11.58		72.17	54.19
Southern Eagle Ray	*Myliobatis tenuicaudatus*	5.75	8.88		7.67	11.78		0.08	0.14			
Sea Mullet	*Mugil cephalus*	0.08	0.13					0.08	0.14		12.67	9.51
Black Bream	*Acanthopagrus butcheri*							0.50	0.87		9.83	7.38
Tailor	*Pomatomus saltatrix*	4.50	6.95		2.92	4.48		1.50	2.60		0.67	0.50
Common Silverbiddy	*Gerres subfasciatus*	3.83	5.92		3.92	6.02		0.75	1.30			
Tarwhine	*Rhabdosargus sarba*	3.67	5.66		3.42	5.25					0.17	0.13
Hawaiian Giant Herring	*Elops hawaiensis*	0.42	0.64		0.83	1.28		1.50	2.60		4.33	3.25
Yellowtail Flathead	*Platycephalus westraliae*	2.25	3.47		0.58	0.90		0.58	1.01		0.50	0.38
Western Striped Grunter	*Helotes octolineatus*	0.58	0.90		1.00	1.54		0.33	0.58			
Mulloway	*Argyrosomus japonicus*							0.25	0.43		1.50	1.13
Yellowfin Whiting	*Sillago schomburgkii*	1.00	1.54		0.17	0.26						
Western Trumpeter Whiting	*Sillago burrus*	0.25	0.39		0.58	0.90		0.17	0.29			
Estuary Cobbler	*Cnidoglanis macrocephalus*	0.17	0.26		0.50	0.77		0.08	0.14			
Yelloweye Mullet	*Aldrichetta forsteri*				0.58	0.90						
Bull Shark	*Carcharhinus leucas*				0.08	0.13					0.17	0.13
Australian Anchovy	*Engraulis australis*	0.08	0.13		0.08	0.13		0.08	0.14			
Silver Trevally	*Pseudocaranx georgianus*	0.08	0.13									
Australian Herring	*Arripis georgianus*	0.08	0.13									
Smalltooth Flounder	*Pseudorhombus jenynsii*	0.08	0.13									
Weeping Toadfish	*Torquigener pleurogramma*				0.08	0.13						
	Total number of species	**17**			**16**			**14**			**10**	
	Average catch rate (fish/net set)	**64.8**			**65.1**			**57.6**			**133.2**	
	Total number of fish	**777**			**781**			**691**			**1,598**	

5.3 Ecological condition in 2024

Nearshore waters

The ecological condition based on fish communities of the nearshore waters of the Swan Canning Estuary was fair (C; FCI score 63) in both summer and autumn (Fig. 4). Scores for individual zones varied markedly from 58 to 72. The best score was in the USE (good; B) and lowest in the CE and LSCE with fair (C) and fair/poor (C/D) scores, respectively. The scores in autumn increased by five points in the USE and four points in the CE, but these zones remained good and fair, respectively. Smaller shifts of around one point were seen in the LSCE, which improved in condition to fair, and in the MSE, albeit the condition of that zone remained good/fair (B/C; Fig. 4).

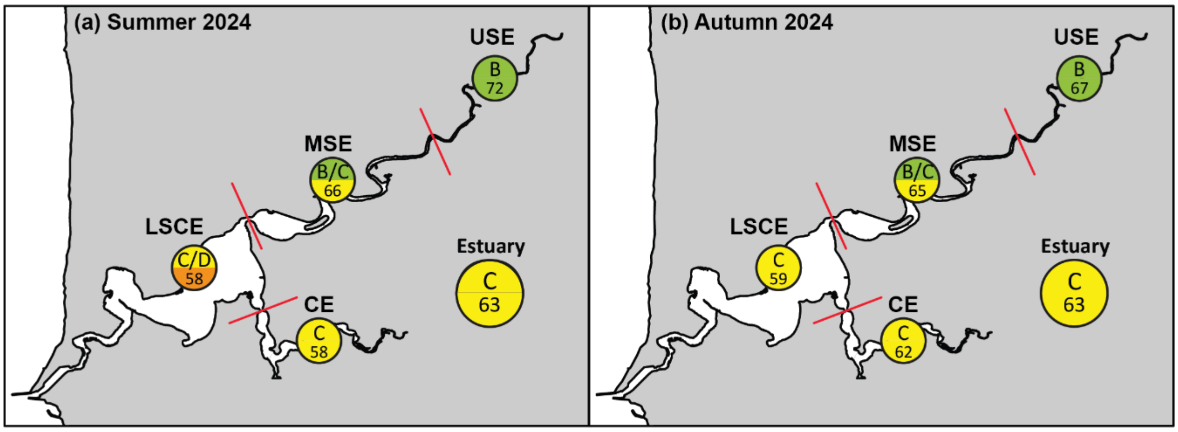
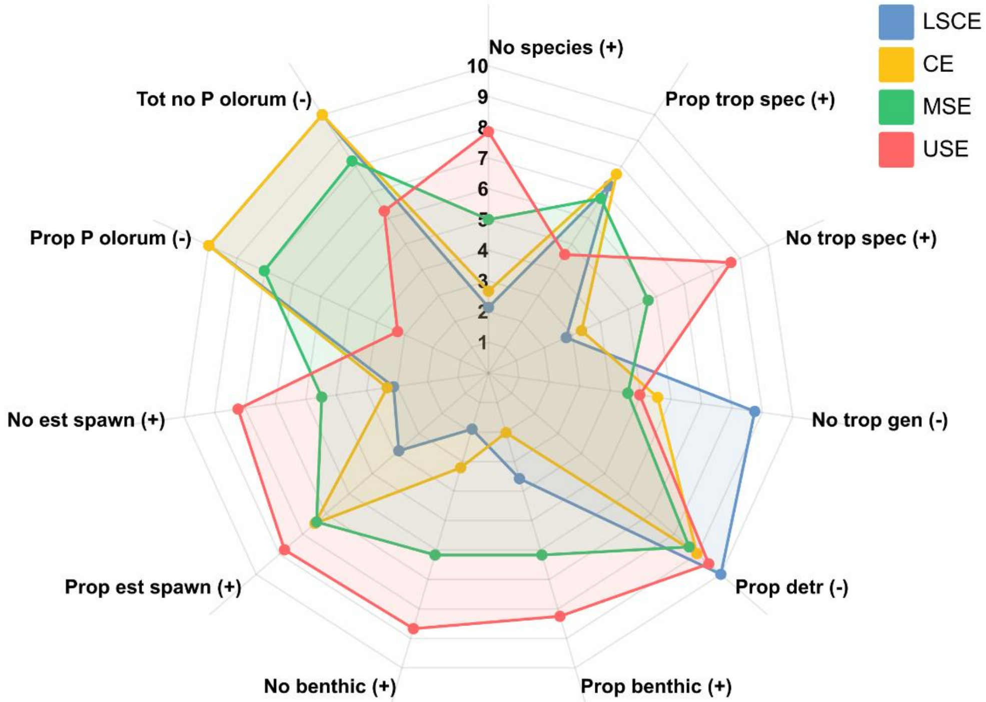


Figure 4. Average nearshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Estuary, and for the estuary as a whole, in the summer and autumn of 2024.

*Note, for visual clarity, mean FCI scores are rounded to the nearest whole number. Mean scores for the LSCE and CE in summer were 57.62 and 58.43, respectively, and thus the score for the LSCE was within one point of the 57.11 grade threshold between poor and fair (Table 2), which explains the apparent disparity in grades between these zones.

Radar plots of the nearshore metric scores for each zone in summer showed that the relatively low score in the LSCE was caused by low values for the *Number of species, Number of trophic specialist species, Number of benthic-associated species* and *Number of estuarine-spawning species* (all positive metrics; Fig. 5a). These reflect the low number of species found in each sample (range = 3 – 8) and that, of the species recorded, only four of the 13 spawn in estuaries and only two were benthic. The composition of the fish communities in the LSCE in summer was also dominated by marine-spawning, small-pelagic hardyhead, thus accounting for the intermediate scores for the *Proportion of benthic-associated individuals* and *the Proportion of estuarine-spawning individuals* (both positive metrics). It is likely that the very low low tides that occurred in this region (Appendix xii), combined with the warm waters, may have resulted in some of the benthic species moving to cooler, deeper waters where they would also be less likely to be predated by birds (Greenwell et al., 2021). Moreover, the high salinities may have altered the spatial distribution of species, resulting in marine species like the Silver Fish and Common Hardyhead entering the estuary in greater numbers and some of the estuarine species moving further upstream. The high salinities would, however, have precluded inhabitation of this zone by the detritivorous Blue-spot Goby (*Psuedogobius olorum*). The absence of this species from the LSCE, resulted in scores of 10 for the *Proportion of detritivores, Total number of P. olorum* and *Proportion of P. olorum* (all negative metrics; Fig. 5a). The combination of high salinities and high water temperatures may also be responsible for a similar pattern of results among metrics in the CE as occurred in the LSCE. However, the CE scored better in the *Proportion of estuarine-spawning* *individuals* due to the schools of hardyheads comprising estuarine-spawning species such as the Spotted and Western hardyheads rather than the Siver Fish and Common Hardyhead.

(a) Summer 2024



(b) Autumn 2024

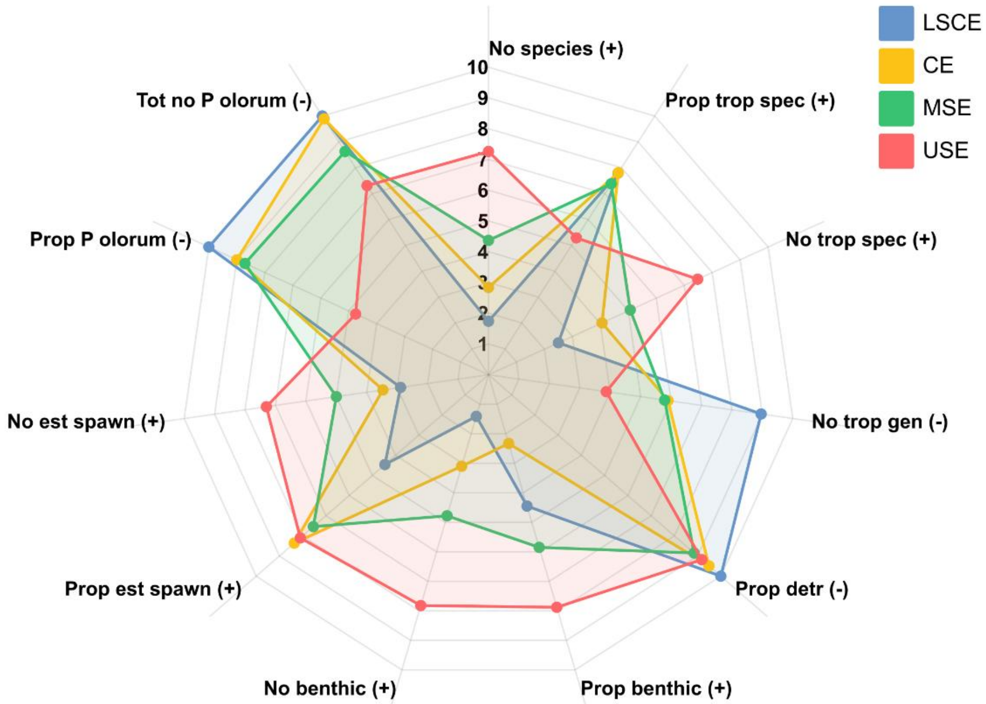


Figure 5. Average scores (0–10) for each component metric of the nearshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2024. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable. Therefore, the larger the area covered by the radar plot the better the condition in that zone. Full metric names and explanations are given in Table 1.

Scores in the MSE and more so in the USE were greater than those in the LSCE and CE (Fig. 4a), which reflected sequential increases in the *Number of species, Number of estuarine-spawning species, Number of benthic-associated species, Number of trophic generalist species* and the *proportions of estuarine-spawning individuals and benthic-associated individuals.* Conversely*,* metrics related to Blue-spot Goby all declined sequentially from their maximum in the LSCE, intermediate values in the MSE and lowest values in the USE (Fig.5a). These patterns likely reflect the movement of estuarine species with preferences for moderate salinities further upstream where salinities were less than full-strength seawater. Salinity is one of the principal drivers of fish faunal composition in estuaries globally (Thiel et al., 2001; Barletta et al., 2005; Whitfield et al., 2006), and the partitioning of species along this axis is well established in south-western Australian estuaries (Potter et al., 2015b; Valesini et al., 2017).

The spatial pattern of overall scores for zones and of their component metrics was similar in autumn to that in summer (Fig. 4 and 5). The absence of flow in the swan axis of the estuary in 2024 before sampling was completed (Appendix vii) resulted in the maintenance of the strong salinity gradient present in summer. The LSCE was the only zone where the condition grade changed, i.e. increased from fair/poor in summer to fair in autumn. This was largely due to increases in the *proportions of* i) *benthic-associated individuals*, ii) estuarine-spawning individuals, and iii) trophic specialists (Fig. 5). This reflected the absence of large schools of marine-spawning hardyheads and larger and more consistent catches of the Southern Longfin Goby. The latter species is distributed primarily across southern Australia from Denham (Shark Bay) on the west coast across southern Australia and Tasmania to Mallacoota in Victoria and is estimated to have a temperature preference range of 14.6 to 26.2 °C and mean of 18.6 °C (Bray et al., 2024; Froese et al., 2024). The cooler and deeper waters present in autumn would have been more suitable for this benthic species.

Offshore waters

The ecological condition based on fish communities of the offshore waters of the Swan Canning Estuary was good (B) in both summer and autumn (Fig. 6). The condition of each zone varied during summer (mean FCI scores of 50 – 68), being good (B) in the LSCE, MSE and USE and poor/fair (D/C) in the CE. In autumn, the mean FCI score in the LSCE increased by 9 points from good to very good (A) and the CE by four points from poor/fair to fair. While the condition in the MSE remained the same (62 and good), the FCI score for the USE decreased by 15 points from 68 to 53, resulting in a change from good to fair (Fig. 6).

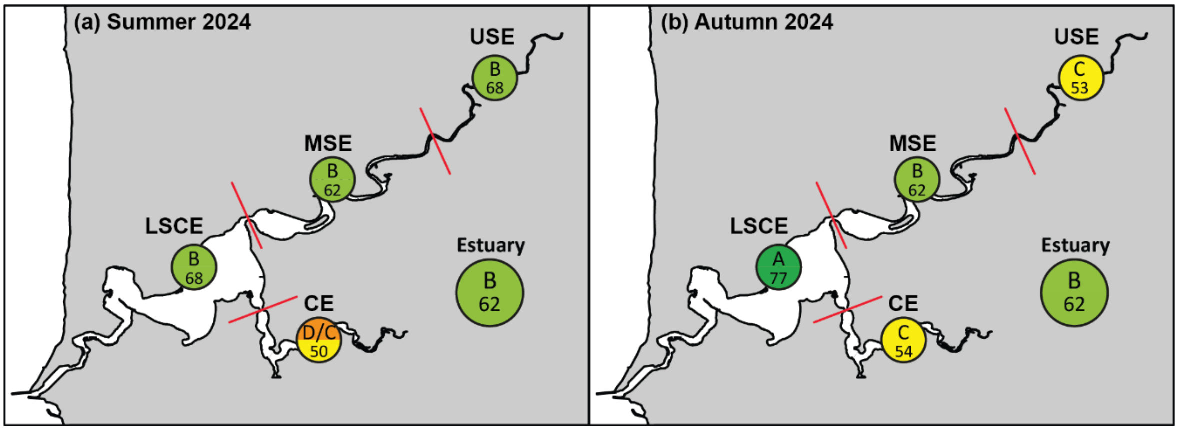


Figure 6. Average offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Estuary, and for the estuary as a whole, in the summer and autumn of 2024.

Radar plots of the offshore metric scores showed that the poor/fair condition of the CE in summer was due to very low scores for the *Proportion of detritivores* (negative metric; 0.2 out of 10; Fig. 7a), low scores for the *Number of species, Number of trophic specialists species* (positive metrics), and the *Number of trophic generalist species* (negative metric). In contrast, very high scores were recorded for the *Proportion of estuarine-spawning individuals*, *Proportion of benthic-associated* individuals and *Shannon-Wiener diversity.* These trends are because, on average, only 4.5 species were caught per sample and that Perth Herring, an estuarine-spawning detritivore, contributed 82% of all fish recorded in this zone and up to 95% in some samples. Moreover, other commonly occurring and relatively abundant species, i.e. Common Silverbiddy, Yellowtail Grunter and Western Striped Grunter, are also benthopelagic and thus contribute to the *Proportion of benthic-associated individuals.* Moreover, the latter two species are also trophic generalists.

The LSCE, MSE and USE typically had relatively high scores for the *Number of species*, *Number of trophic specialists*, and the *Proportion of benthic individuals* (Fig. 7a). These values could be due to the offshore movement of fish from nearshore to deeper waters to avoid shallow depths, predation from birds, and higher water temperatures and, particularly in the USE, movement of estuarine species further upstream. The *Proportion of estuarine-spawning individuals* was lowest in the LSCE, most likely due to marine affinities of the lower estuary being less favourable to estuarine species (Loneragan et al., 1989; Valesini et al., 2017).

Between summer and autumn, the biggest change in the mean offshore FCI scores occurred in the USE, which declined from good (68) to good/fair (53), influenced mainly by the reductions in the *Number of trophic specialist species, Proportion of detritivores* (negative) and, to a lesser extent, *Shannon-Wiener diversity* (Fig. 6 and 7). In summer, this zone was dominated by Perth Herring, Sea Mullet, Yellowtail Grunter, Black Bream and Giant Herring. The occurrence and/or abundance of each of these species declined, together with Mulloway, in autumn and the proportion of Perth Herring increased. There was a bloom of *Karlodinium* spp. that was present in the USE and further upstream for a month before autumn sampling commenced and was still at bloom densities during the first portion of sampling and only subsided two days before the final samples were collected. While no significant fish kills were recorded (DBCA, unpublished data), fish species including Perth Herring, Sea Mullet, Black Bream and Yellowtail Grunter have been shown to move away from previous *Karlodinium* blooms in the USE (Hallett, 2012; Hallett et al., 2016). As such, the presence of this bloom may have caused some of the fish in the USE to move away, lowering the FCI score. In previous instances, this has resulted in a decline in FCI score (Hallett et al., 2019).

The mean FCI score for the MSE remained the same in summer and autumn (i.e. 62; good condition), which contrasts with the previous three years (2021, 2022 and 2023), where scores were lower in autumn. In each of these previous years, freshwater flow led to stratification and associated hypoxia and, in some years, also the presence of *Karlodinium* spp. (Tweedley et al., 2022b, a; 2023). The maintenance of a good condition in both seasons in 2024 is likely to reflect high and stable salinities present throughout the vertical axis of the water column and the lack of hypoxic conditions and toxic algal blooms. The mean score for the LSCE improved from good (68) in summer to very good (77) in autumn. This was mainly driven by an increase in the *Proportion of detritivores*, which was a result of the lower occurrence and catches of Perth Herring caught in Autumn.

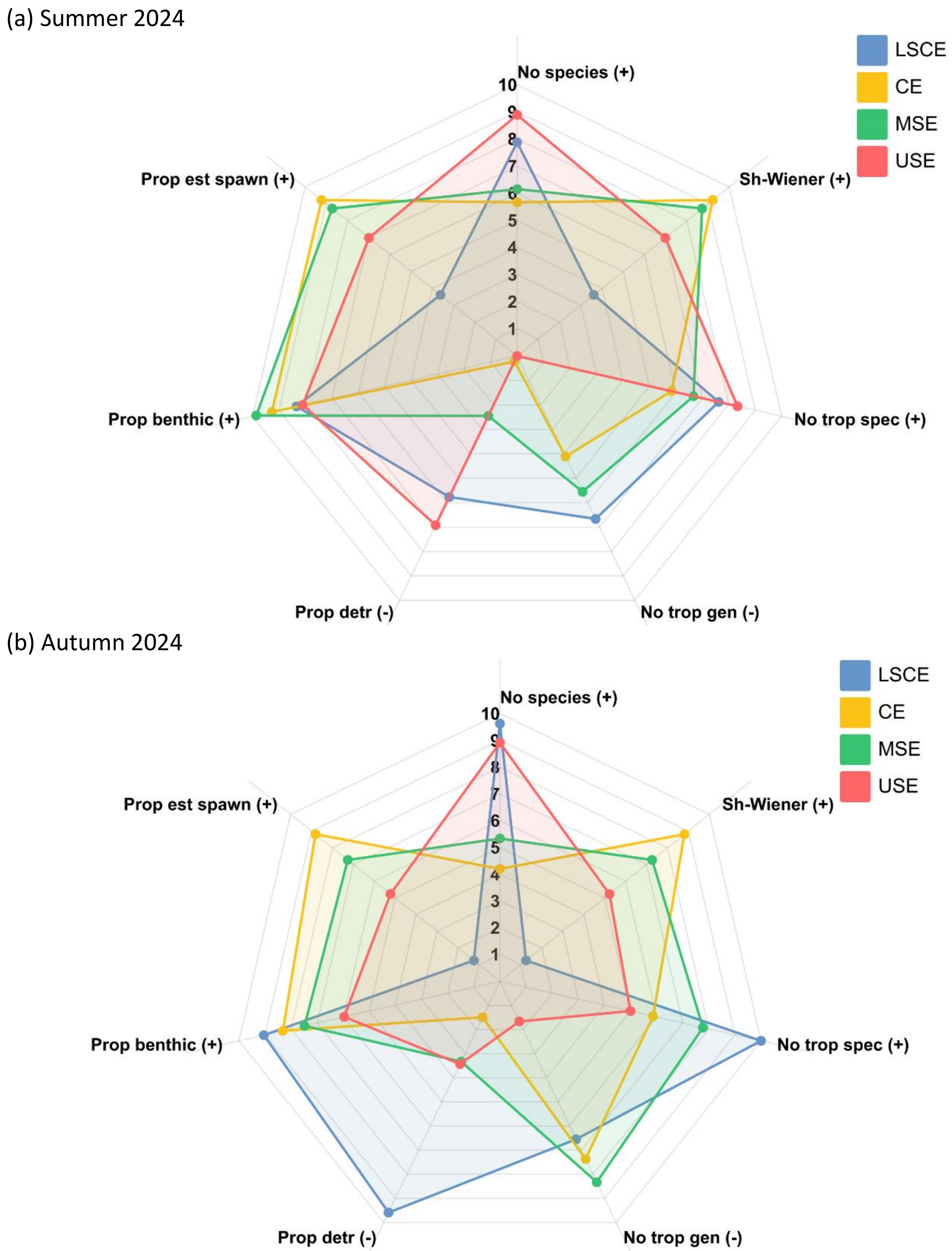


Figure 7. Average scores (0–10) for each component metric of the offshore Fish Community Index, calculated from samples collected throughout the LSCE, CE, MSE and USE zones in (a) summer and (b) autumn 2024. Note that an increase in the score for positive metrics (+) reflects an increase in the underlying variable, whereas an increase in the score for negative metrics (-) reflects a decrease in the underlying variable. Therefore, the larger the area covered by the radar plot the better the condition in that zone. Metric names and explanations are given in Table 1.

Longer-term trends in ecological condition

Overall results for Swan Canning Estuary in 2024 indicate that the nearshore waters were in fair condition (C) with an average score across zones of 63. This is the fifth-lowest score recorded and the lowest since 2019, but markedly better than those recorded between 2005 and 2007 and consistent with the scores since 2011 (Fig 8). The mean offshore FCI score for the estuary overall indicated good (B) condition during 2024 and was the highest ever recorded. The current score of good is in line with the generally upward trend from 2016 onwards (Fig. 9), and is the sixth time good condition has been obtained (i.e. also 2012, 2015, 2020, 2022 and 2023). Combined, the somewhat contrasting scores for the nearshore and offshore waters, are the fourth-highest recorded and similar to those in 2022 and 2023 (ranked first and third, respectively). Thus, the trend for relatively good conditions for the estuary as a whole in recent years has continued in 2024.

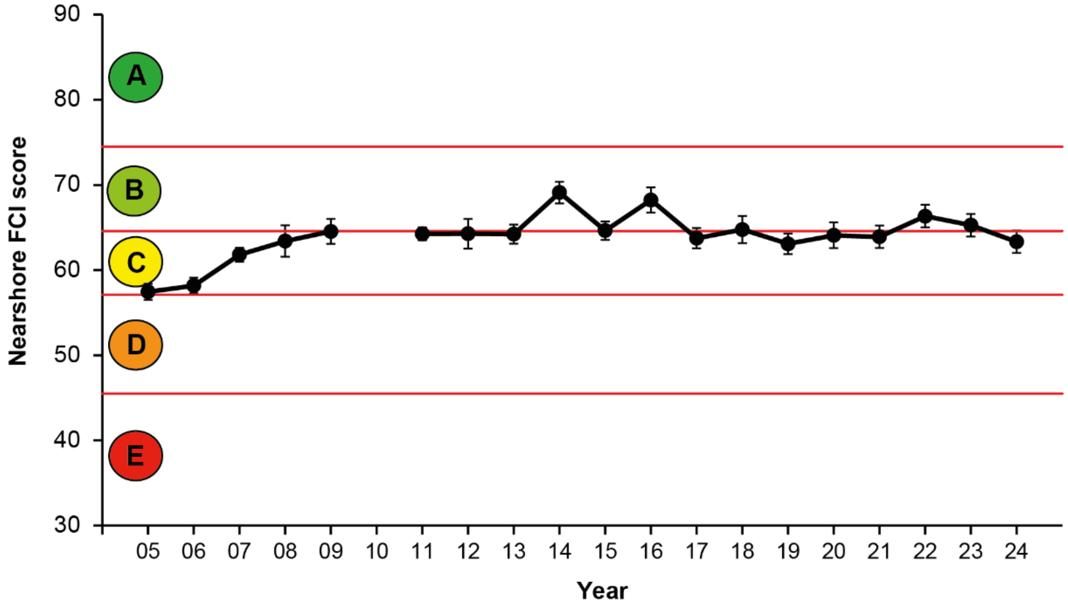


Figure 8. Trend plot of average (±SE) nearshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for the Swan Canning Estuary between 2005 and 2024. Red lines denote boundaries between condition grades. No data were collected in 2010.

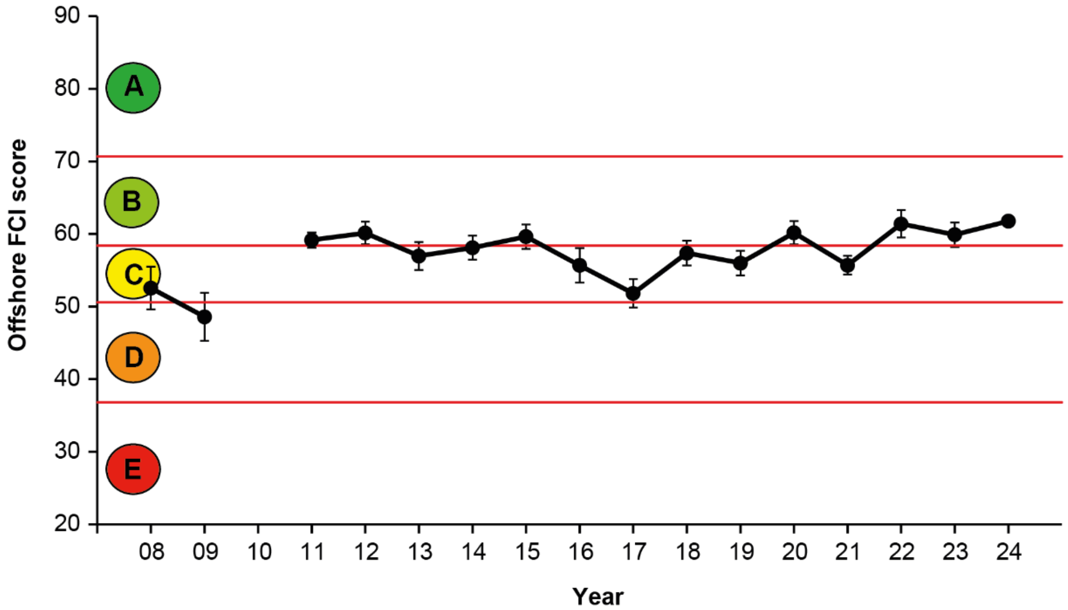


Figure 9. Trend plot of average (±SE) offshore Fish Community Index (FCI) scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor), for the Swan Canning Estuary between 2008 and 2024. Red lines denote boundaries between condition grades. No data were collected in 2010.

6. Summary

The Fish Community Index (FCI) considers the fish community as a whole and provides an objective means to assess how the structure and function of these communities in shallow, nearshore (< 1.5 m deep) and deeper, offshore waters (> 1.5 m deep) respond to a wide array of stressors affecting the ecosystem. Note that the FCI does not provide information on the population dynamics or health of particular species (in comparison to e.g. Cottingham et al., 2014; Crisp et al., 2018), nor does it provide information on the size or status of the fish stocks in the estuary (e.g. Smith et al., 2021; Obregón et al., 2022).

Across the entire estuary, the ecological condition of both nearshore and offshore waters in 2024 was assessed as fair (C) and good (B), respectively, based on their fish communities (Table 5). Combined, the nearshore and offshore index scores are among the highest ever recorded, continuing a trend over the last few years. In all years since 2012, the mean FCI scores have been greater in the nearshore than offshore waters; however, the magnitude of the difference was the least this year. This reflects the water temperatures and saline conditions in summer, which may have caused some fish to move from the nearshore waters into the deeper, cooler, offshore waters, particularly in the LSCE. Moreover, the lack of flow from the Swan River prevented the occurrence of stratification and hypoxia and thus offshore scores in the MSE did not decline in autumn as had occurred in recent years. Although offshore FCI values did decline in the USE in autumn likely due to a bloom of the potentially toxic dinoflagellate *Karlodinium* spp., scores in the CE were amongst the highest recorded. The offshore waters of this zone have consistently scored poorly relative to other zones across both seasons, receiving a poor (D) grade in > 50% of monitored seasons, yet the grades in summer and autumn were poor/fair and fair, respectively, giving an overall grade of fair (Table 5).

Table 5. Fish Community Index (FCI) scores and corresponding ecological condition grades for each zone of the estuary, and the estuary as a whole, during the 2024 monitoring period (mean of all summer and autumn of 2024). LSCE = Lower Swan Canning Estuary, CE = Canning Estuary, MSE = Middle Swan Estuary, USE = Upper Swan Estuary.

	Nearshore		**Offshore**	
	Mean FCI score	*Condition*	*Mean FCI score*	*Condition*
LSCE	58.36	C	72.37	A
CE	60.23	C	52.07	C
MSE	65.43	B/C	62.14	B
USE	69.30	B	60.54	B
Estuary	**63.33**	**C**	**61.78**	**B**

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8. Appendices

Appendix (i). Descriptions of (a) nearshore and (b) offshore Fish Community Index monitoring sites. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

Zone	Site Code	Lat-Long (S, E)	Description
(a) – *Nearshore*			
LSCE	LSCE3	-32°01’29’’, 115°46’27’’	Shoreline in front of vegetation on eastern side of Point Roe, Mosman Pk
	LSCE4	-31°59’26’’, 115°47’08’’	Grassy shore in front of houses to east of Claremont Jetty
	LSCE5	-32°00’24’’, 115°46’52’’	North side of Point Walter sandbar
	LSCE6	-32°01’06’’, 115°48’19’’	Shore in front of bench on Attadale Reserve
	LSCE7	-32°00’11’’, 115°50’29’’	Sandy bay below Point Heathcote
	LSCE8	-31°59’11’’, 115°49’40’’	Eastern side of Pelican Point, immediately south of sailing club
CE	CE1	-32°01’28’’, 115°51’16’’	Sandy shore to south of Deepwater Point boat ramp
	CE2	-32°01’54’’, 115°51’33’’	Sandy beach immediately to north of Mount Henry Bridge
	CE5	-32°01’40’’, 115°52’58’’	Bay in Shelley Beach, adjacent to jetty
	CE6	-32°01’29’’, 115°53’11’’	Small clearing in vegetation off North Riverton Drive
	CE7	-32°01’18’’, 115°53’43’’	Sandy bay in front of bench, east of Wadjup Point
	CE8	-32°01’16’’, 115°55’14’’	Sandy beach immediately downstream of Kent Street Weir
MSE	MSE2	-31°58’12’’, 115°51’07’’	Sandy beach on South Perth foreshore, west of Mends St Jetty
	MSE4	-31°56’34’’, 115°53’06’’	Shoreline in front of Belmont racecourse, north of Windan Bridge
	MSE5	-31°56’13’’, 115°53’23’’	Beach to west of jetty in front of Maylands Yacht Club
	MSE6	-31°57’13’’, 115°53’56’’	Small beach upstream of Belmont Water Ski Area boat ramp
	MSE7	-31°55’53’’, 115°55’10’’	Beach in front of scout hut, east of Garratt Road Bridge
	MSE8	-31°55’37’’, 115°56’18’’	Vegetated shoreline, Claughton Reserve, upstream of boat ramp
USE	USE1	-31°55’20’’, 115°57’03’’	Small beach adjacent to jetty at Sandy Beach Reserve, Bassendean
	USE3	-31°53’43’’, 115°57’32’’	Sandy bay opposite Bennett Brook, at Fishmarket Reserve, Guildford
	USE4	-31°53’28’’, 115°58’32’’	Shoreline in front of Guildford Grammar stables, opposite Lilac Hill Park
	USE5	-31°53’13’’, 115°59’29’’	Small, rocky beach after bend in river at Ray Marshall Park
	USE6	-31°52’41’’, 115°59’31’’	Small beach with iron fence, in front of Caversham house
	USE7	-31°52’22’’, 115°59’39’’	Sandy shore on bend in river, below house on hill, upstream of powerlines
(b) – *Offshore*			
LSCE	LSCE1G	-32°00’24’’, 115°46’56’’	In deeper water *ca* 100 m off north side of Point Walter sandbar
	LSCE2G	-32°00’12’’, 115°48’07’’	Alongside seawall west of Armstrong Spit, Dalkeith
	LSCE3G	-32°01’00’’, 115°48’44’’	Parallel to shoreline, running westwards from Beacon 45, Attadale
	LSCE4G	-32°00’18’’, 115°50’01’’	In deep water of Waylen Bay, from *ca* 50 m east of Applecross jetty
	LSCE5G	-31°59’37’’, 115°51’09’’	Perpendicular to Como Jetty, running northwards
	LSCE6G	-31°59’12’’, 115°49’42’’	*Ca* 20 m from, and parallel to, sandy shore on east side of Pelican Point
CE	CE1G	-32°01’58’’, 115°51’36’’	Underneath Mount Henry Bridge, parallel to northern shoreline
	CE2G	-32°01’48’’, 115°51’46’’	Parallel to, and *ca* 20 m from, western shoreline of Aquinas Bay
	CE3G	-32°01’49’’, 115°52’19’’	To north of navigation markers, Aquinas Bay
	CE4G	-32°01’48’’, 115°52’33’’	Adjacent to Old Post Line (SW-ern end; Salter Point)
	CE5G	-32°01’36’’, 115°52’52’’	Adjacent to Old Post Line (NE-ern end; Prisoner Point)
	CE6G	-32°01’20’’, 115°53’15’’	Adjacent to Old Post Line, Shelley Water
MSE	MSE1G	-31°58’03’’, 115°51’03’’	From jetty at Point Belches towards Mends St Jetty, Perth Water
	MSE2G	-31°56’57’’, 115°53’05’’	Downstream of Windan Bridge, parallel to Burswood shoreline
	MSE3G	-31°56’22’’, 115°53’05’’	Downstream from port marker, parallel to Joel Terrace, Maylands
	MSE4G	-31°57’13’’, 115°54’12’’	Parallel to shore from former boat shed jetty, Cracknell Park, Belmont
	MSE5G	-31°55’57’’, 115°55’12’’	Parallel to southern shoreline, upstream of Garratt Road Bridge
	MSE6G	-31°55’23’’, 115°56’25’’	Parallel to eastern bank at Garvey Pk, from south of Ron Courtney Island
USE	USE1G	-31°55’19’’, 115°57’09’’	Parallel to tree-lined eastern bank, upstream of Sandy Beach Reserve
	USE2G	-31°53’42’’, 115°57’40’’	Along northern riverbank, running upstream from Bennett Brook
	USE3G	-31°53’16’’, 115°58’42’’	Along northern bank on bend in river, to north of Lilac Hill Park
	USE4G	-31°53’17’’, 115°59’23’’	Along southern bank, downstream from bend at Ray Marshall Pk
	USE5G	-31°52’13’’, 115°59’40’’	Running along northern bank, upstream from Sandalford winery jetty
	USE6G	-31°52’13’’, 116°00’18’’	Along southern shore adjacent to Midland Brickworks, from outflow pipe

Appendix (ii). Descriptions of sampling and processing procedures.

Nearshore sampling methods

- On each sampling occasion, one replicate sample of the nearshore fish community is collected from each of the fixed, nearshore sampling sites.
- Sampling is not conducted during or within 3-5 days following any significant flow event.
- Nearshore fish samples are collected using a beach seine net that is 21.5 m long, comprises two 10 m-long wings (6 m of 9 mm mesh and 4 m of 3 mm mesh) and a 1.5 m-long bunt (3 mm mesh) and fishes to a depth of 1.5 m.
- This net is walked out from the beach to a maximum depth of approximately 1.5 m and deployed parallel to the shore, and is then rapidly dragged towards and onto the shore, so that it sweeps a roughly semicircular area of approximately 116 m^2.
- If a seine net deployment returns a catch of fewer than five fish, an additional sample is performed at the site (separated from the first sample by either 15 minutes or by 10-20 m distance). In the event that more than five fish are caught in the second sample, this second replicate is then used as the sample for that site and those fish from the first sample returned to the water alive. If, however, 0-5 fish are again caught, the original sample can be assumed to have been representative of the fish community present and be used as the sample for that site. The fish from the latter sample are then returned alive to the water. The above procedure thus helps to identify whether a collected sample is representative of the fish community present and enables instances of false negative catches to be identified and eliminated.
- Once an appropriate sample has been collected, any fish that may be readily identified to species (e.g. those larger species which are caught in relatively lower numbers) are counted and returned to the water alive.
- All other fish caught in the nets are placed into zip-lock polythene bags, euthanised in an ice slurry and preserved on ice in eskies in the field, except in cases where large catches (e.g. thousands) of small fish are obtained. In such cases, an appropriate sub-sample (e.g. one half to one eighth of the entire catch) is retained and the remaining fish are returned alive to the water. All retained fish are then bagged and frozen until their identification in the laboratory.

Offshore sampling methods

- On each sampling occasion, one replicate sample of the offshore fish community is collected from each of the fixed, offshore sampling sites.
- Sampling is not conducted within 3-5 days following any significant flow event.
- Offshore fish samples are collected using a sunken, multimesh gill net that consists of eight 20 m-long panels with stretched mesh sizes of 35, 51, 63, 76, 89, 102, 115 and 127 mm. These nets are deployed (i.e. laid parallel to the bank) from a boat immediately before sunset and retrieved after three hours.
- Given the time and labour associated with offshore sampling and the need to monitor the set nets for safety purposes, a maximum of three replicate net deployments is performed within a single zone in any one night. The three nets are deployed sequentially, and retrieved in the same order.
- During net retrieval (and, typically, when catch rates are sufficiently low to allow fish to be removed rapidly in the course of retrieval), any fishes that may be removed easily from the net are carefully removed, identified, counted, recorded and returned to the water alive as the net is pulled into the boat.
- All other fish caught in the nets are removed once the net has been retrieved. Retained fish are placed into zip-lock polythene bags in an ice slurry, preserved on ice in eskies in the field, and subsequently frozen until their identification in the laboratory.

Following their identification to the lowest possible taxon in the field or laboratory by fish specialists trained in fish taxonomy, all assigned scientific and common names are checked and standardised by referencing the Checklist of Australian Aquatic Biota (CAAB) database (Rees *et al.* on-line version), and the appropriate CAAB species code is allocated to each species. The abundance data for each species in each sample is entered into a database for record and subsequent computation of the biotic indices.

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

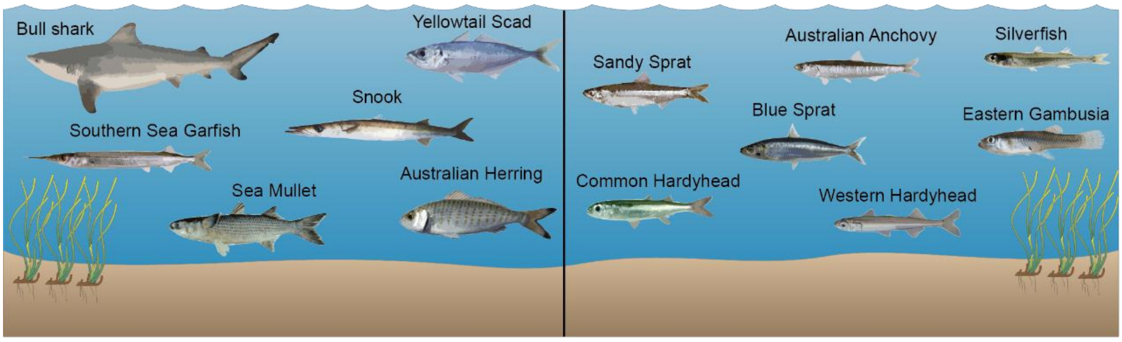
Appendix (iii). List of species caught from the Swan Canning Estuary, and their functional guilds: D, Demersal; P, Pelagic; BP, Benthopelagic; SP, Small pelagic; SB, Small benthic; MS, Marine straggler; MM, Marine migrant; SA, Semi-anadromous; ES, Estuarine species; FM, Freshwater migrant; ZB, Zoobenthivore; PV, Piscivore; ZP, Zooplanktivore; DV, Detritivore; OV, Omnivore; OP, Opportunist; HV, Herbivore. See below for a pictorial depiction of the guilds and Potter et al. (2015a); Whitfield et al. (2022) for a full description and rationale.

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

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

Appendix (iv). Pictoral desciptions of the habitat guilds using species present in the Swan-Canning Estuary with those in bold depicted in the diagrams.

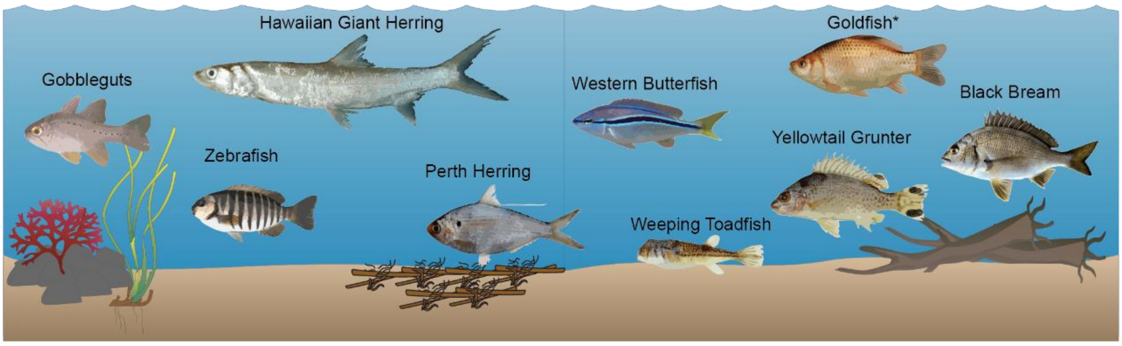
(a) Pelagic **(b) Small pelagic**



Free-swimming species associated with the surface or middle depths of the estuary

Pelagic species that reach ≤ 15 cm total length as adults

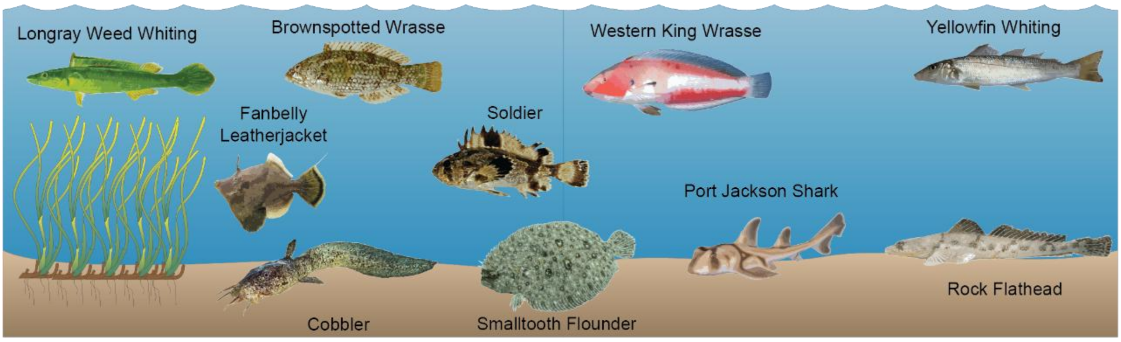
(c) Benthopelagic



Species that live the bottom as well as in midwaters and/or near the surface of the estuary

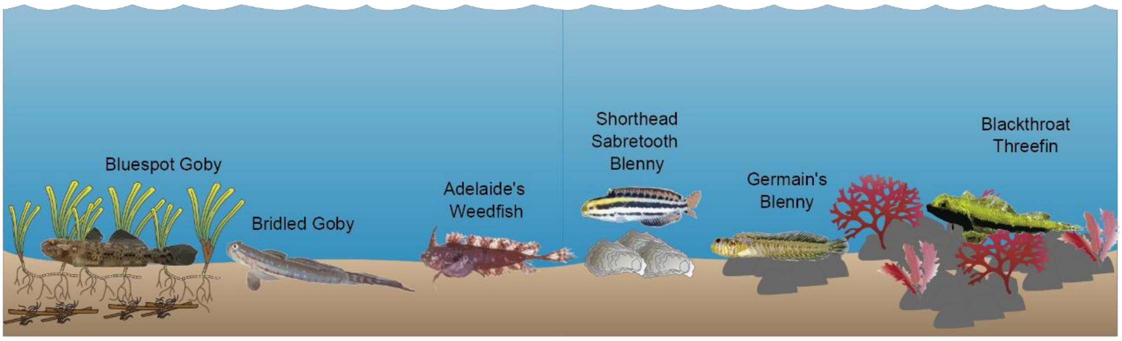
Brownspotted Wrasse

(d) Demersal



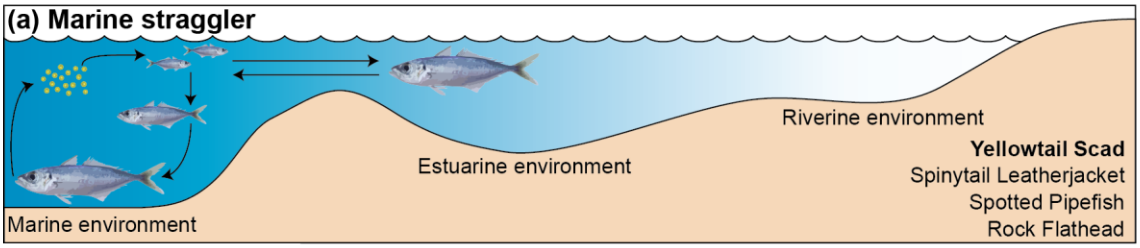
Species that live on or near the bottom of the estuary

(d) Small benthic

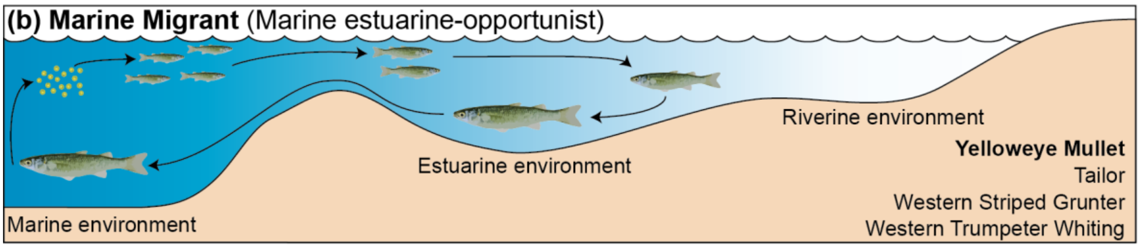


Species that reach ≤ 15 cm total length as adults that live on the bottom of the estuary

Appendix (v). Pictorial descriptions of the estuarine use guilds using species present in the Swan-Canning Estuary with those in bold depicted in the diagrams.

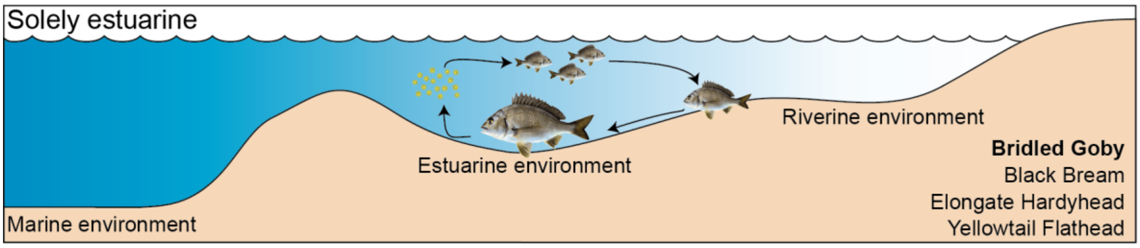


Adults spawn at sea and individuals (adults and juveniles) typically enter estuaries sporadically and in low numbers and are most common in the lower reaches where salinities typically do not decline far below ~35. Belong to populations in marine waters and are often stenohaline.

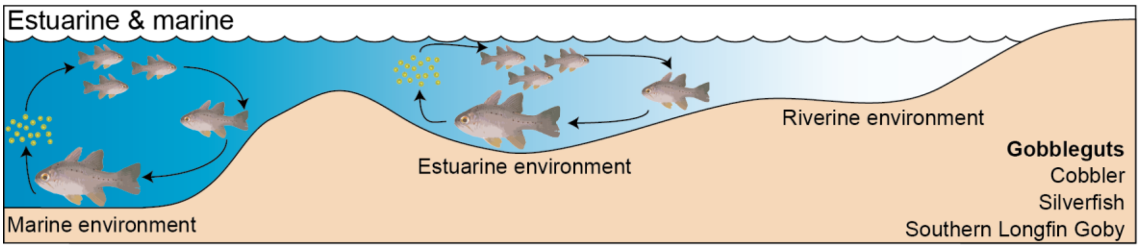


Regularly enter estuaries in substantial numbers, particularly as juveniles, but use, to varying degrees, coastal marine waters as alternative nursery areas.

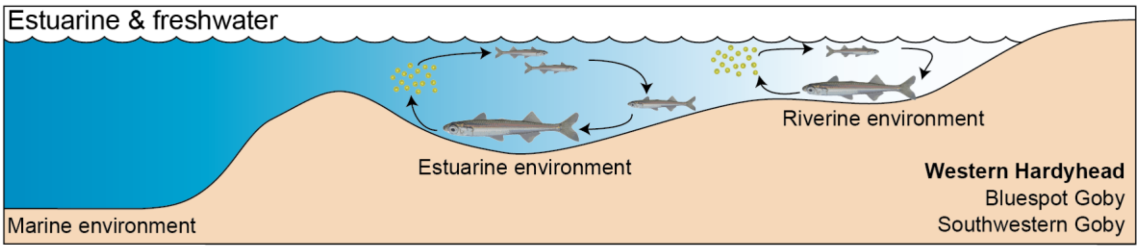
(c) Estuarine species: Species with populations where individuals complete their life cycles in the estuary and includes species with the three life-history strategies below.



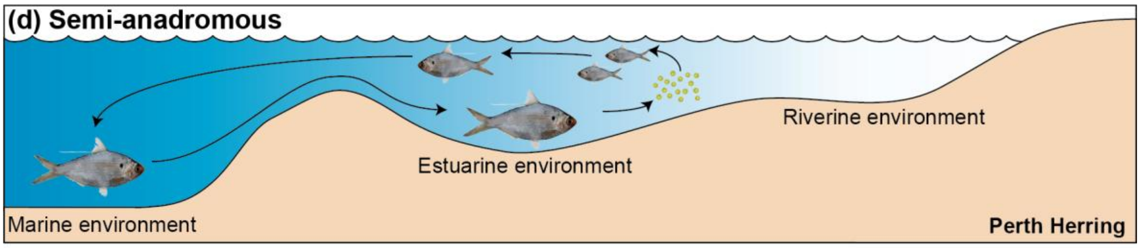
Species found only in estuaries.



Species also represented by marine populations.

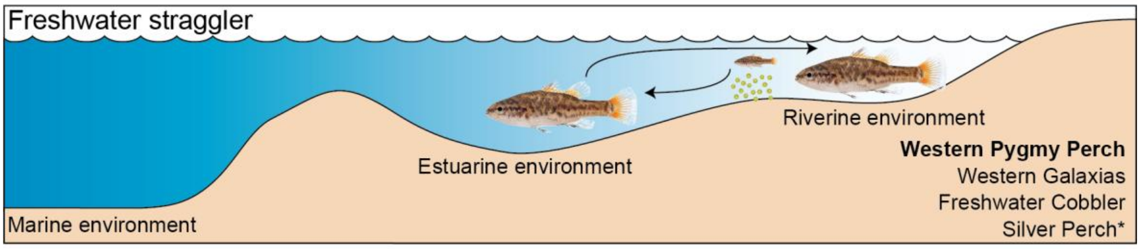


Species also represented by freshwater populations.

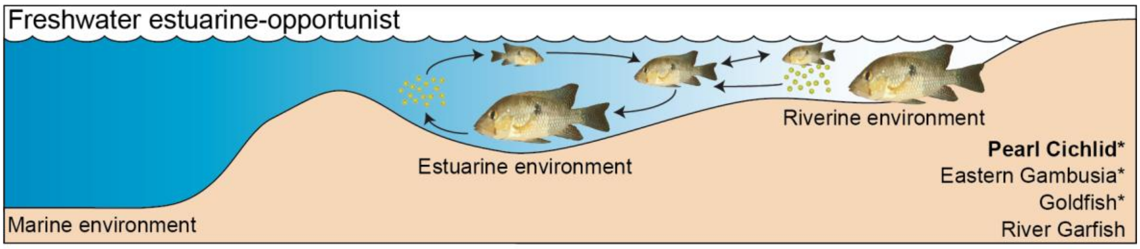


Spawning run from the sea extends only as far as the upper estuary rather than into fresh water.

(e) Freshwater migrant: Species that spawn in freshwater estuary and includes species with the two life-history strategies below.

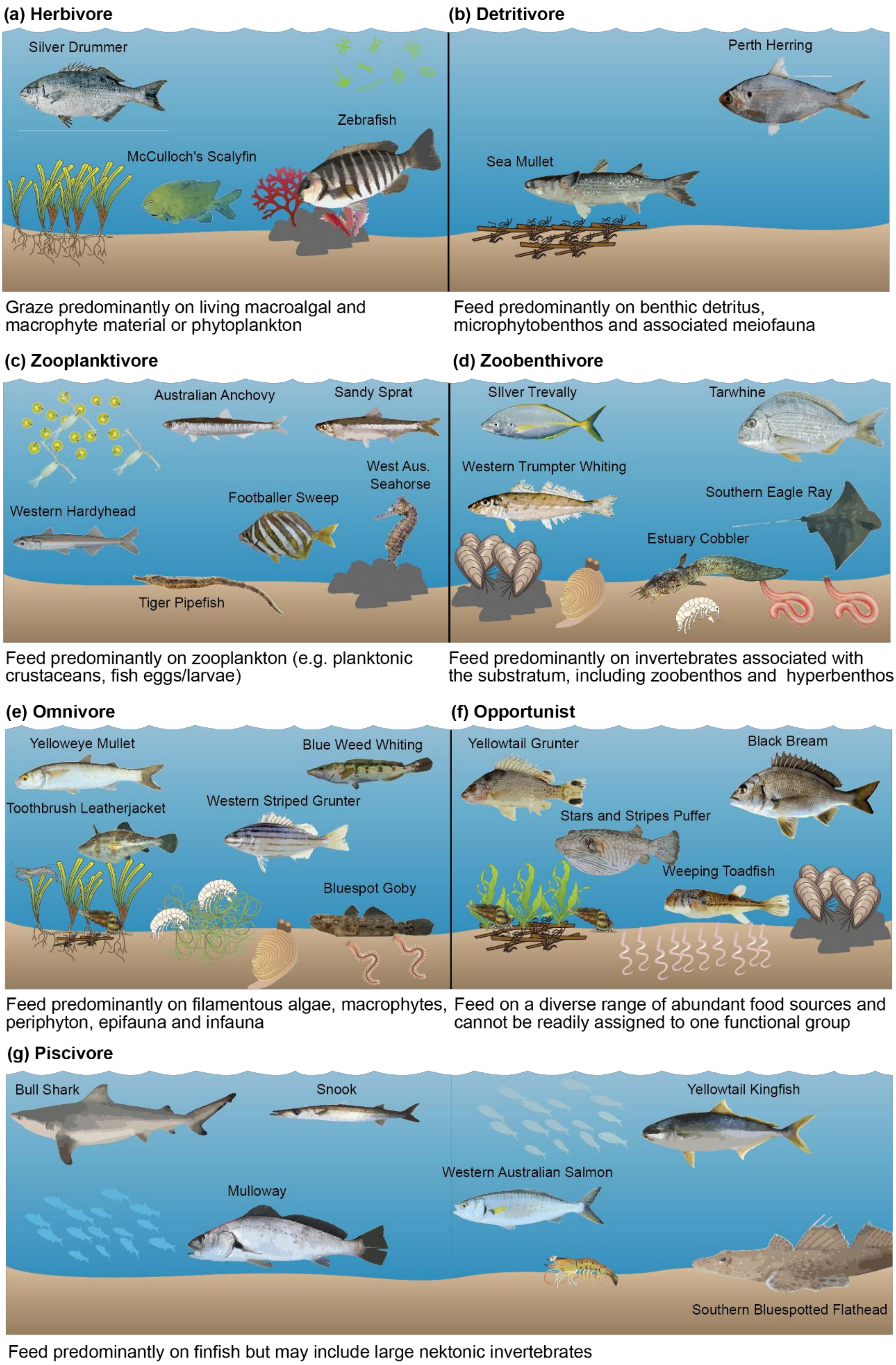


Found in low numbers in estuaries and whose distribution is usually limited to the low salinity, upper reaches of estuaries.



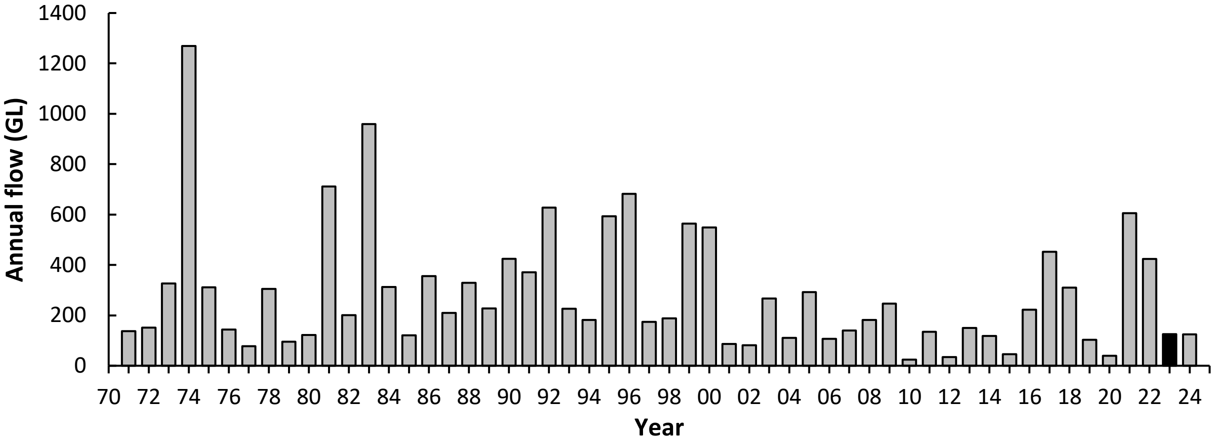
Found regularly and in moderate numbers in estuaries and whose distribution can extend well beyond the oligohaline sections of these systems.

Appendix (vi). Pictorial descriptions of the feeding guilds using species present in the Swan-Canning Estuary with those in bold depicted in the diagrams.

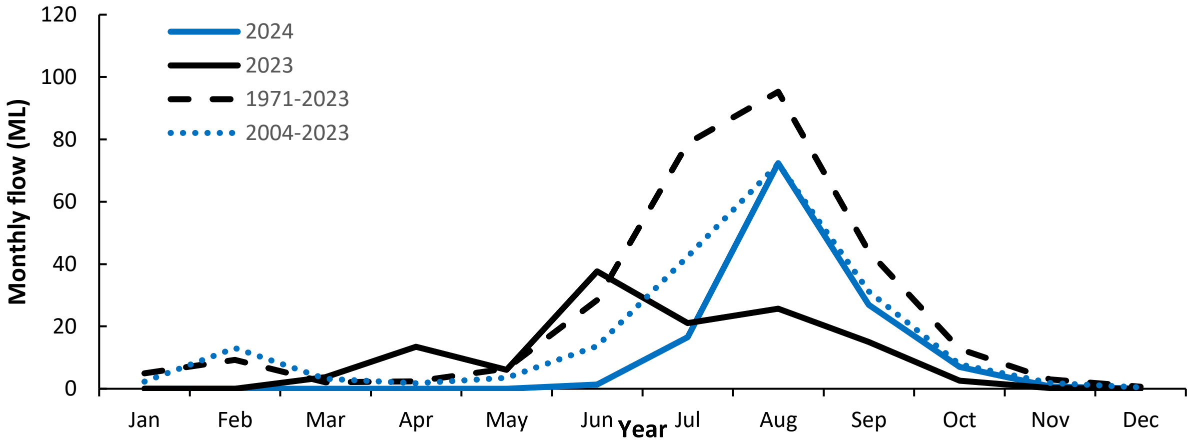


Appendix (vii). (a) Total annual flow between 1971 and 2024 and (b) total monthly flow in 2023 and 2024 compared to longer-term averages at Walyunga on the Swan River (gauging station 16401). Data from 2023 are highlighted in black in (a) and as the solid black line in (b). Data recorded by the Department of Water and Environmental Regulation and extracted from https://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx. Data in 2024 current up to 31 December 2024.

(a)

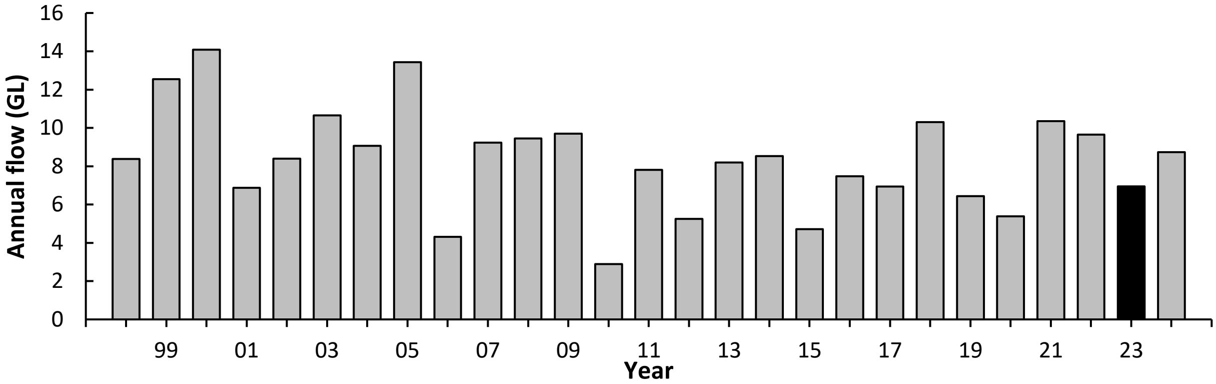


(b)

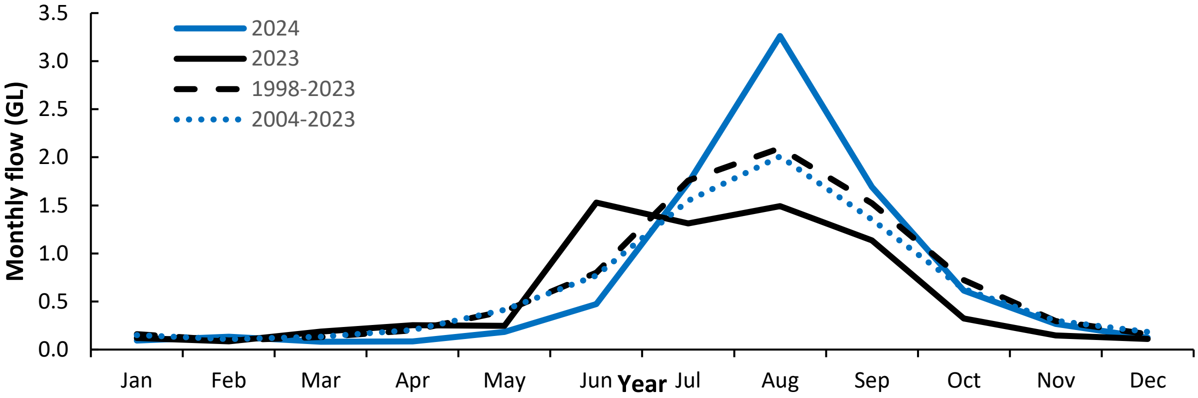


Appendix (viii). (a) Total annual flow between 1998 and 2024 and (b) total monthly flow in 2023 and 2024 compared to longer-term averages at Seaforth on the Canning River (gauging station 16417). Data from 2023 are highlighted in black in (a) and as the solid black line in (b). Data recorded by the Department of Water and Environmental Regulation and extracted from https://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx. Data in 2024 current up to 31 December 2024.

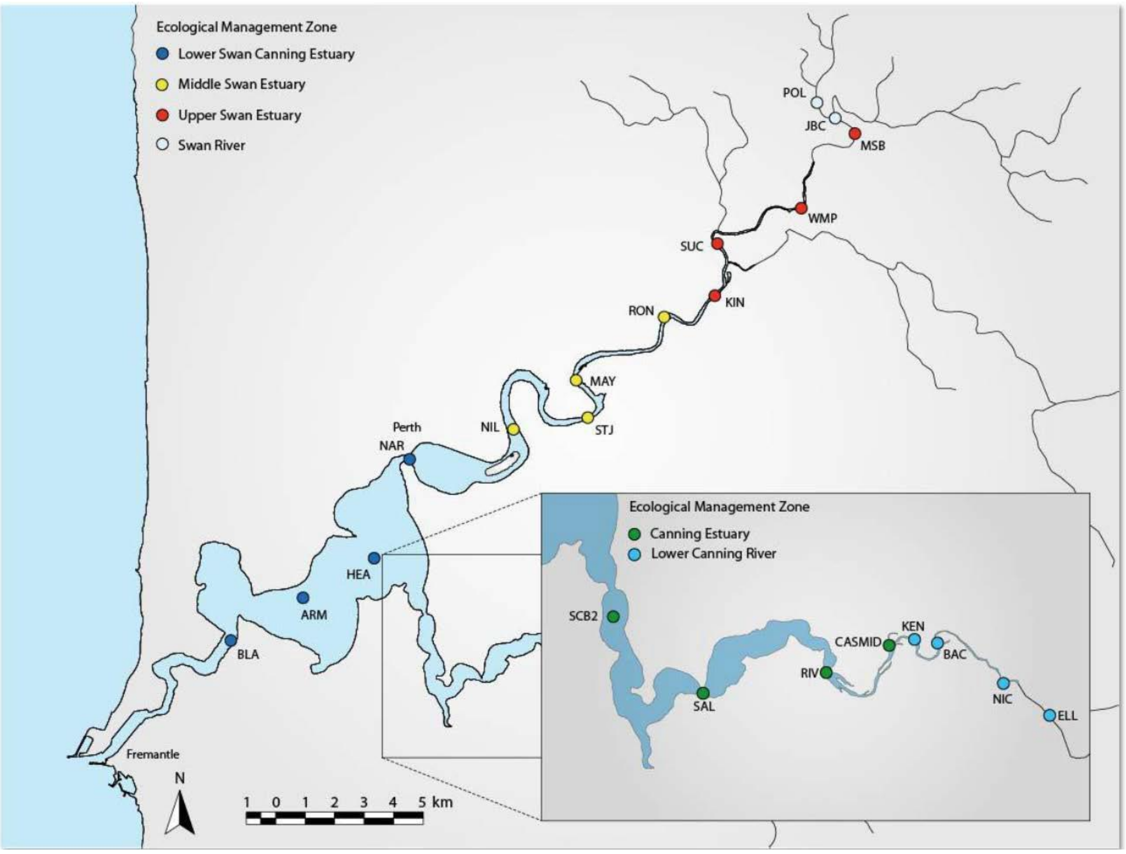
(a)



(b)

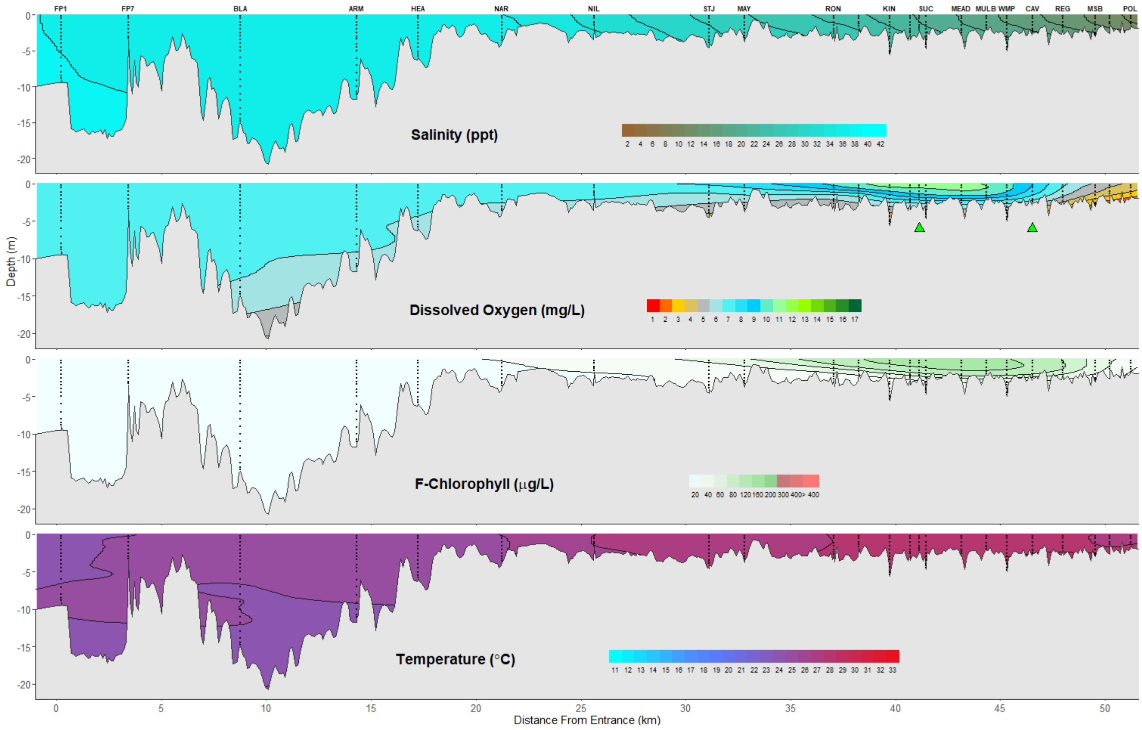


Appendix (ix). A representative selection of vertical contour plots of salinity (ppt), dissolved oxygen concentrations (mg/L), Chlorophyll fluorescence (µg/L) and water temperature (°C) measured at monitoring stations along the length of the Swan Canning Estuary (see map) on occasions throughout the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

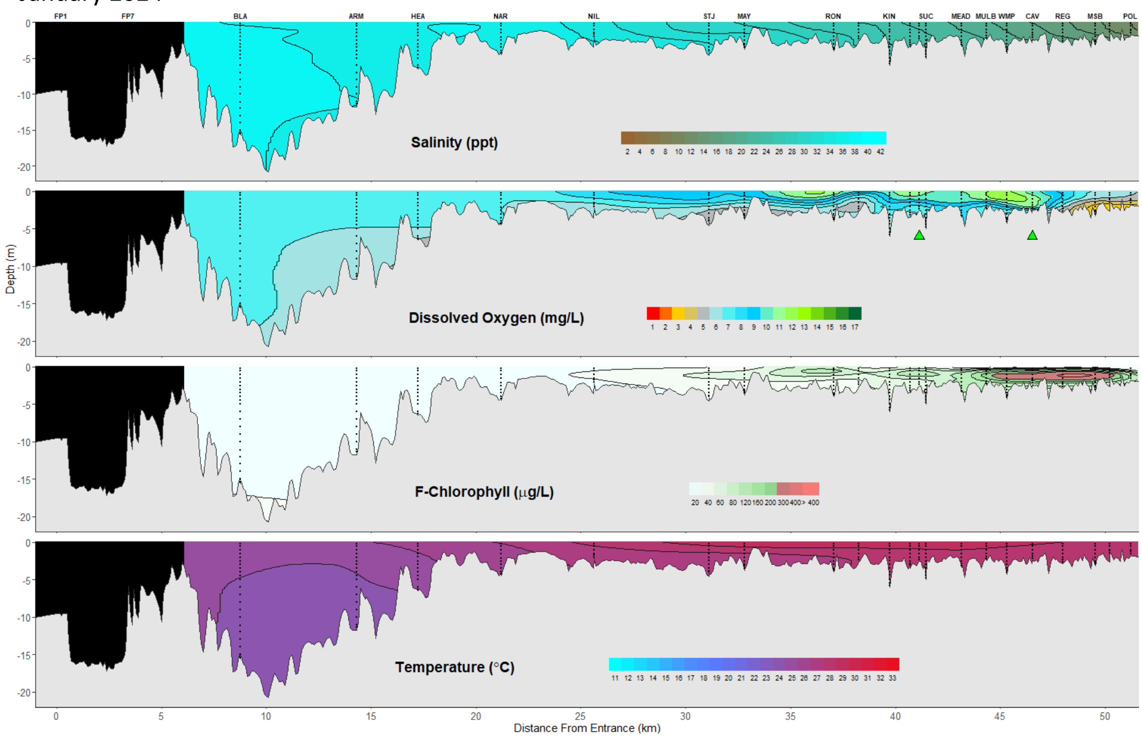


LSCE, MSE and USE zones in summer through autumn 2024

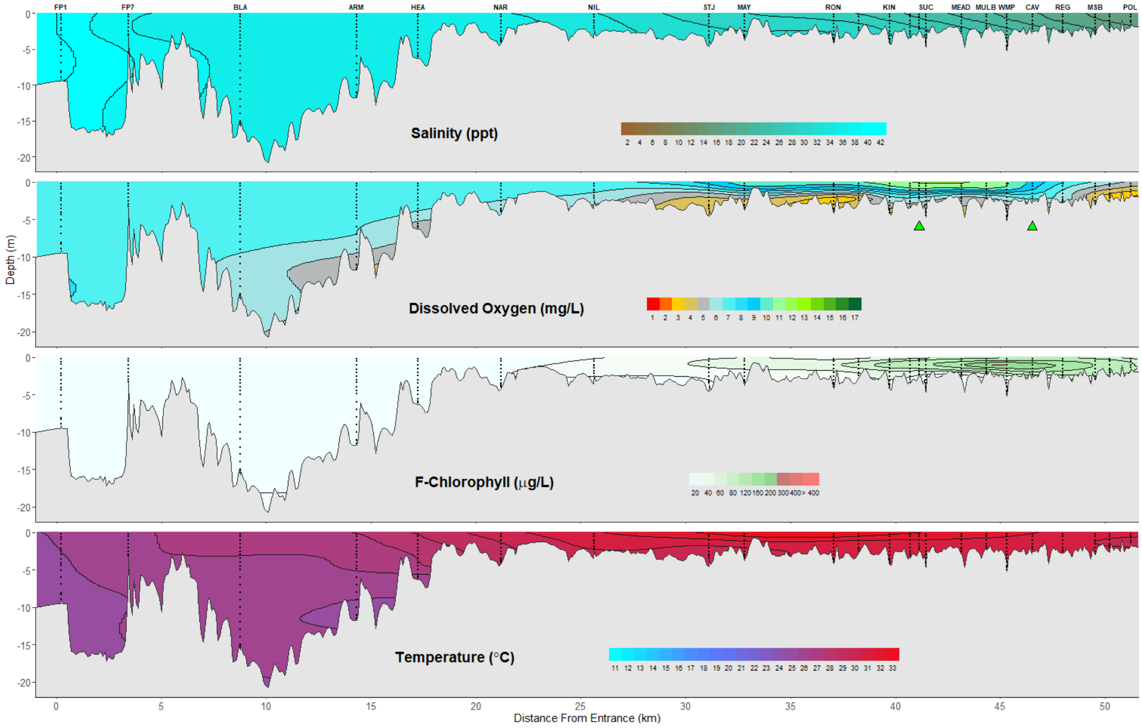
2nd January 2024



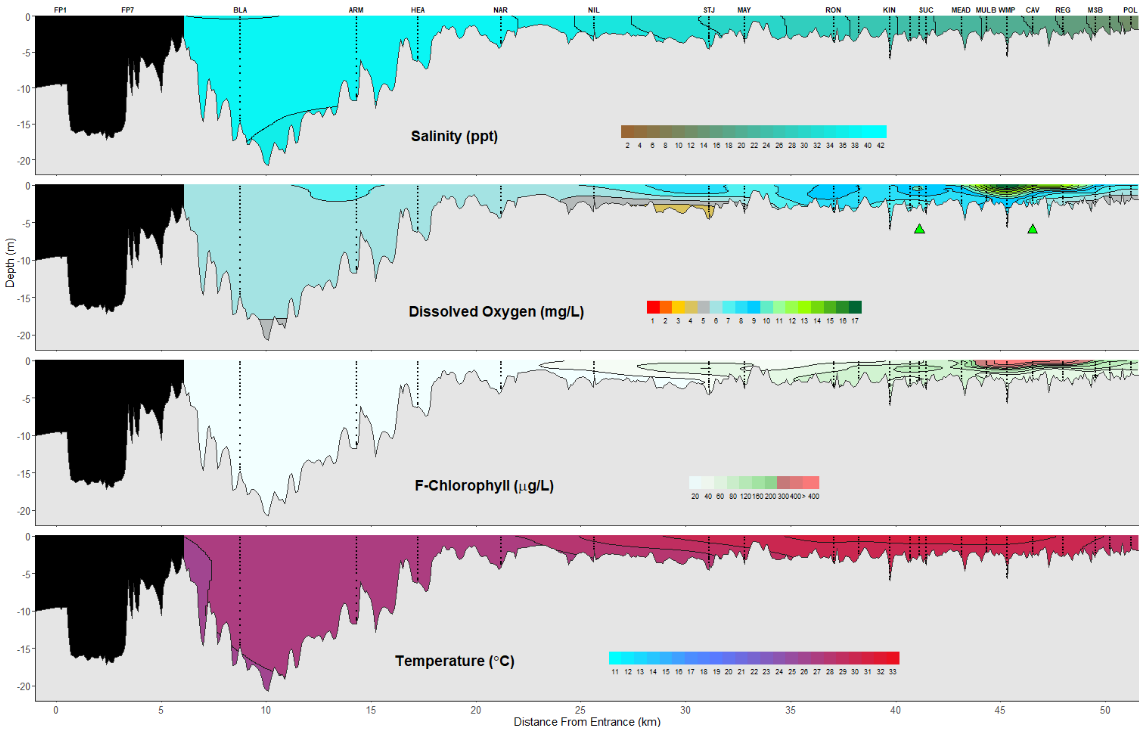
8th January 2024



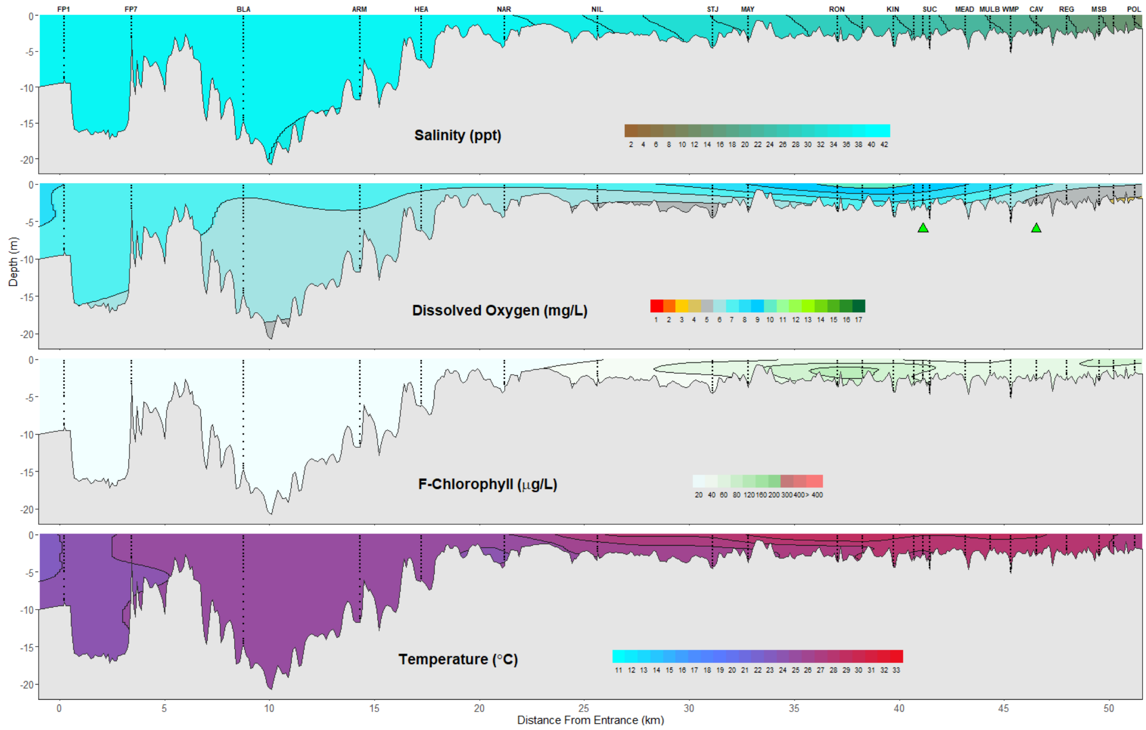
15th January 2024



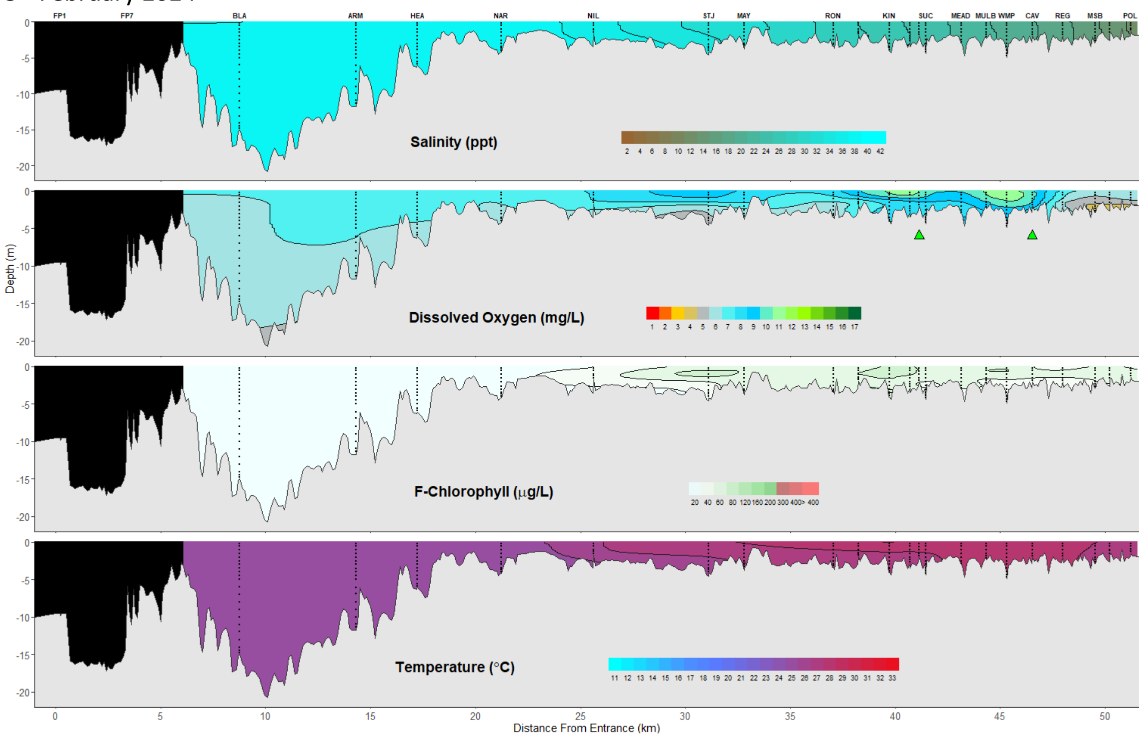
22nd January 2024



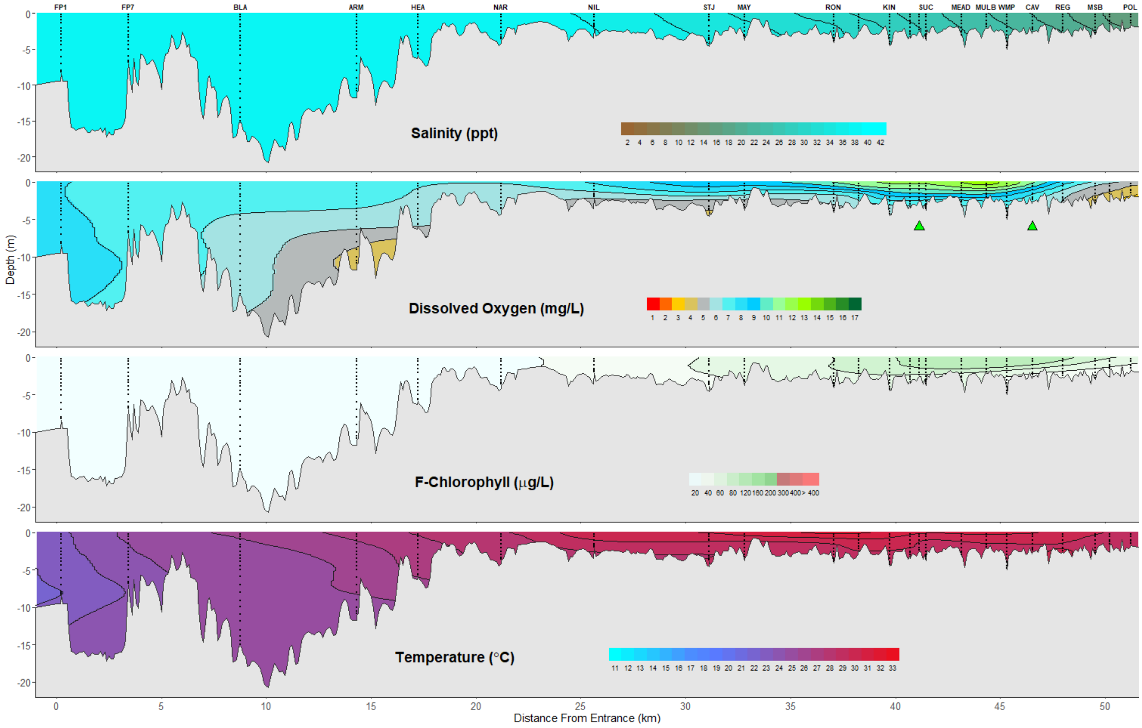
29th January 2024



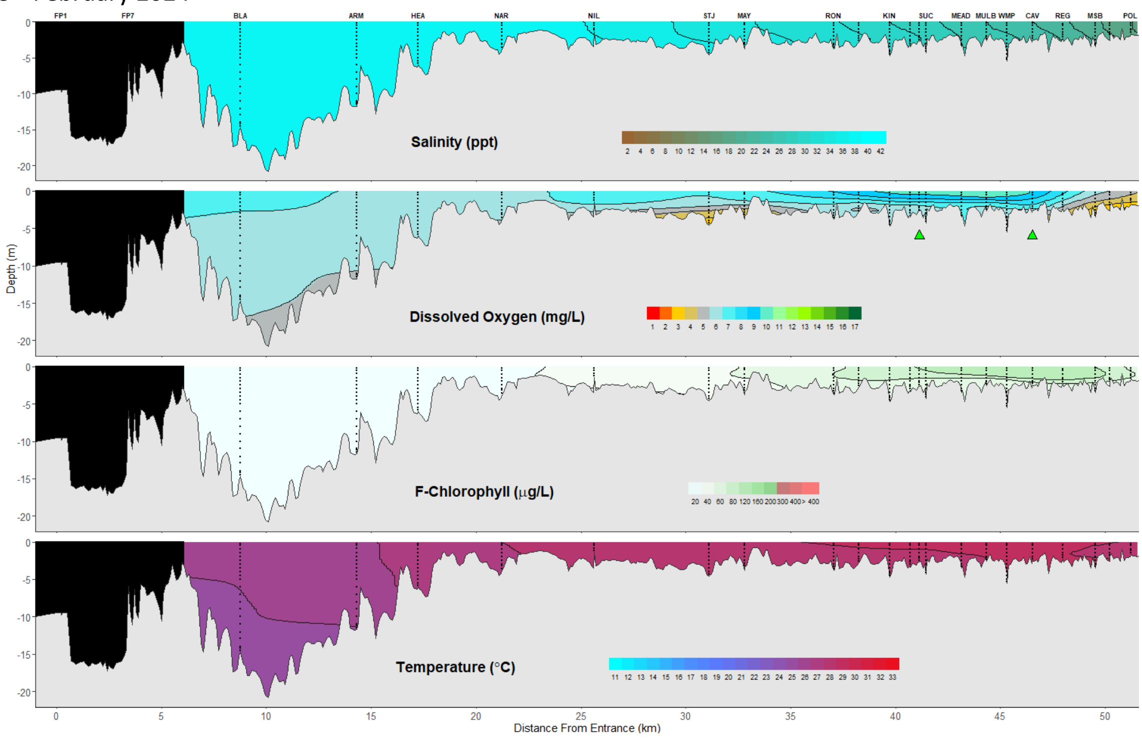
5th February 2024



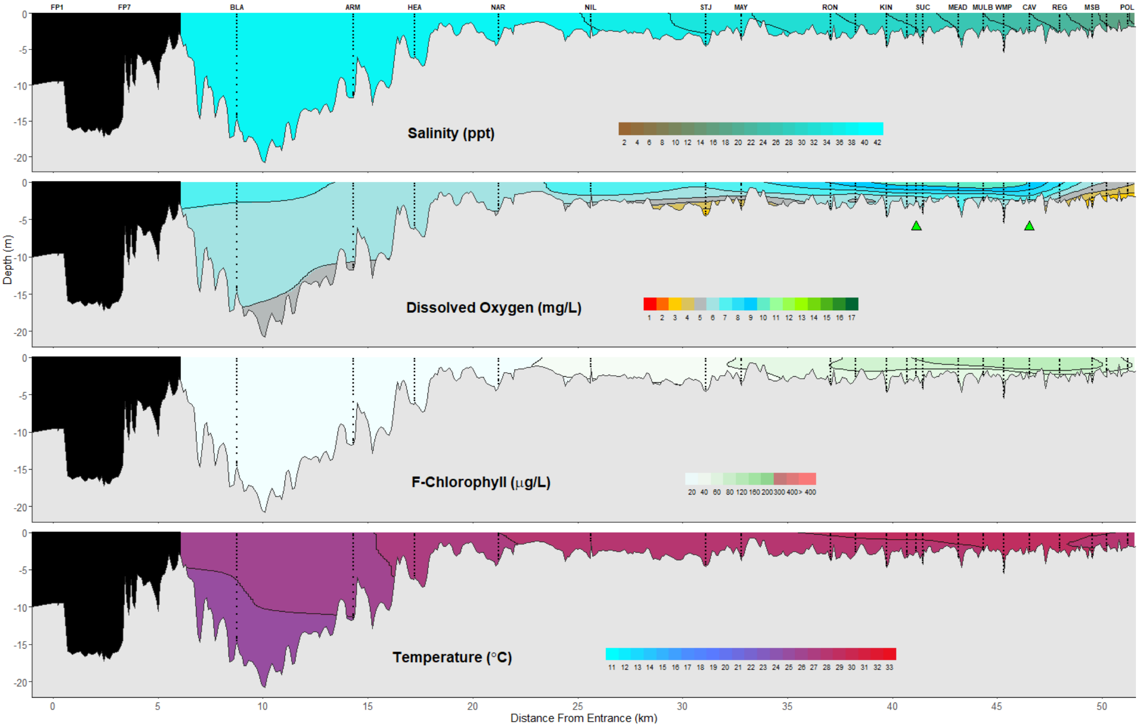
12th February 2024



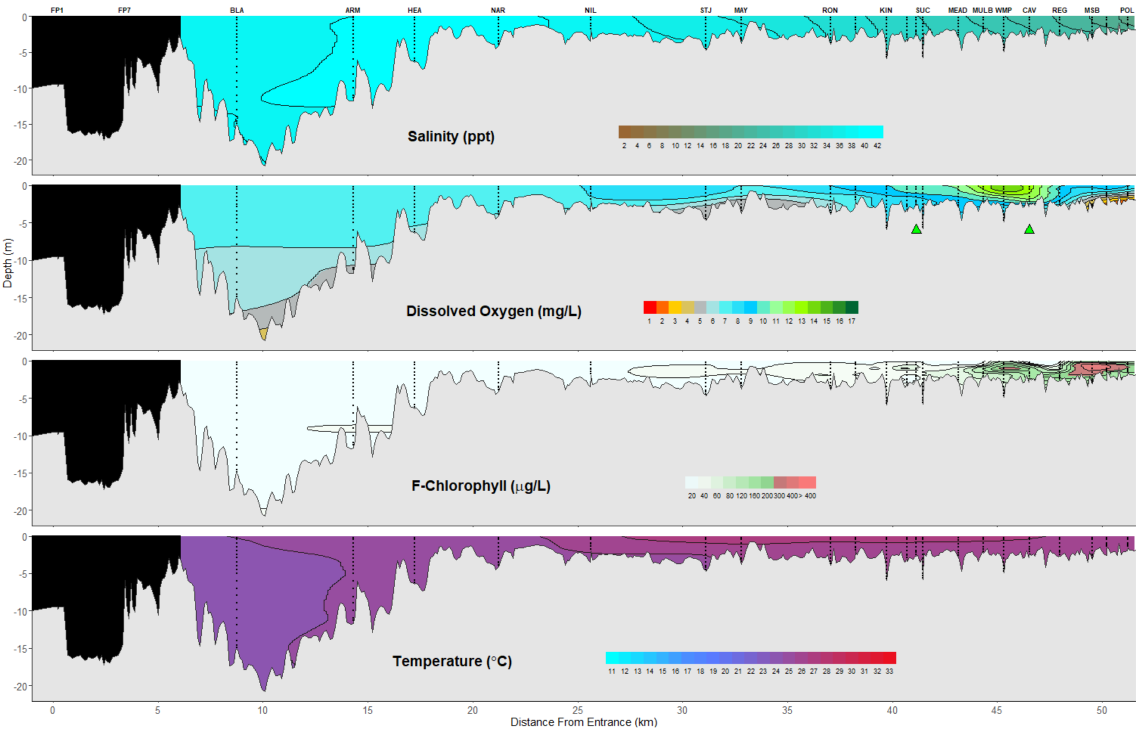
19th February 2024



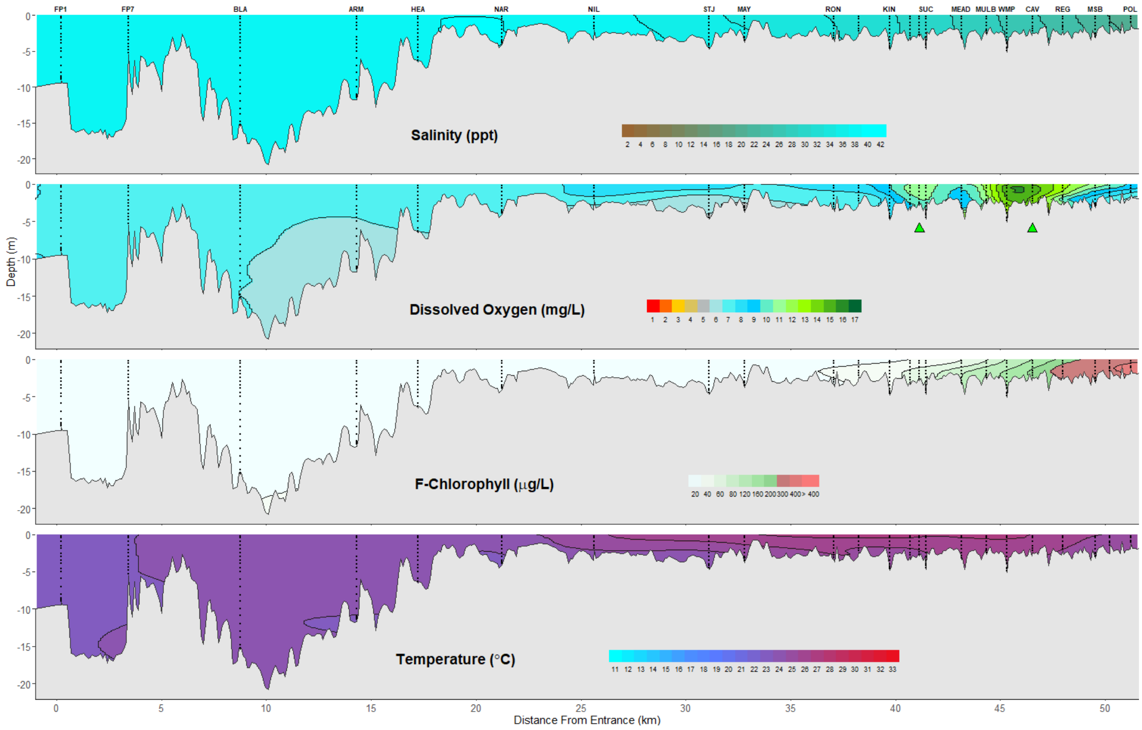
26th February 2024



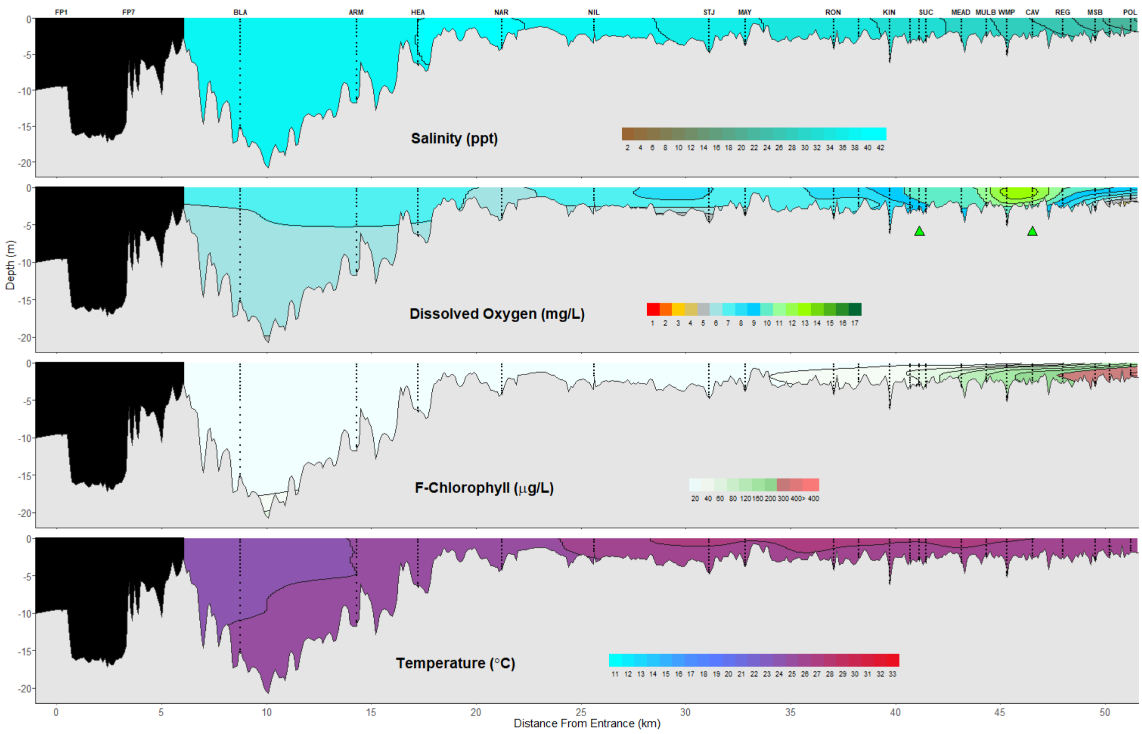
5th March 2024



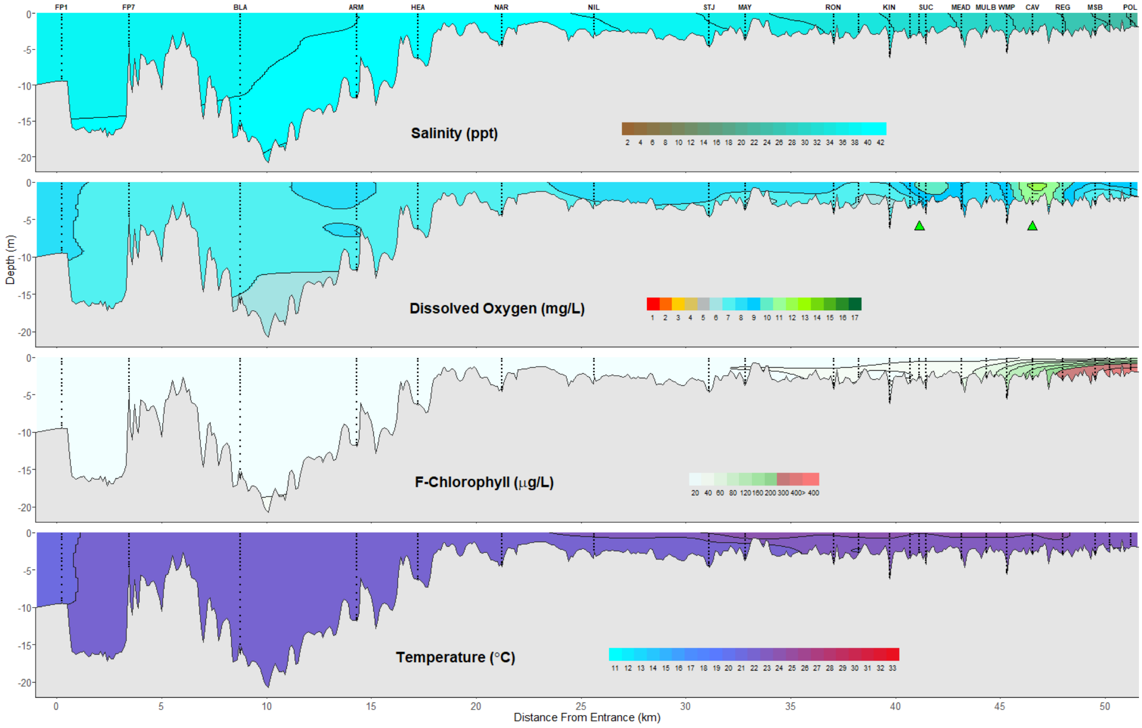
11th March 2024



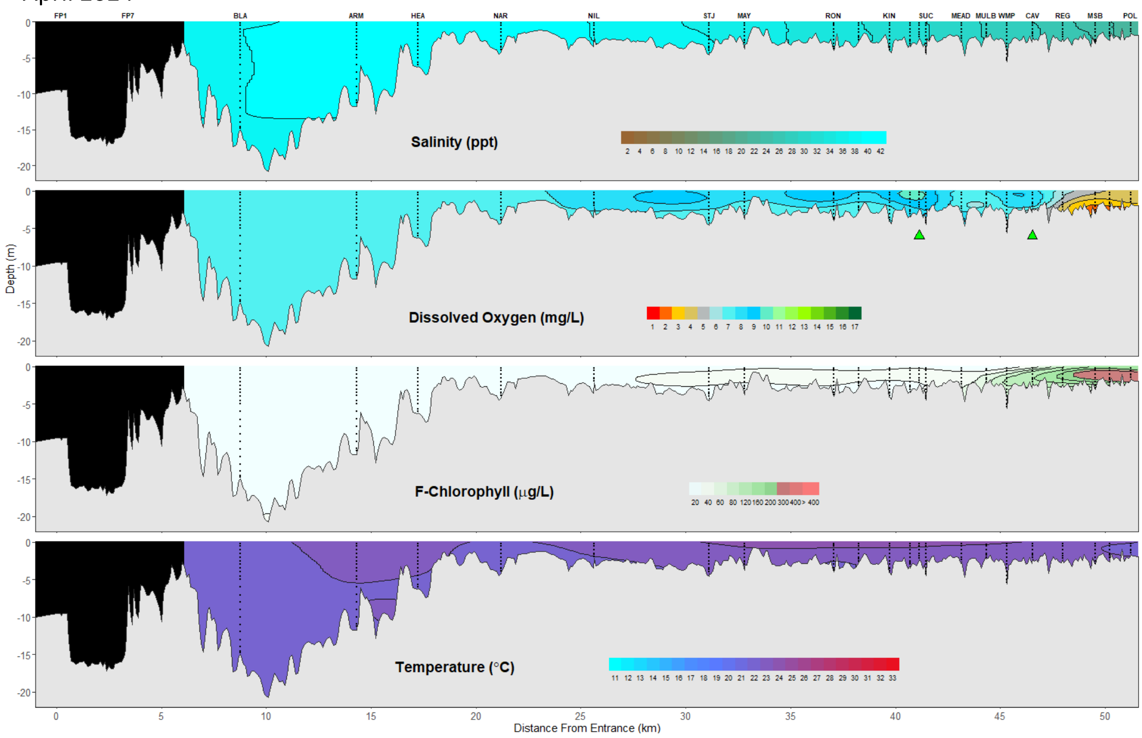
18th March 2024



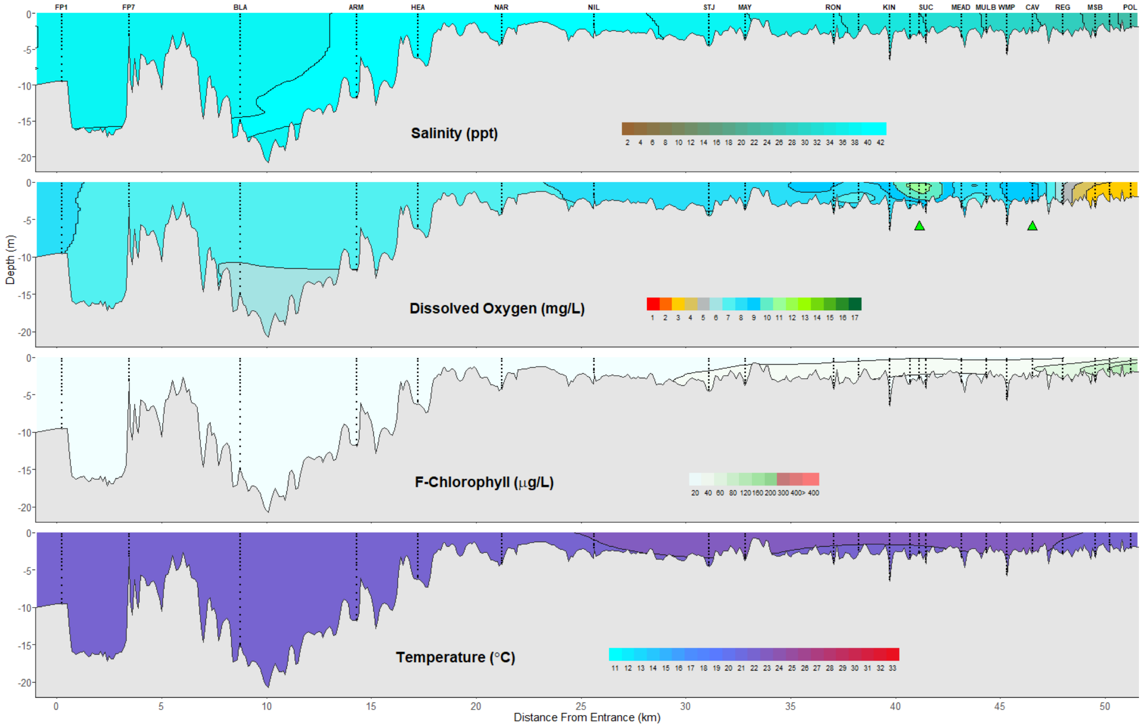
25th March 2024



2nd April 2024



8th April 2024



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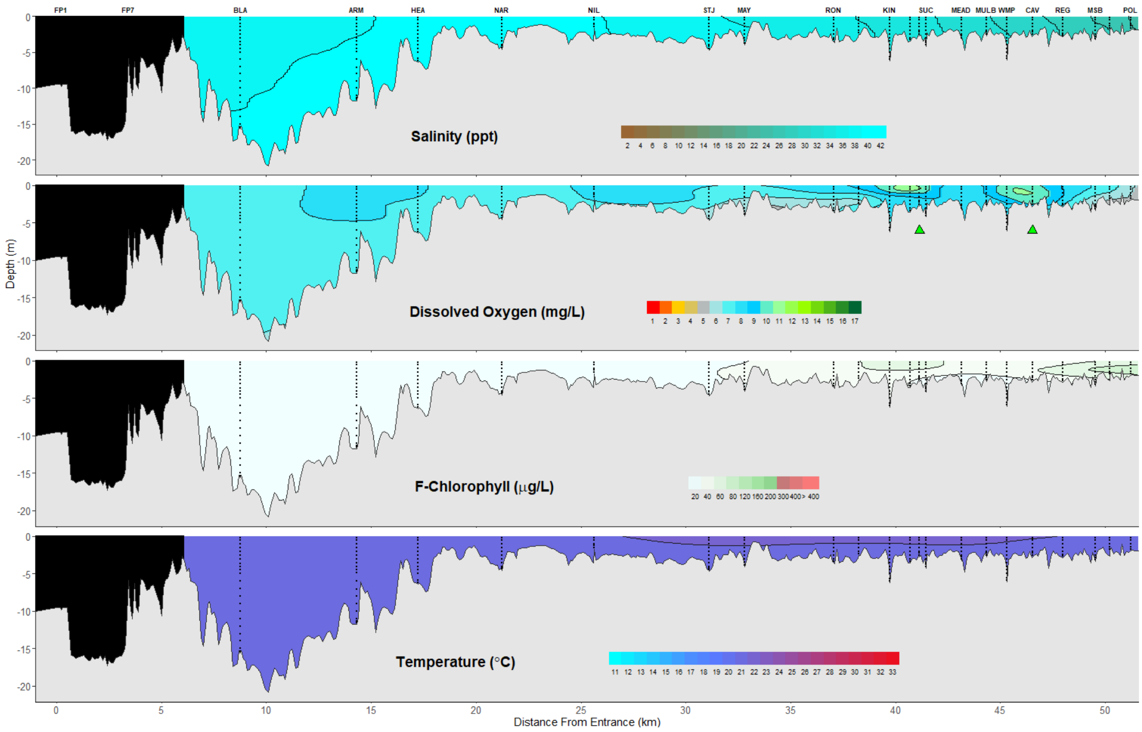

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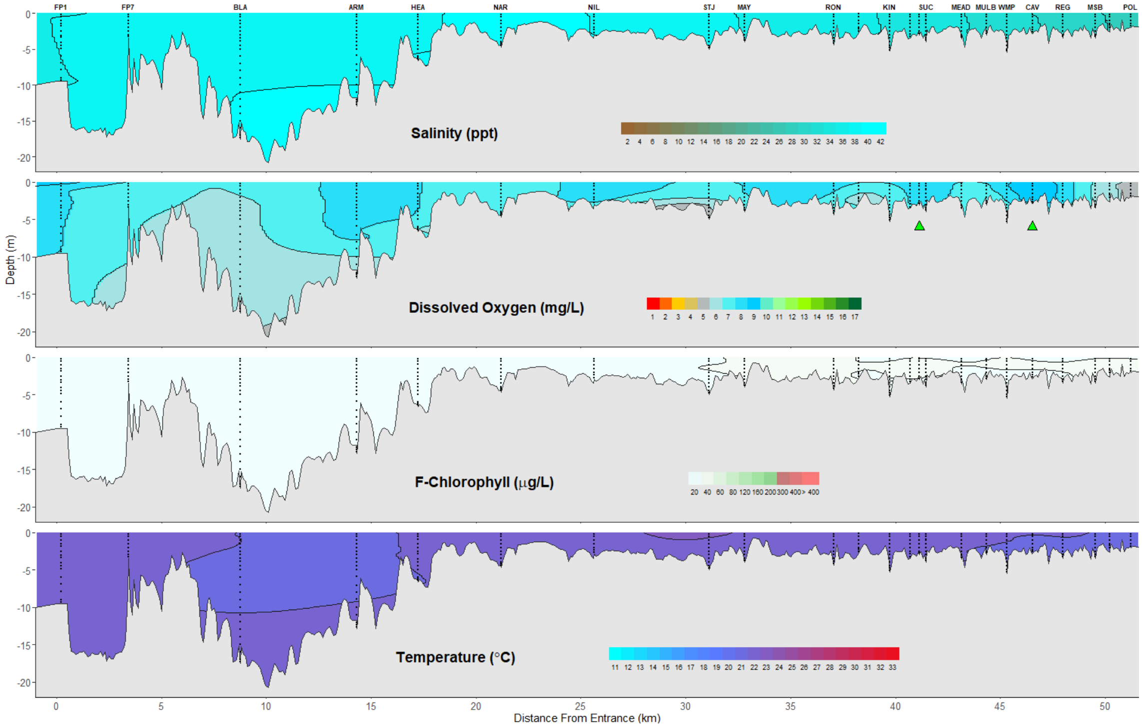

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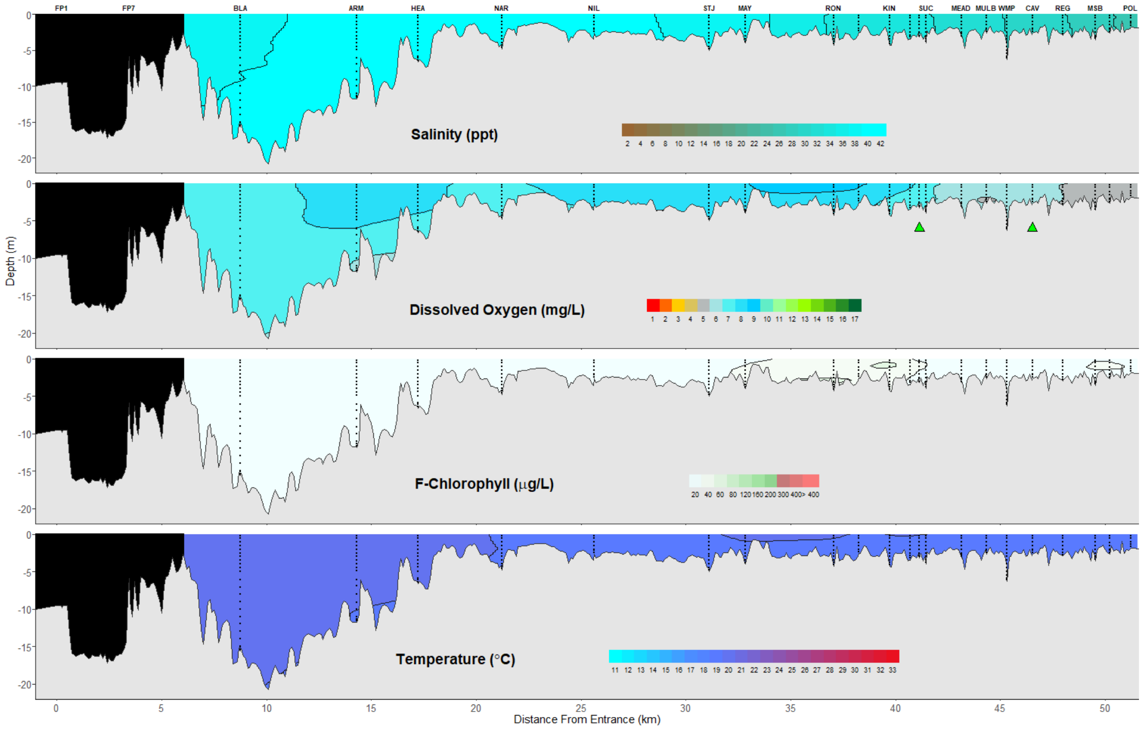
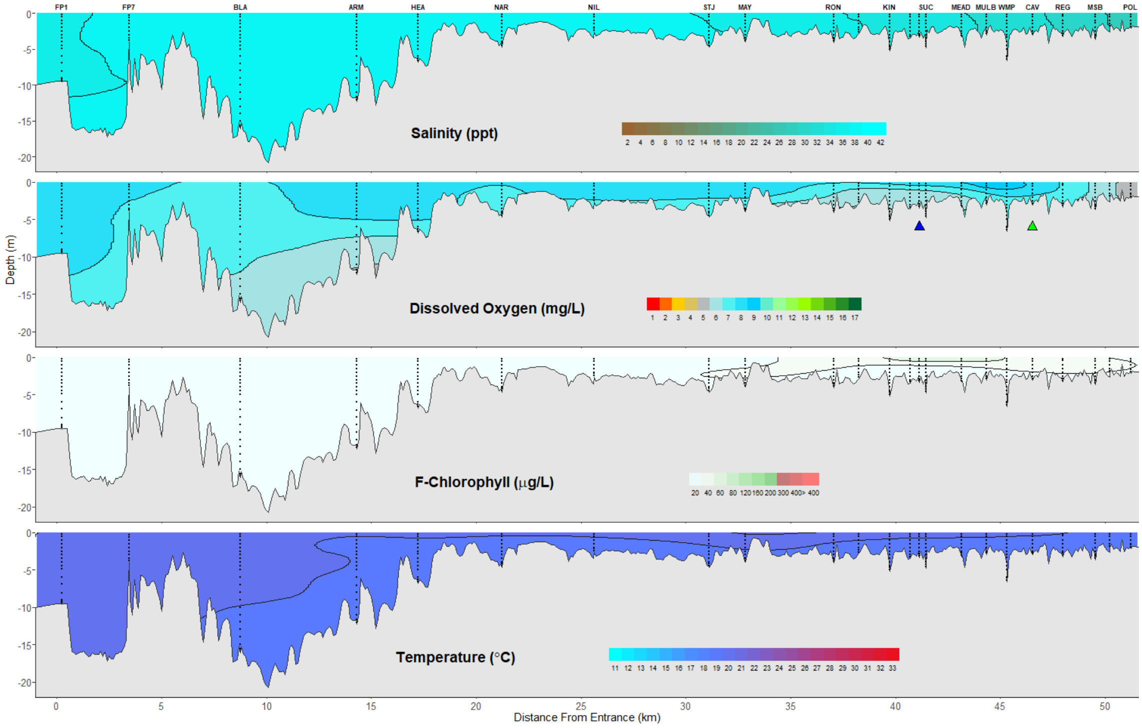
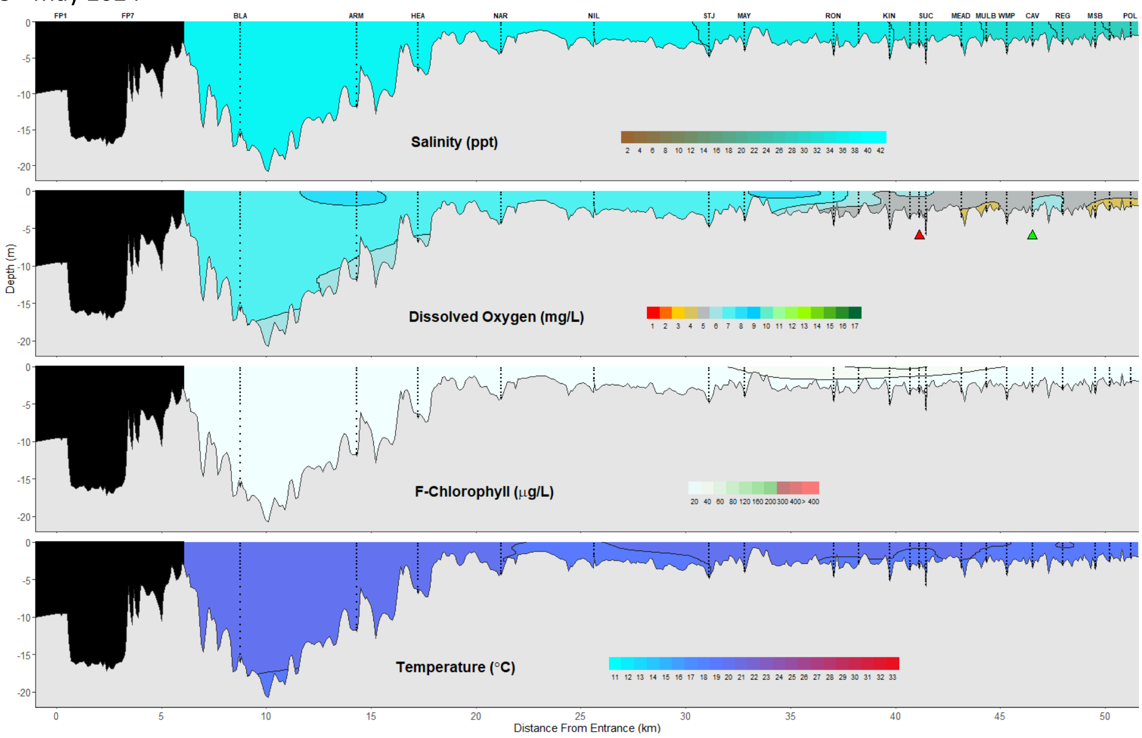


6th May 2024



13th May 2024



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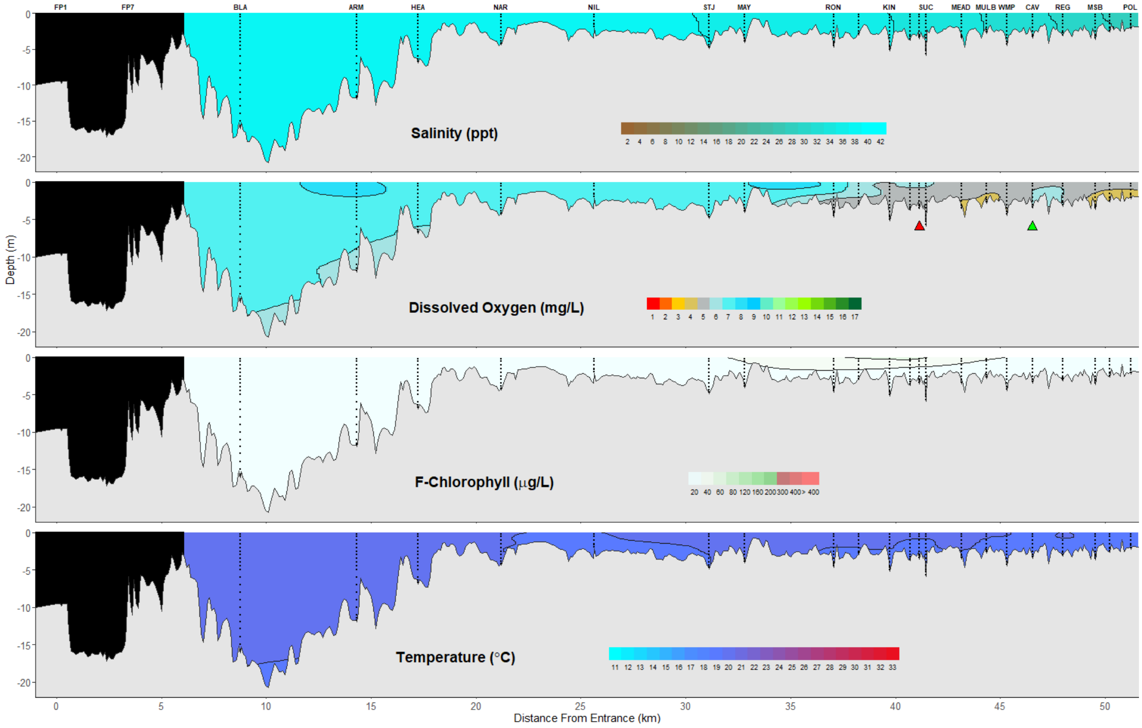

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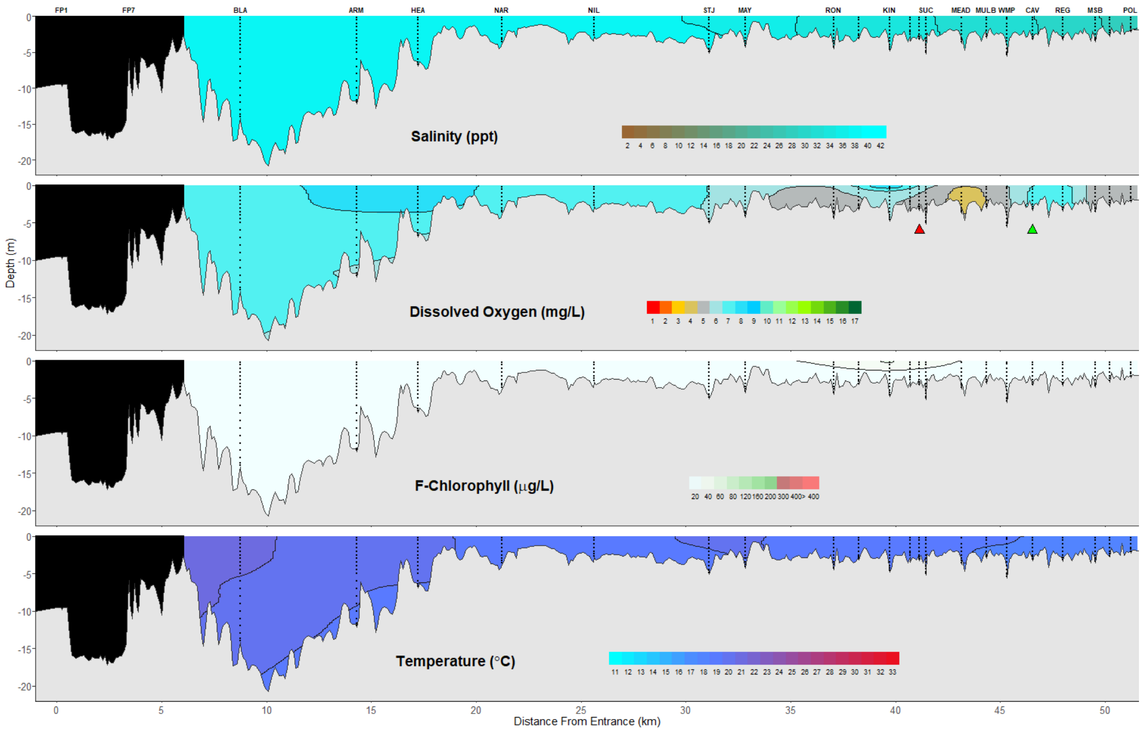
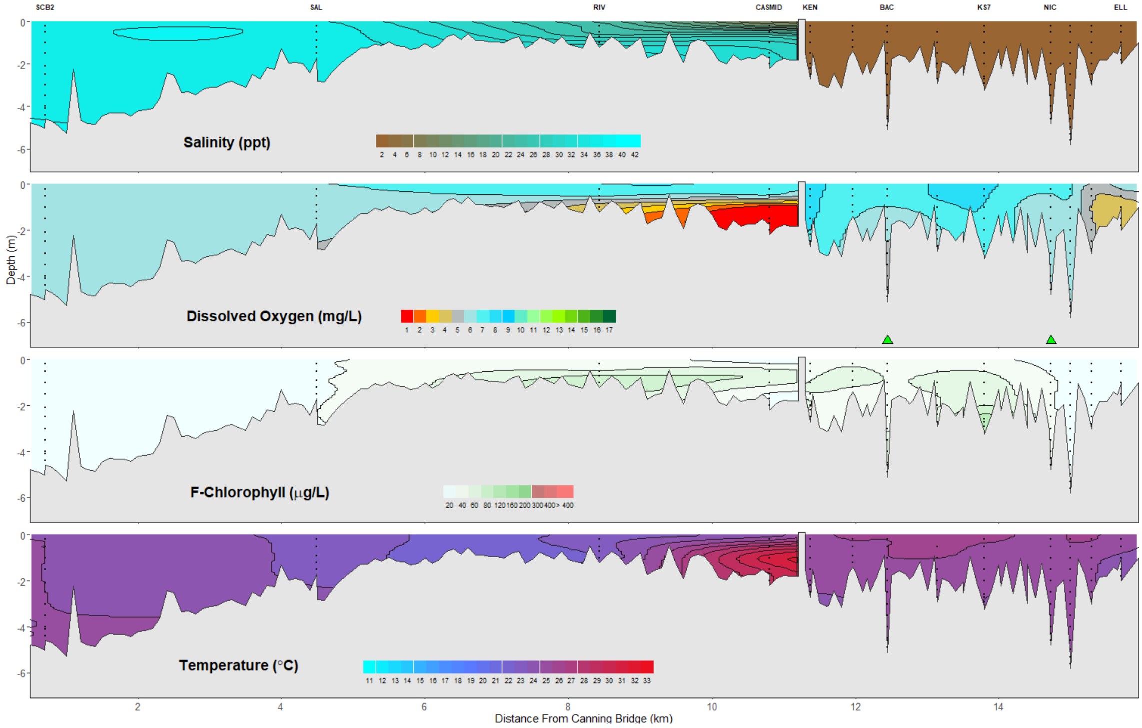
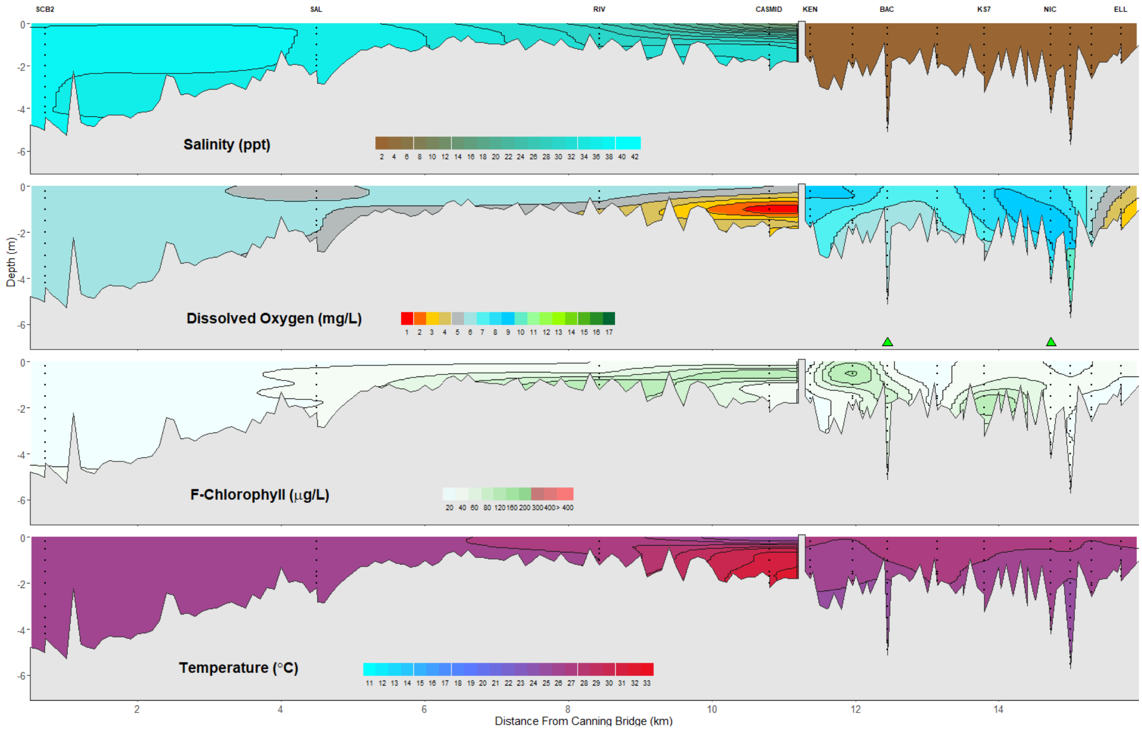


CE zone in summer through autumn 2024

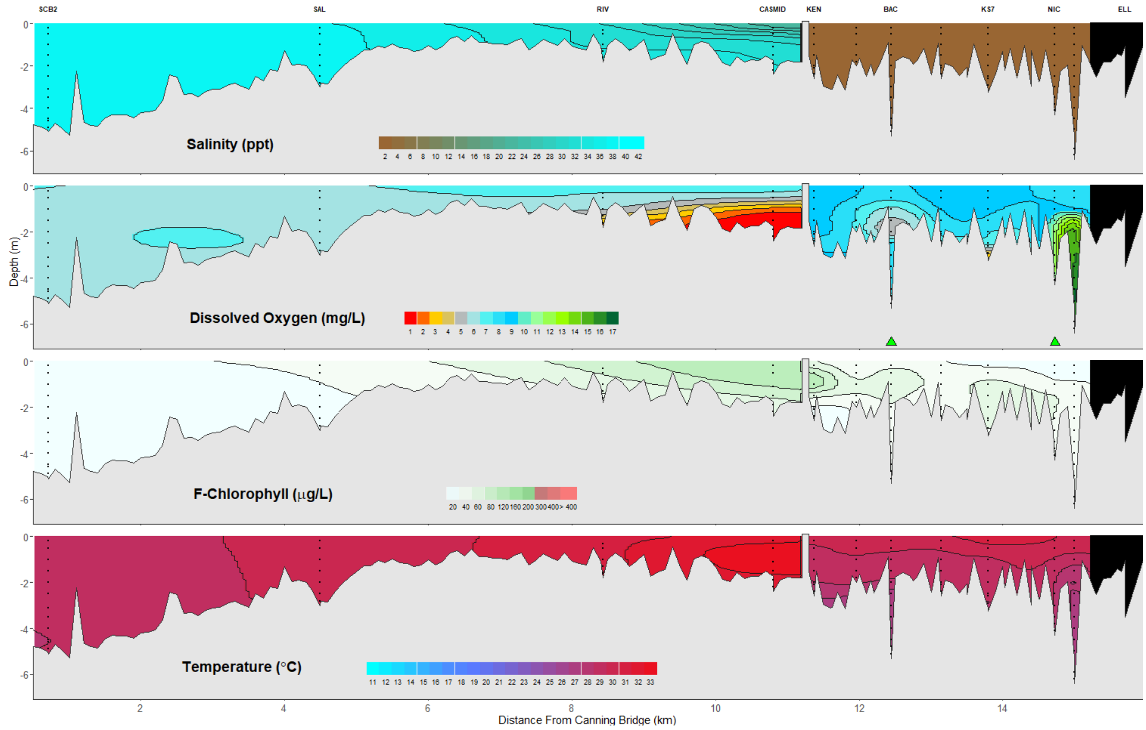
3rd January 2024



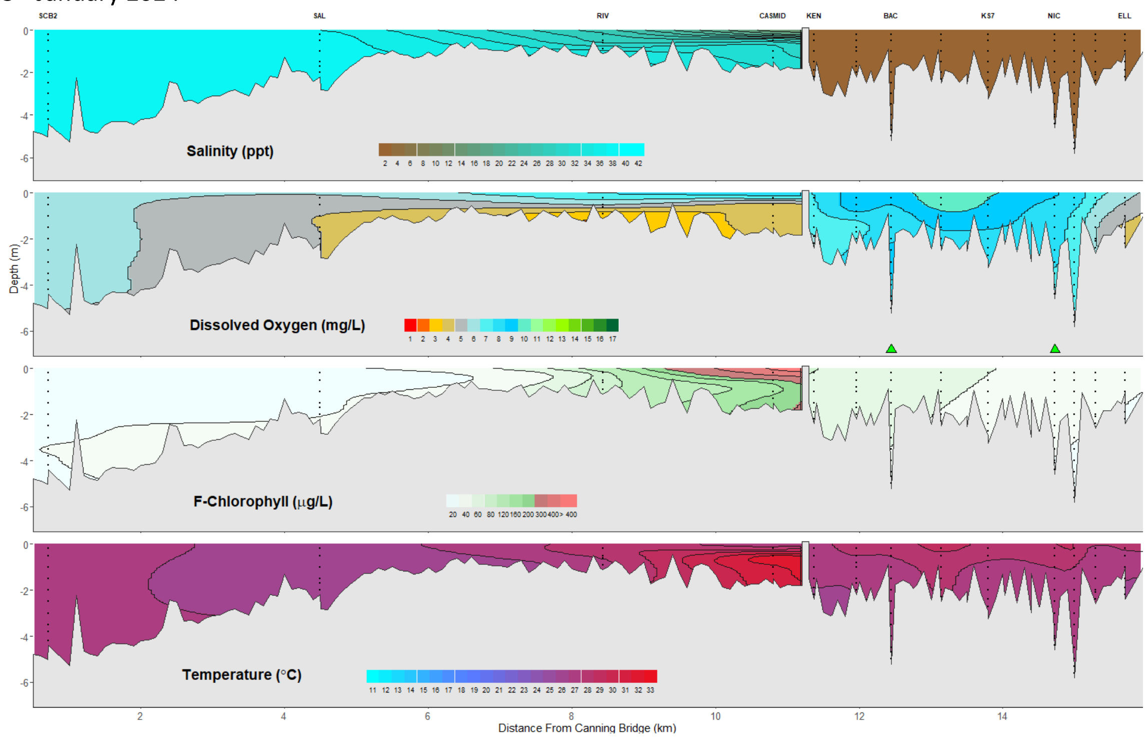
9th January 2024



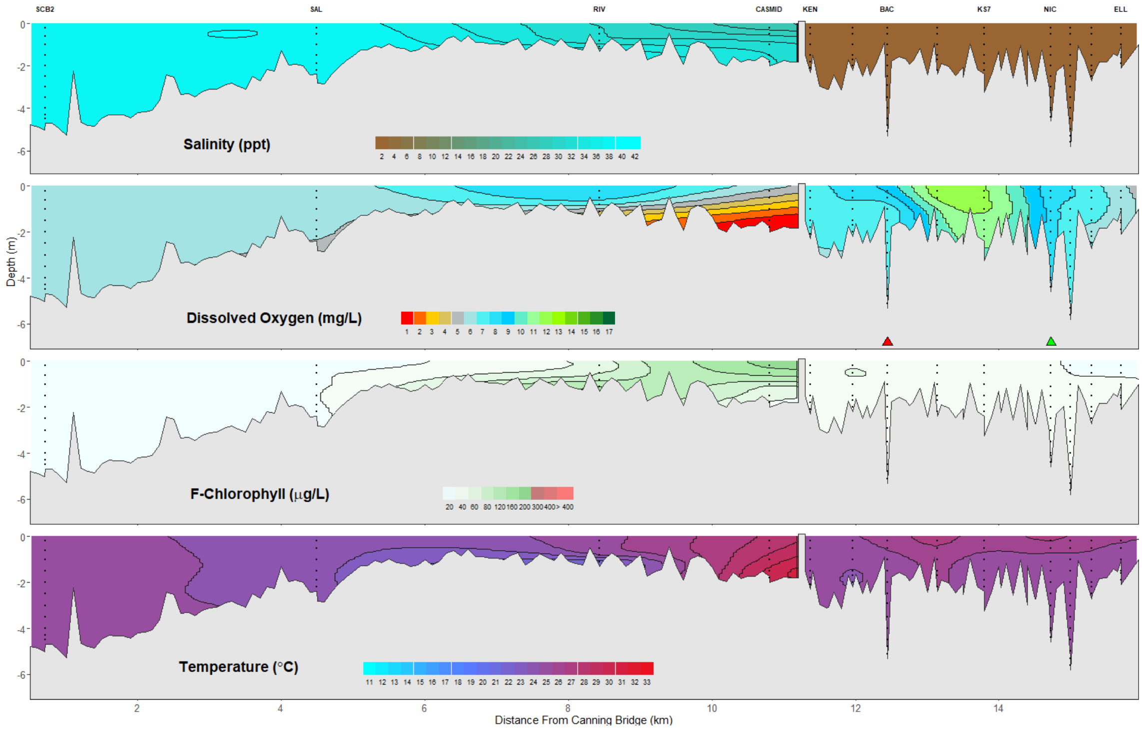
16th January 2024



23rd January 2024



30th January 2024



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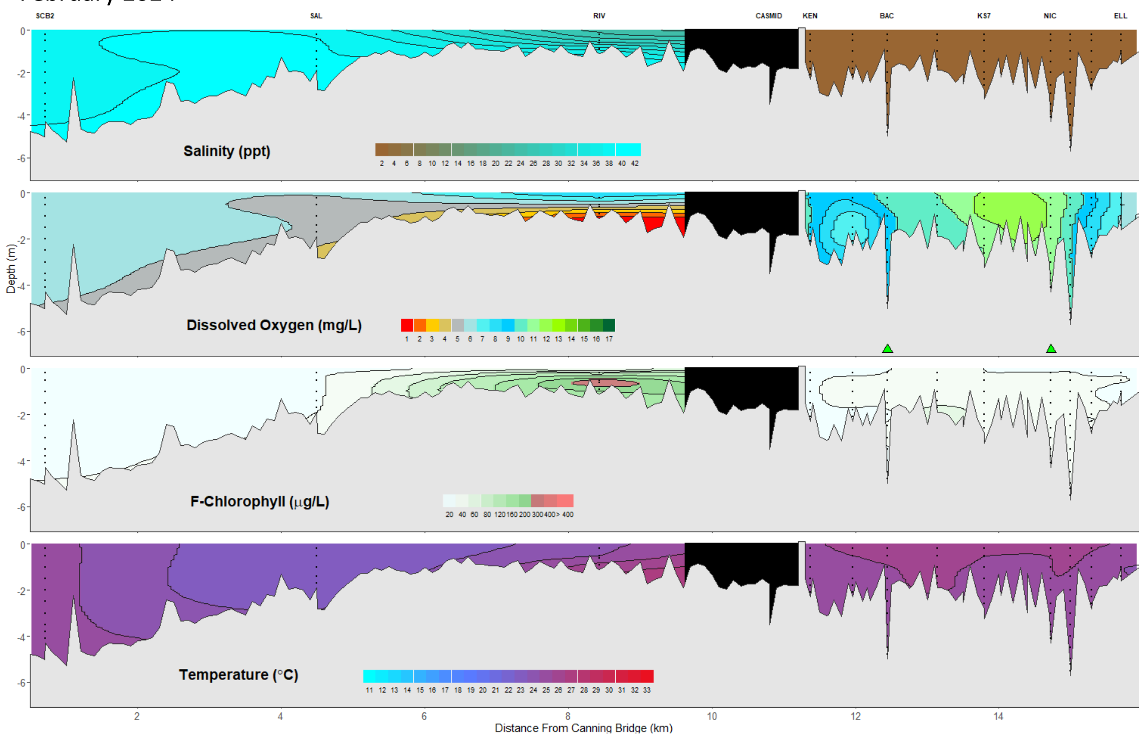
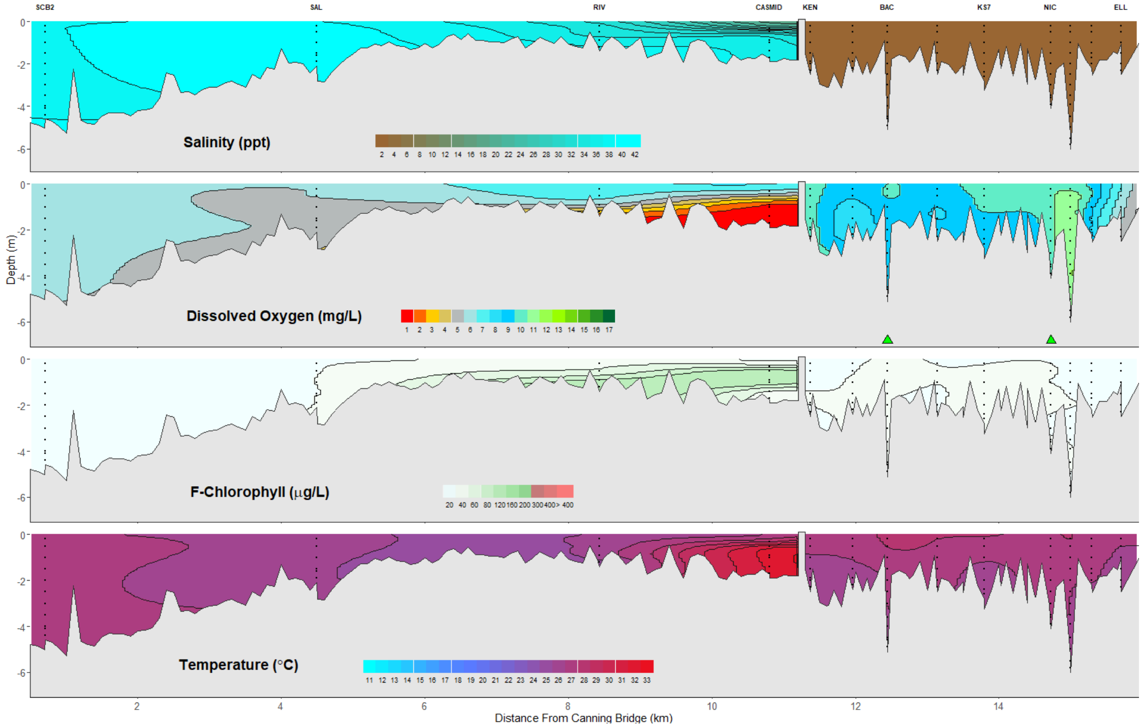


13th February 2024



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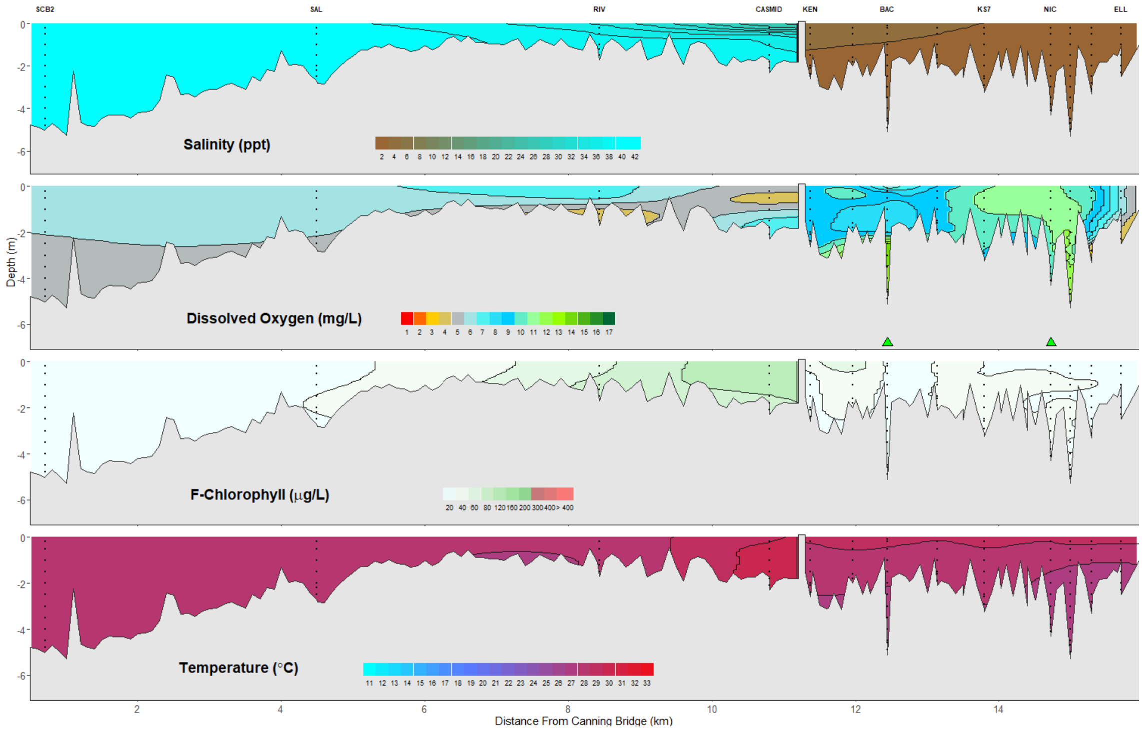

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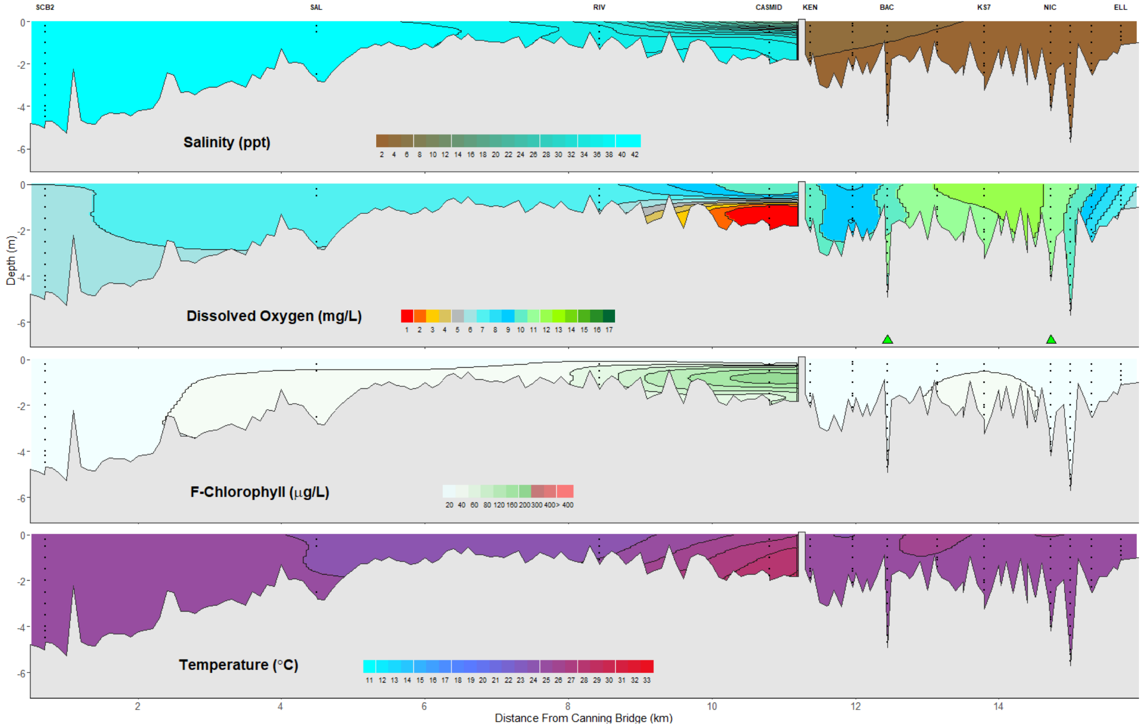
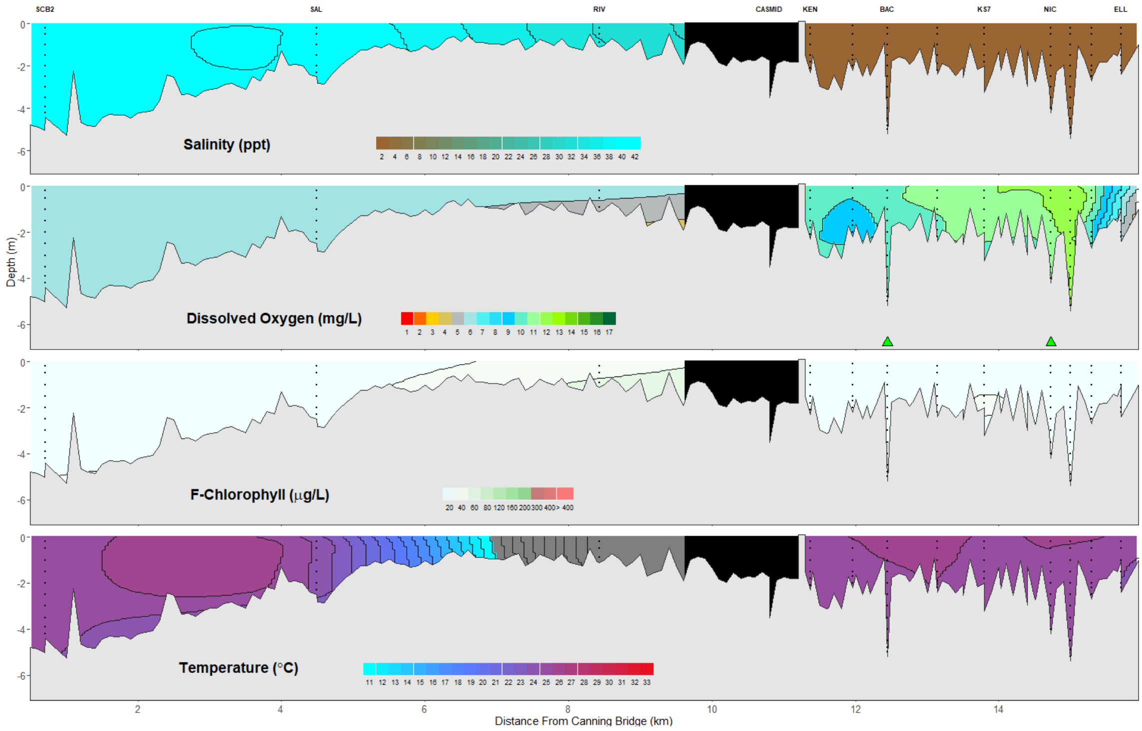
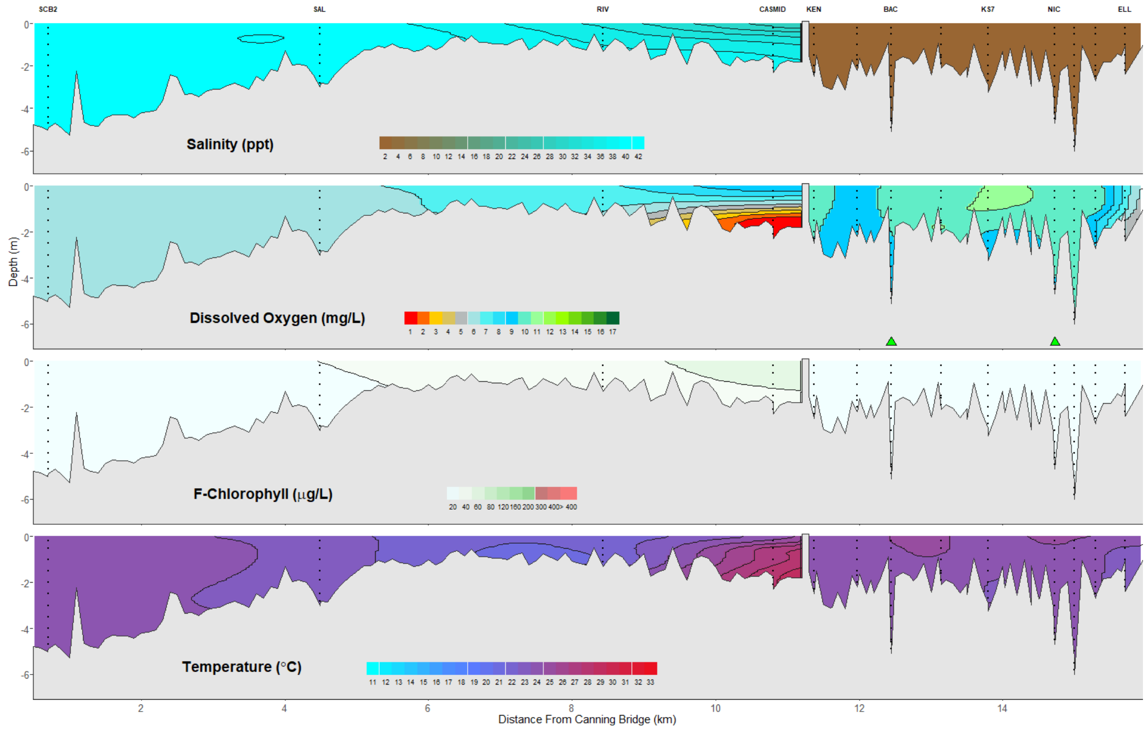


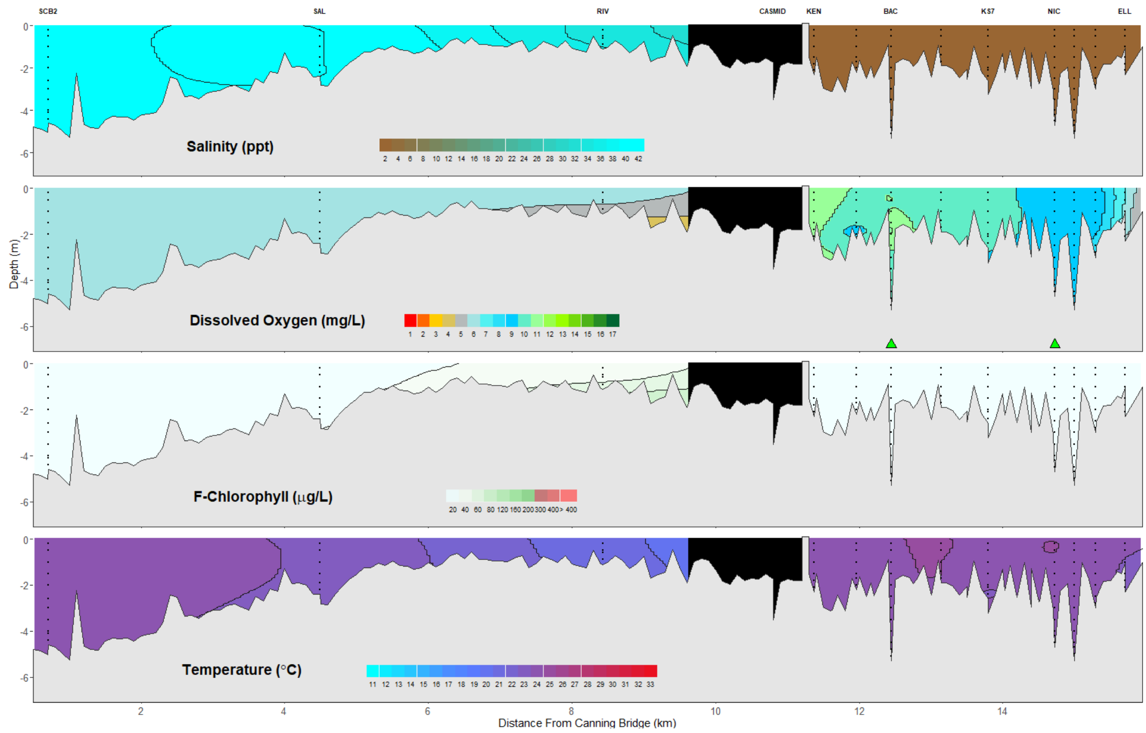
6th March 2024



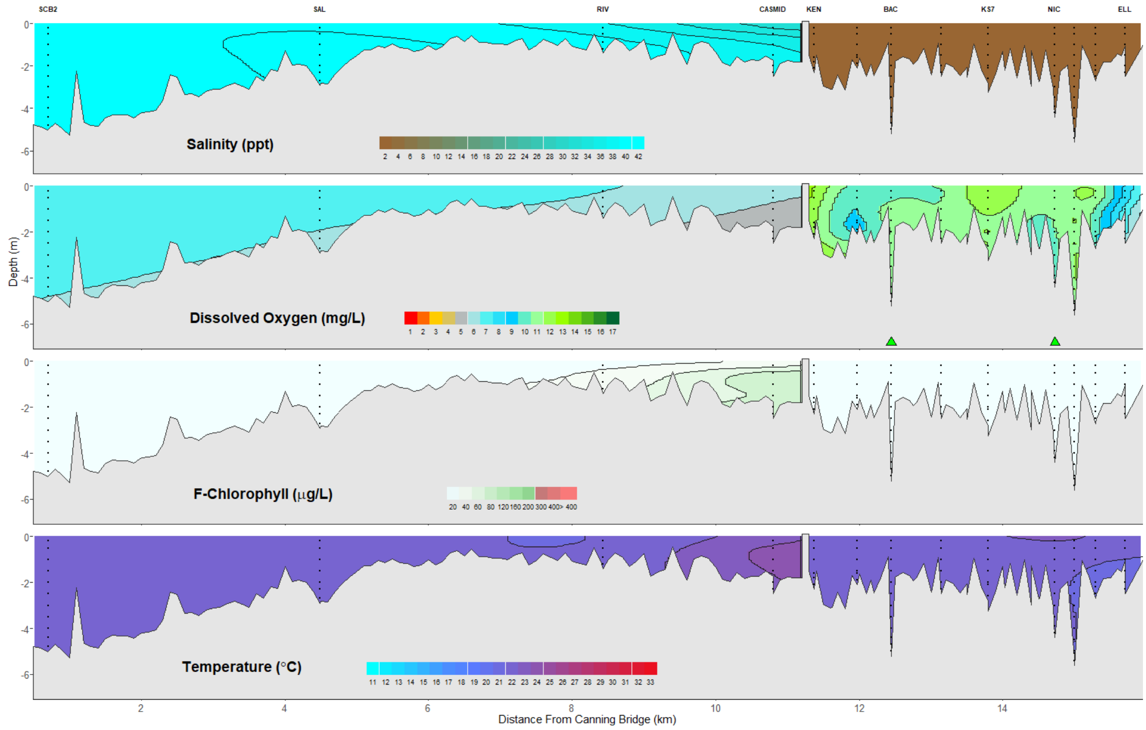
12th March 2024



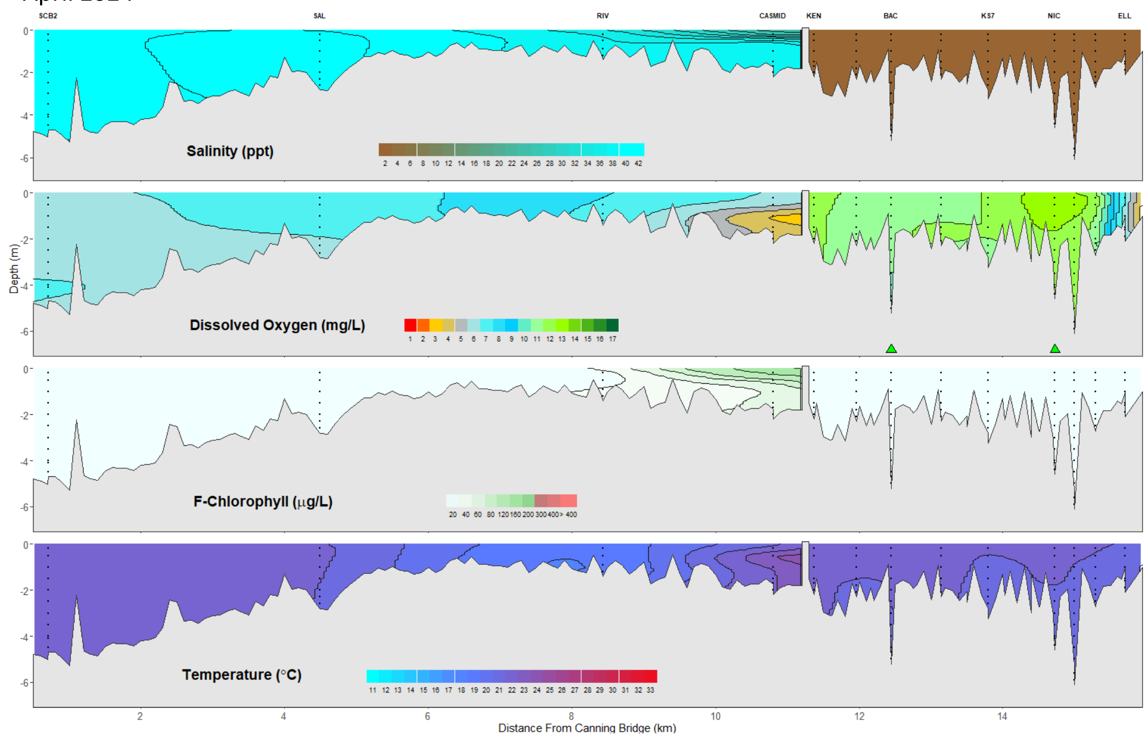
19th March 2024



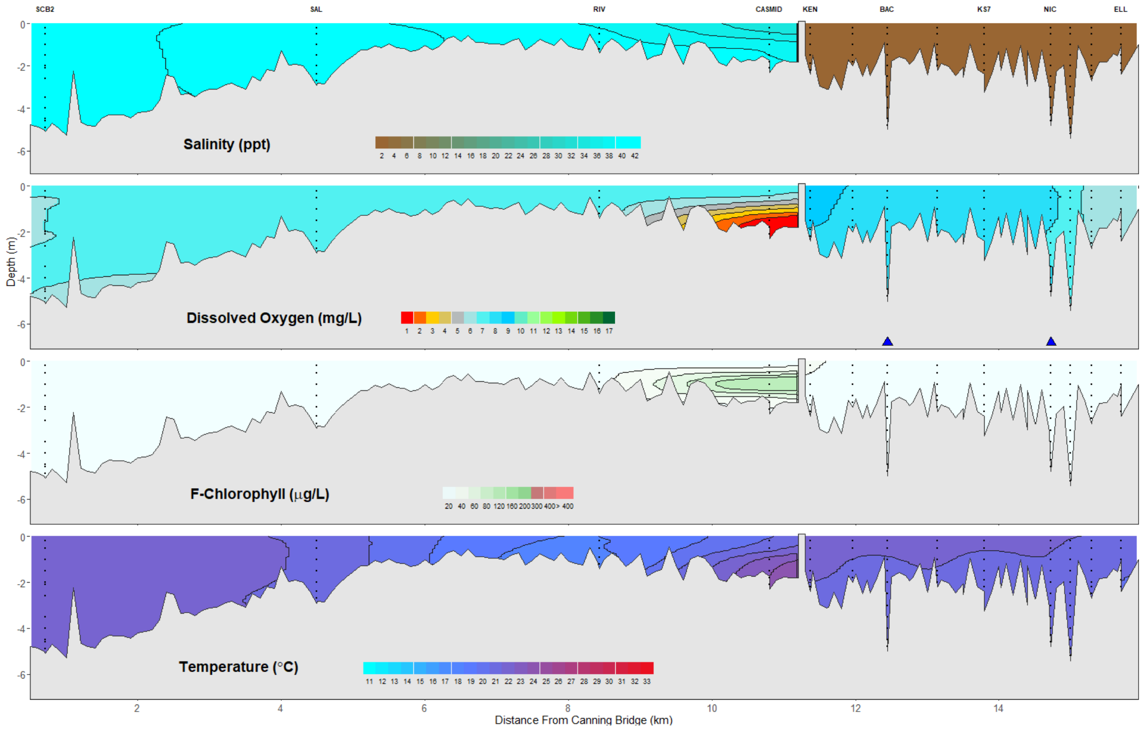
26th March 2024



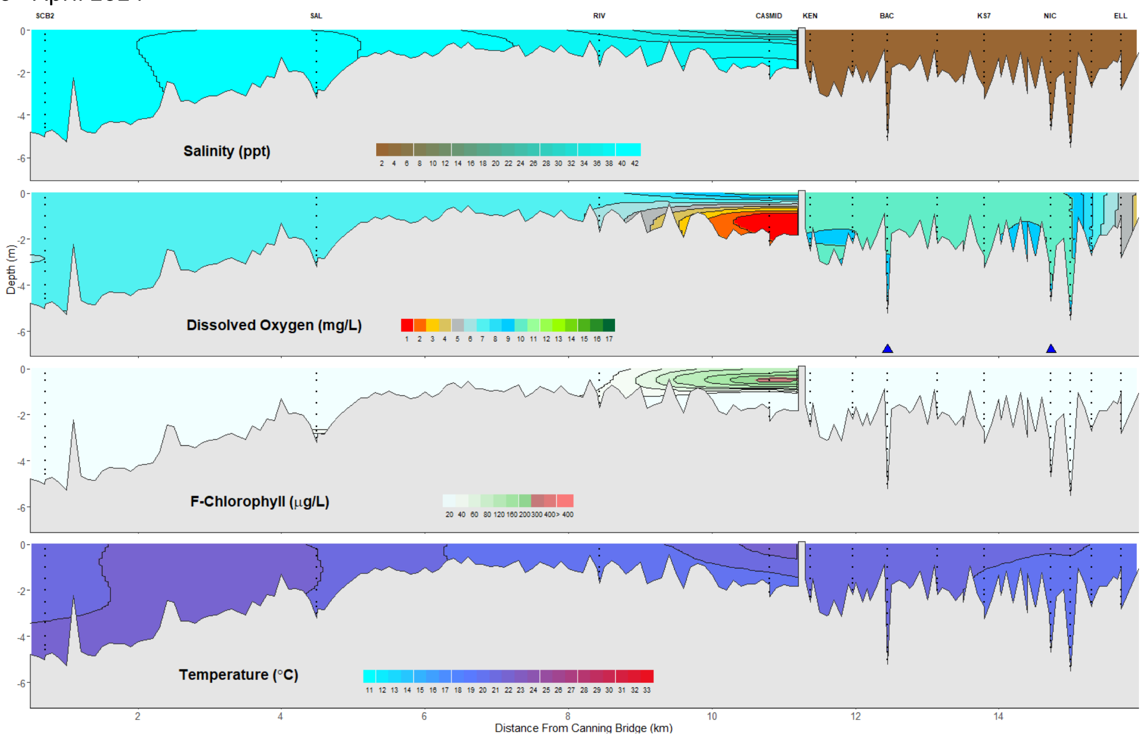
3rd April 2024



9th April 2024



16th April 2024



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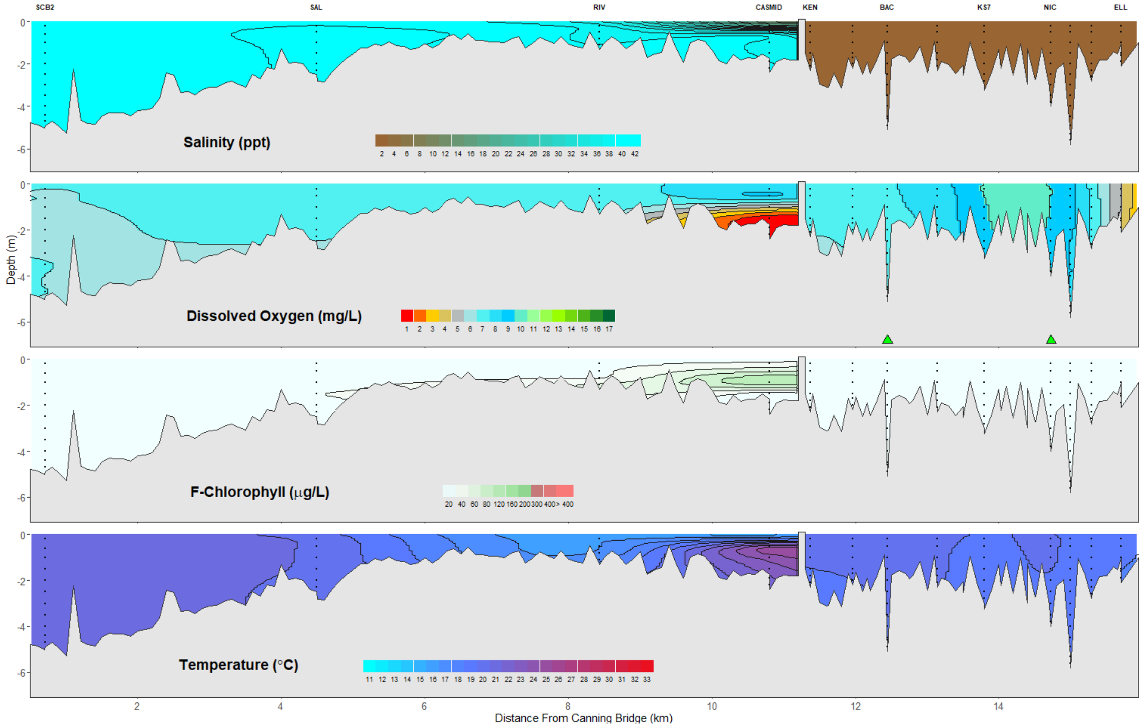
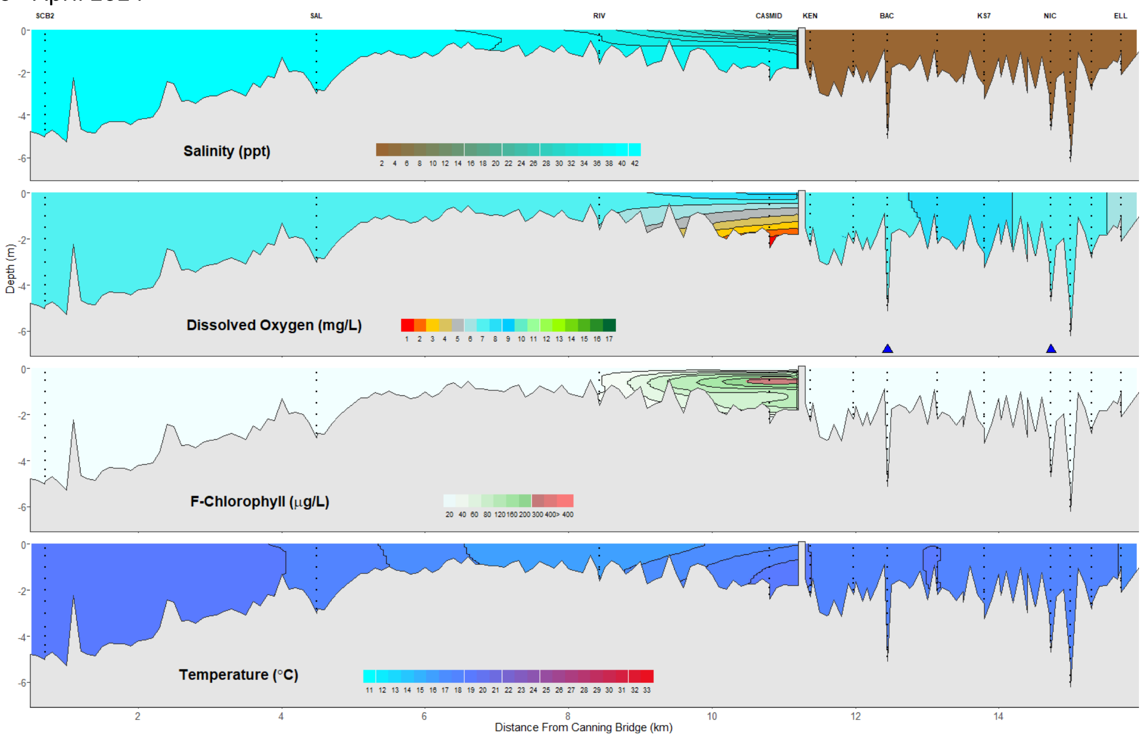
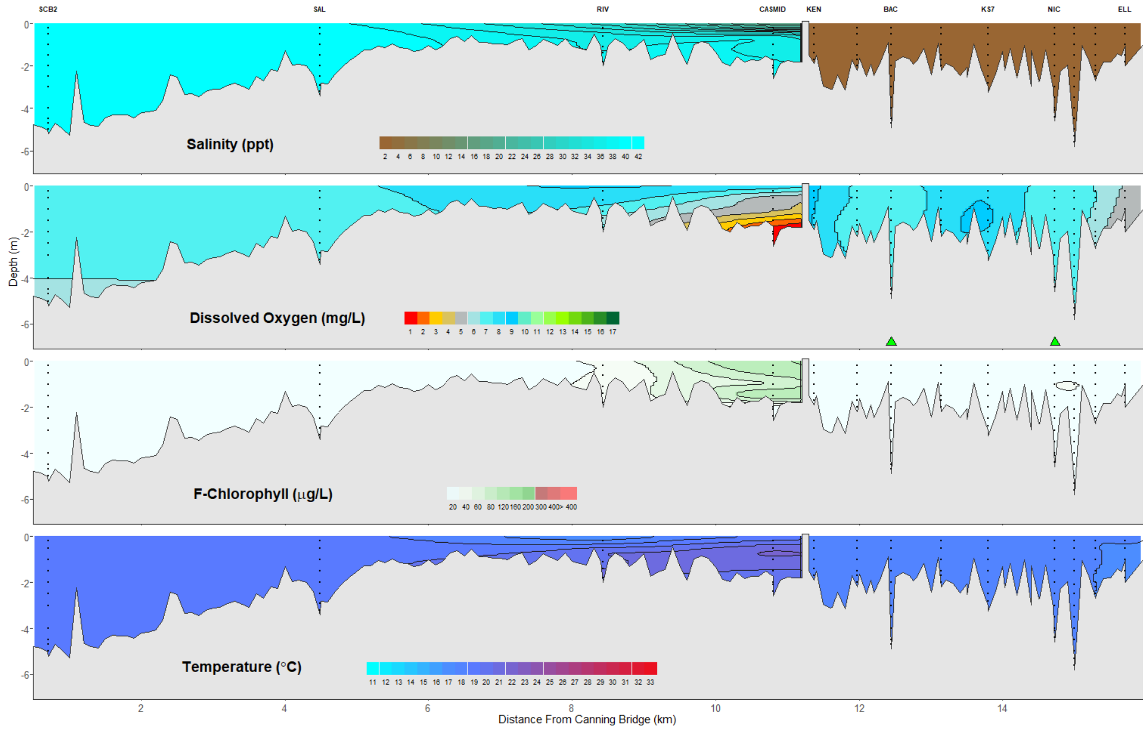


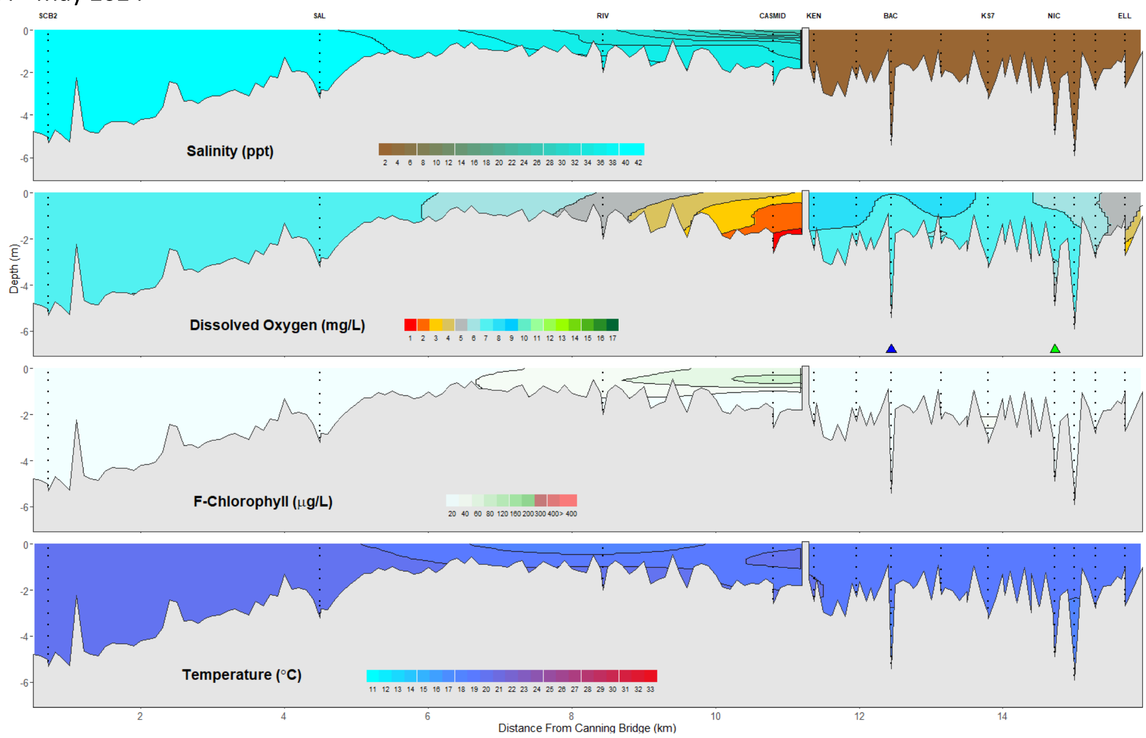
30th April 2024



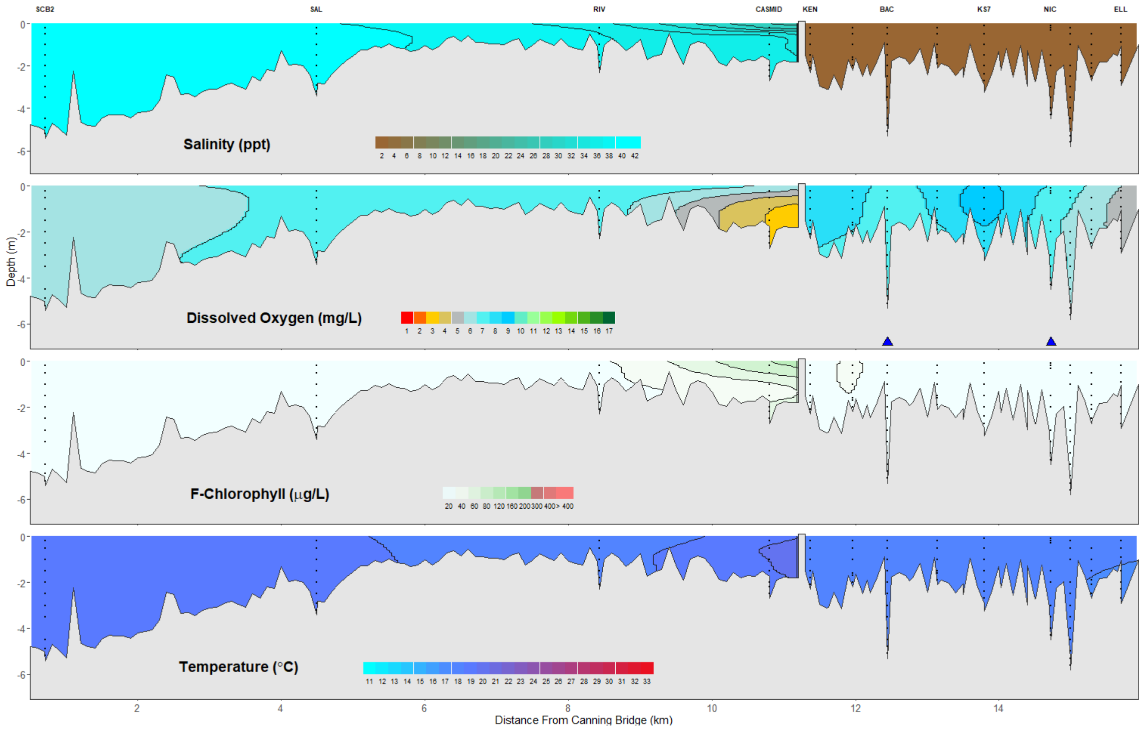
7th May 2024



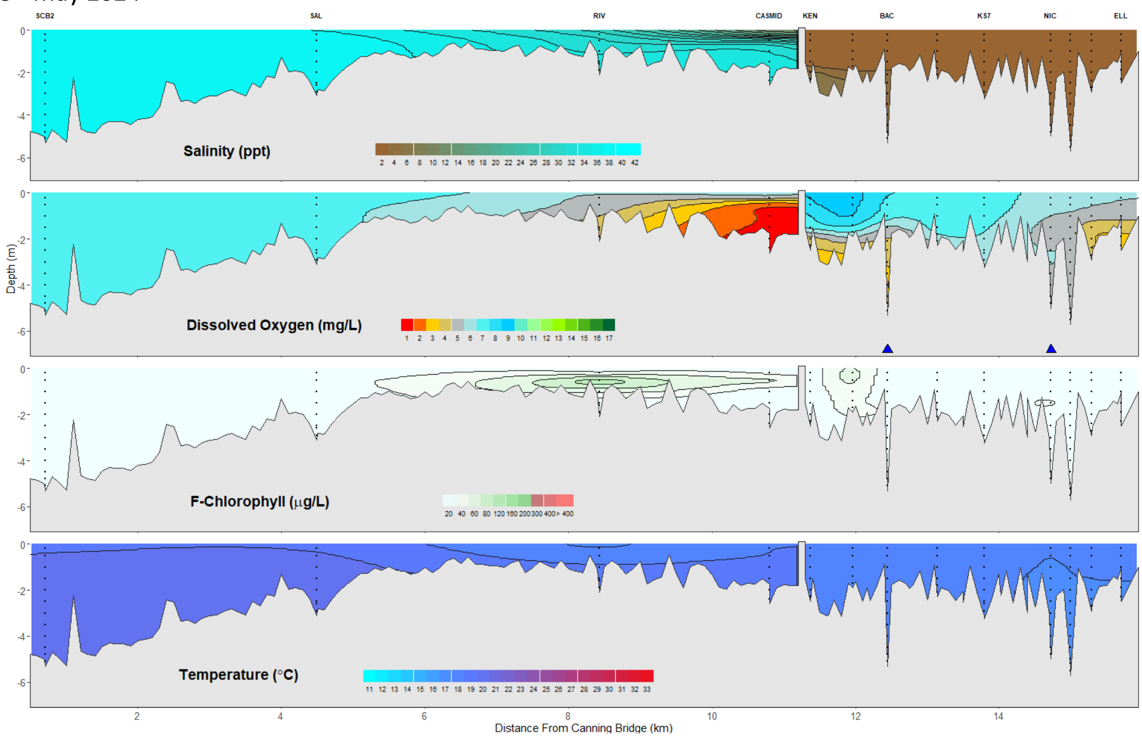
14th May 2024



21st May 2024



28th May 2024



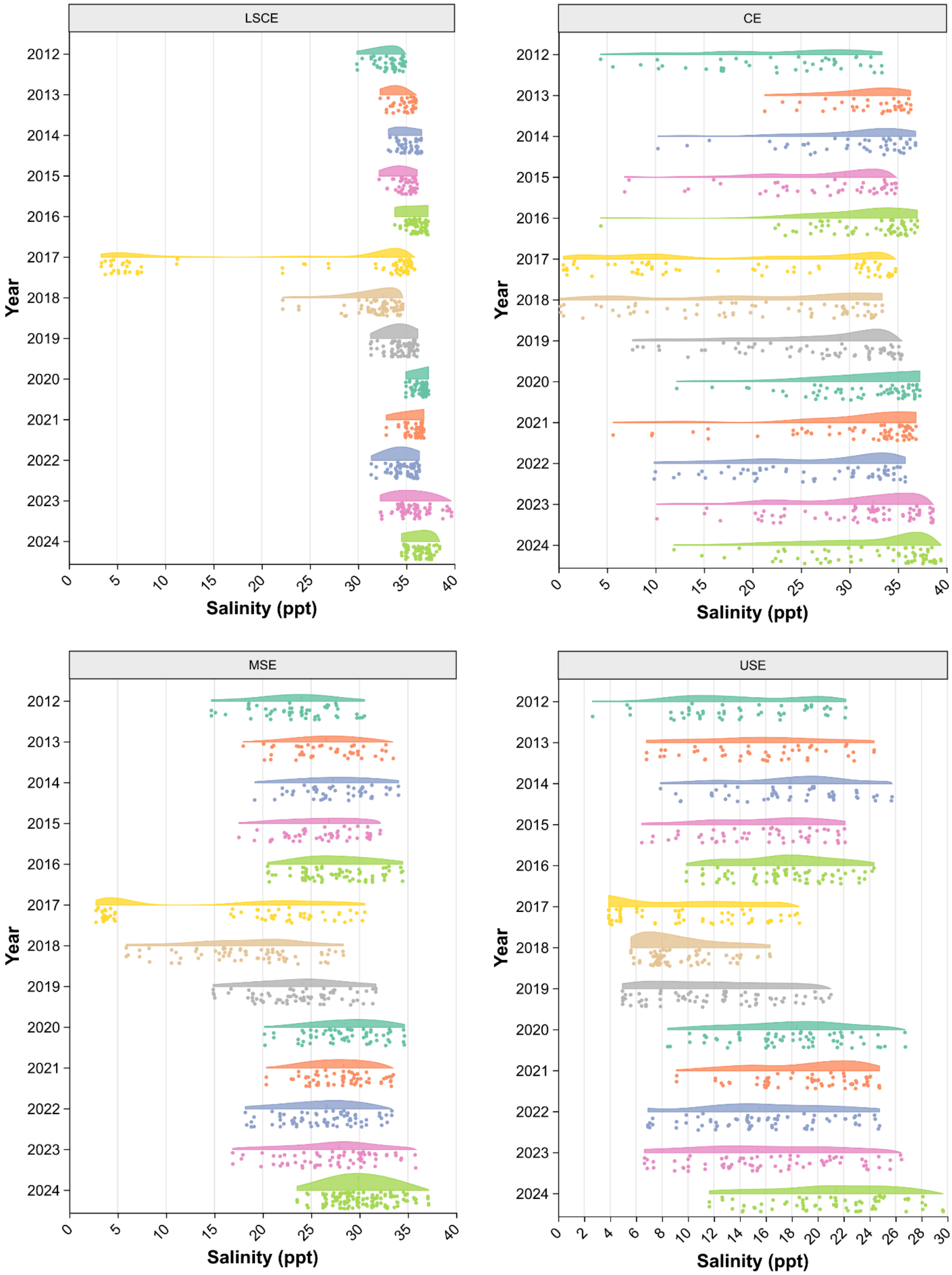
<u>Appendix (x).</u> Spot measurements of salinity (ppt), temperature (°C) and dissolved oxygen (DO; mgL^{-1}) at the surface and, for offshore sites, also the bottom of the water column collected at the same time as the samples of the fish community. – denotes no data were recorded.

Nearshore		Summer						Autumn					
		Surface			Bottom			Surface			Bottom		
Zone	Site Code	Sal	Temp	DO	Sal	Temp	DO	Sal	Temp	DO	Sal	Temp	DO
LSCE	LSCE3	36.3	25.8	7.3				36.6	19.4	7.3			
	LSCE4	37.3	26.7	7.2				37.6	20.4	8.7			
	LSCE5	37.4	25.8	6.8				33.6	20.9	8.4			
	LSCE6	38.6	28.2	7.4				37.3	20.2	7.9			
	LSCE7	39.2	30.2	8.4				37.6	20.0	7.6			
	LSCE8	-	-	-				38.4	20.0	7.5			
CE	CE1	38.6	27.8	6.5				39.0	19.9	7.2			
	CE2	38.8	27.4	6.5				39.2	20.0	7.4			
	CE5	38.7	32.3	6.2				-	-	-			
	CE6	39.0	31.2	7.5				39.6	17.5	6.9			
	CE7	39.1	31.2	9.3				-	-	-			
	CE8	20.7	30.1	4.7				34.7	22.5	14.5			
MSE	MSE2	38.4	26.9	6.7				36.3	20.3	7.4			
	MSE4	36.7	29.8	6.8				37.1	19.6	7.7			
	MSE5	35.8	29.6	7.5				37.1	19.8	7.9			
	MSE6	34.2	28.6	7.6				36.5	19.7	6.8			
	MSE7	30.8	28.0	7.7				35.4	19.5	6.3			
	MSE8	29.4	29.0	11.2				34.7	19.1	6.4			
USE	USE1	36.5	24.9	6.7				33.9	18.9	5.1			
	USE3	37.2	24.3	6.7				32.6	19.3	7.1			
	USE4	36.7	24.8	6.5				31.6	19.1	7.0			
	USE5	22.4	31.4	12.8				30.7	19.2	7.5			
	USE6	22.3	29.5	12.7				31.1	18.3	8.3			
	USE7	21.9	29.5	11.6				30.7	18.4	6.4			

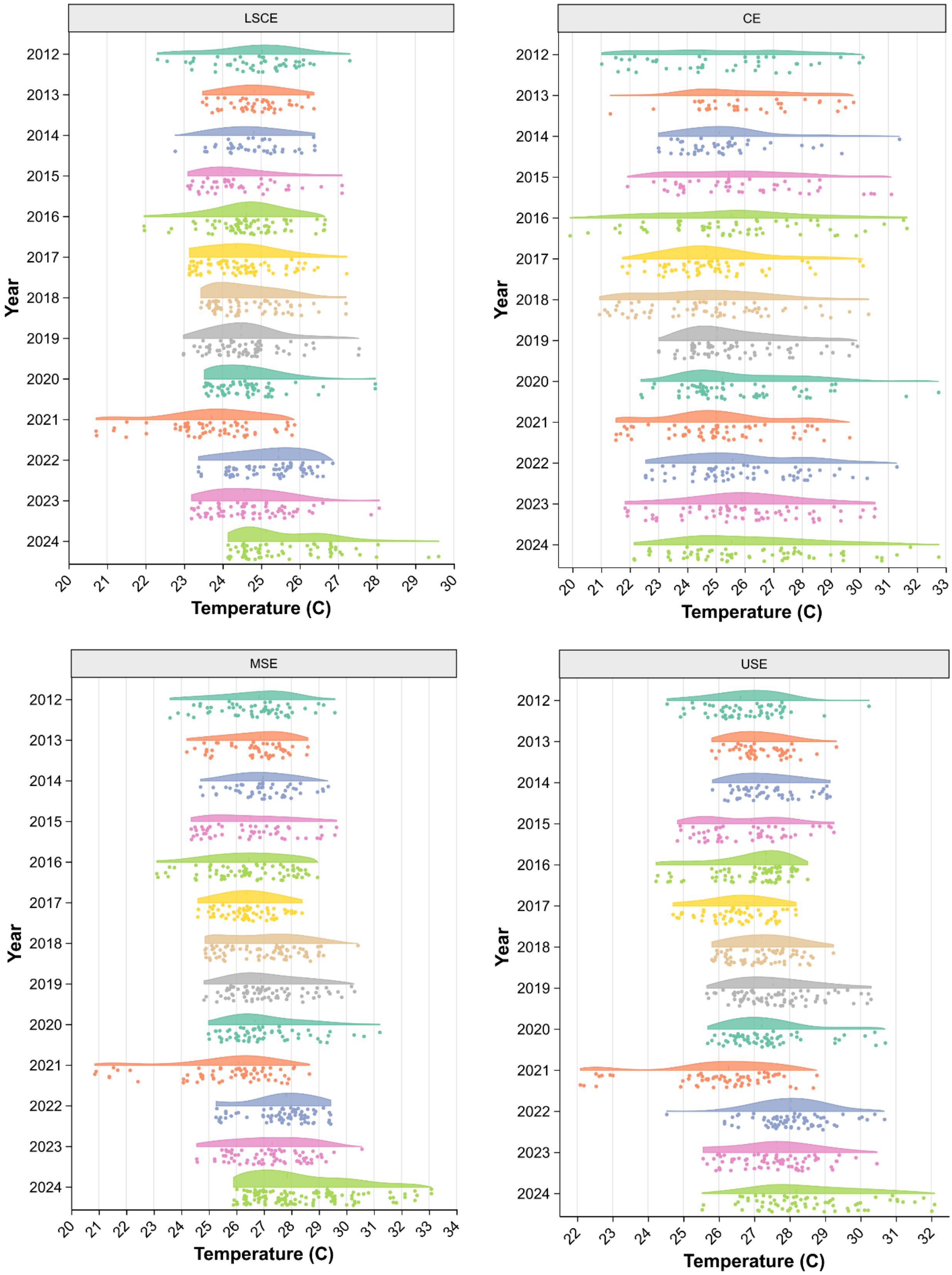
Offshore		Summer						Autumn					
		Surface			Bottom			Surface			Bottom		
Zone	Site Code	Sal	Temp	DO	Sal	Temp	DO	Sal	Temp	DO	Sal	Temp	DO
LSCE	LSCE1G	37.4	25.3	6.7	37.4	25.2	6.8	37.8	19.3	7.5	38.0	19.4	6.9
	LSCE2G	38.2	26.7	7.5	38.0	26.3	6.8	37.9	19.4	7.9	37.8	19.5	8.0
	LSCE3G	38.2	24.9	6.4	38.2	24.2	5.5	38.0	19.0	7.5	38.1	18.9	7.1
	LSCE4G	36.4	24.9	5.5	37.6	24.7	5.1	37.8	19.7	7.5	37.9	19.7	7.5
	LSCE5G	37.8	25.8	6.8	37.8	25.7	6.6	38.6	19.9	7.6	38.7	19.9	7.7
	LSCE6G	38.8	26.2	6.9	38.5	24.8	4.9	38.4	20.5	7.8	38.5	19.8	7.4
CE	CE1G	38.9	27.4	6.7	38.8	27.3	6.5	39.3	18.3	6.7	39.3	18.3	6.6
	CE2G	39.3	27.7	6.8	39.2	28.0	6.6	39.5	18.0	6.9	39.5	18.0	6.5
	CE3G	39.3	27.4	6.6	39.2	27.8	6.4	39.6	17.8	6.9	39.6	17.8	6.8
	CE4G	39.0	28.1	6.7	39.1	28.3	6.6	39.7	19.2	7.2	39.7	19.3	7.1
	CE5G	39.0	28.1	6.1	39.0	28.4	6.6	39.8	19.2	7.2	39.8	19.2	7.2
	CE6G	39.1	29.6	7.4	39.1	29.5	7.5	39.7	7.2	19.5	39.7	19.4	7.4
MSE	MSE1G	38.6	26.5	6.5	38.6	25.8	5.6	38.6	19.3	7.0	38.6	19.3	6.7
	MSE2G	37.3	27.5	6.8	37.5	26.8	5.6	37.4	19.2	7.8	37.4	19.2	7.9
	MSE3G	36.7	27.8	7.9	37.1	26.8	6.0	37.2	19.4	7.9	37.2	19.4	8.1
	MSE4G	34.2	27.4	6.7	35.6	27.3	4.1	36.6	19.5	7.3	36.9	19.1	6.1
	MSE5G	31.2	28.4	8.3	32.1	27.8	6.3	35.0	19.2	7.0	35.6	19.1	5.9
	MSE6G	29.8	28.9	9.9	30.6	28.4	5.9	34.8	19.2	7.0	34.9	18.9	5.1
USE	USE1G	-	-	-	-	-	-	33.4	18.8	5.8	33.9	18.5	4.4
	USE2G	-	-	-	-	-	-	31.9	18.9	6.9	32.2	18.9	6.5
	USE3G	-	-	-	-	-	-	31.1	18.6	7.0	31.6	18.6	6.1
	USE4G	22.7	28.5	11.5	23.2	27.7	7.1	31.2	18.6	6.4	32.4	18.1	4.9
	USE5G	20.6	29.1	8.6	21.6	28.5	7.7	29.9	18.1	7.8	30.7	18.3	6.6
	USE6G	20.3	29.2	7.9	21.4	28.7	7.9	29.7	19.0	7.5	30.4	18.3	6.8

Appendix (xi). Rainfall plots of spot measurements of salinity (ppt), temperature (°C) and dissolved oxygen (DO; mgL^{-1}) at the surface waters at four sites in each management zone (see Appendix ix) recorded weekly in summer (i.e. January and February) and autumn (April and May) in each year between 2012 and 2024.

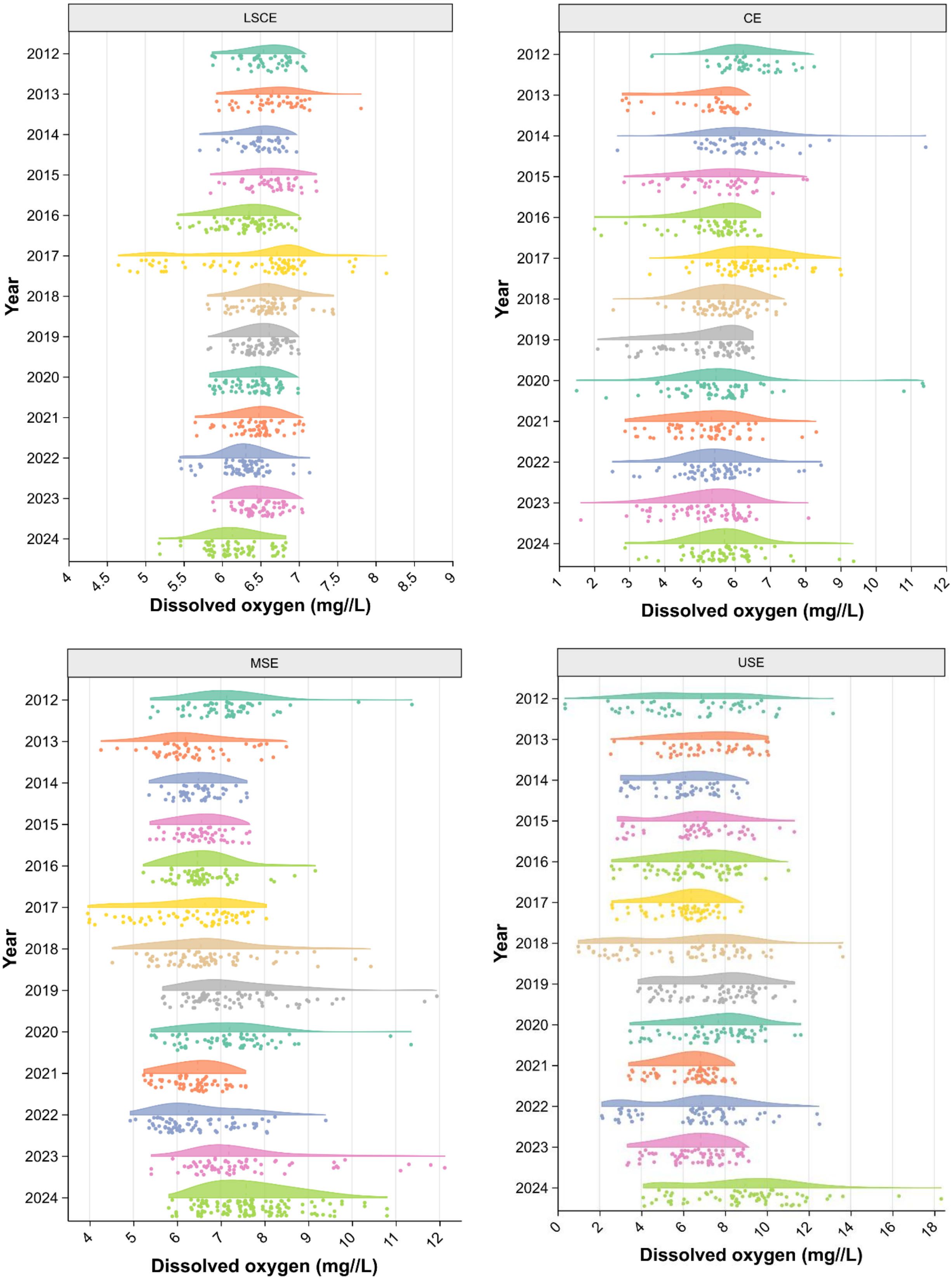
Summer



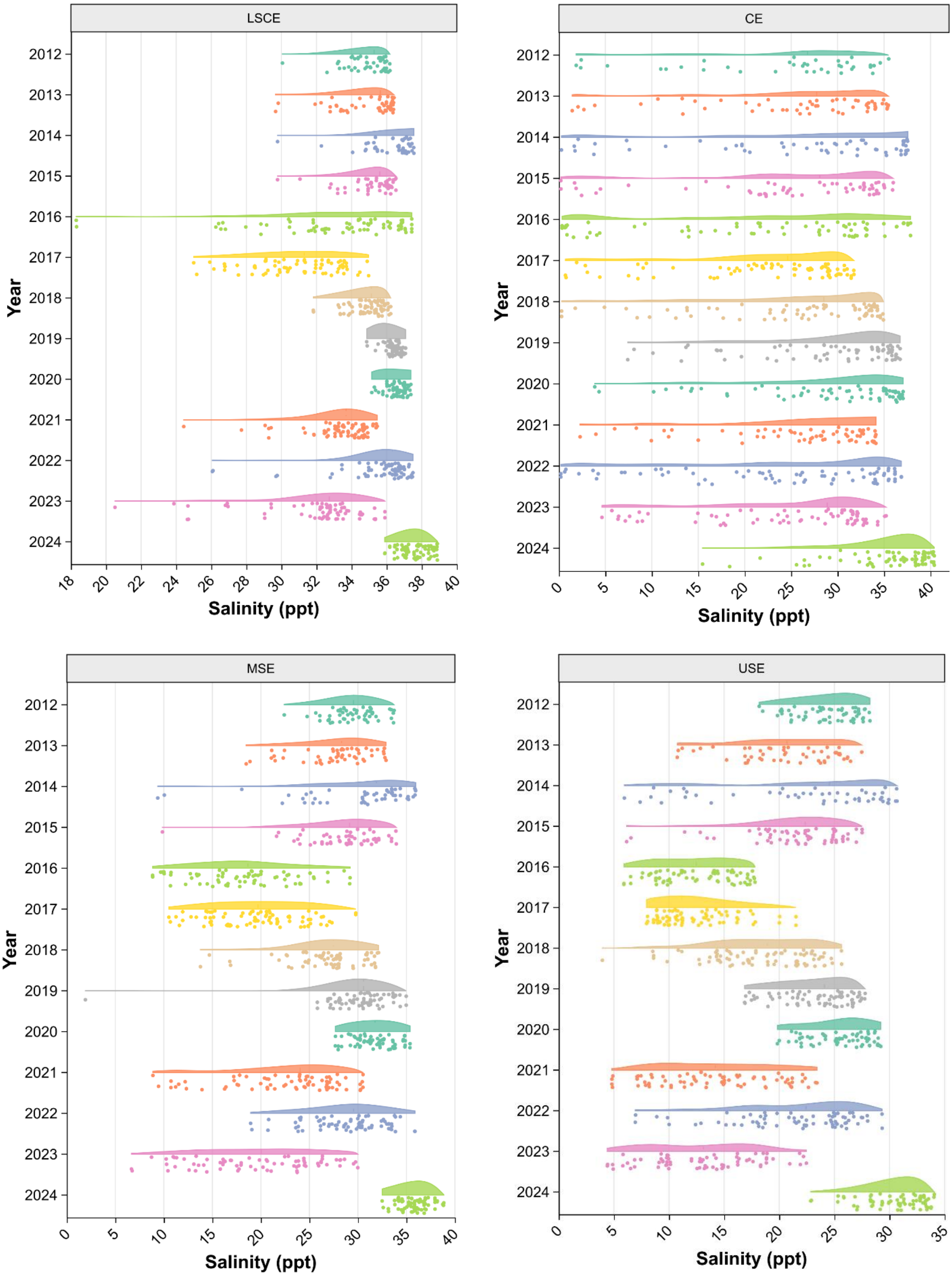
Summer


LSCE
CE
MSE
USE
Year
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Temperature (C)
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

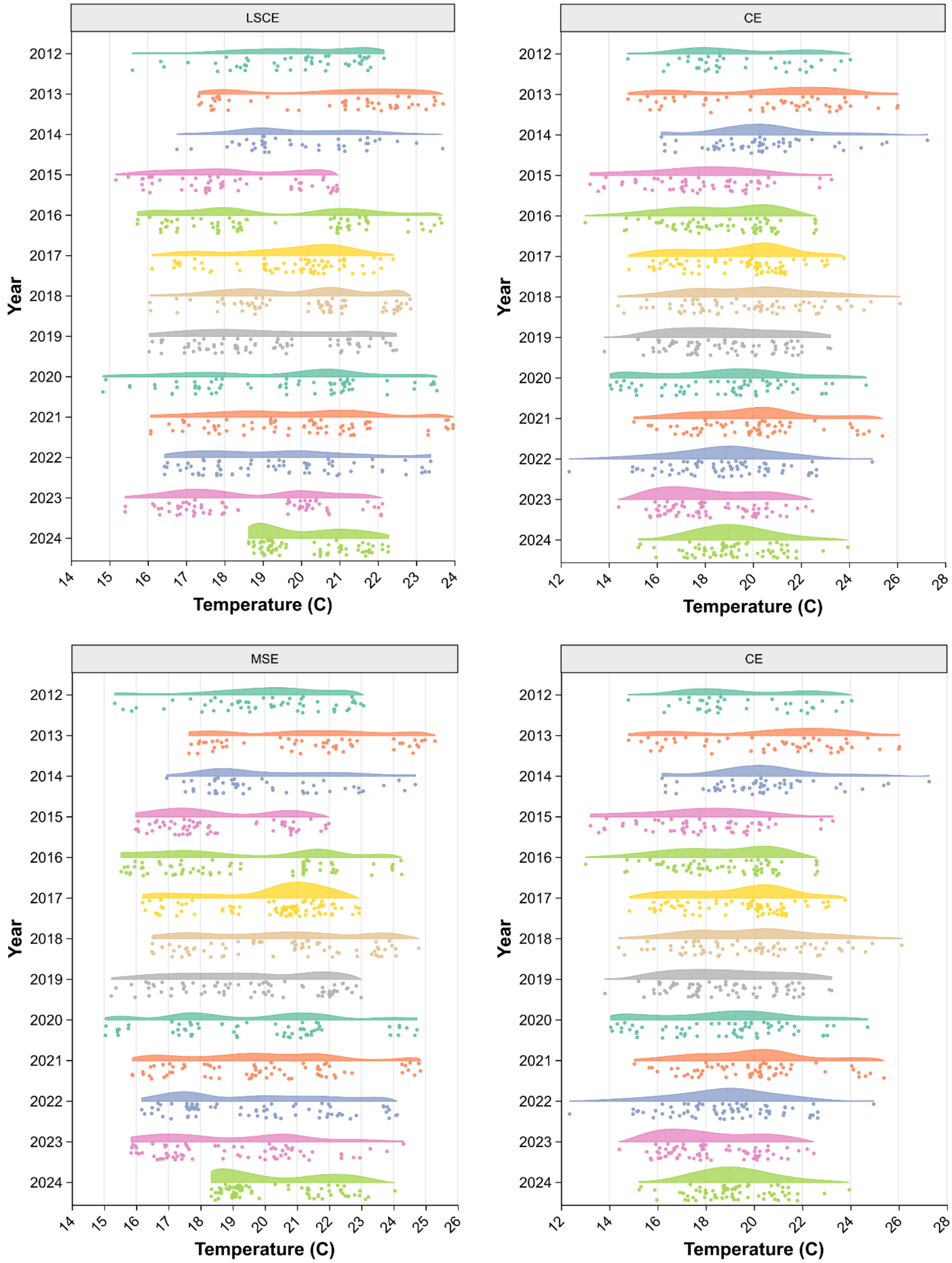
Summer


LSCE
CE
MSE
USE
Year
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Dissolved oxygen (mg//L)

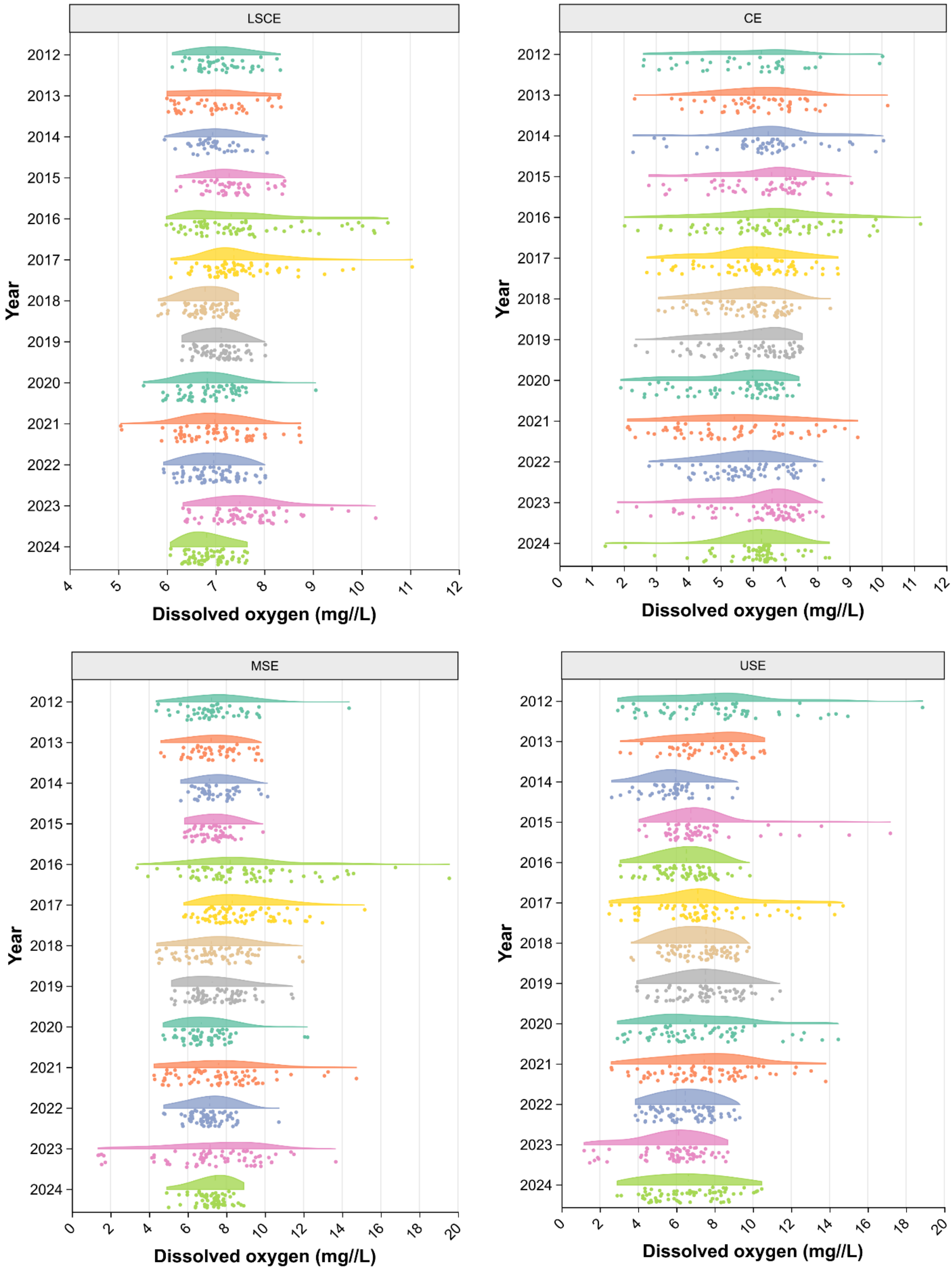
Autumn


LSCE
CE
MSE
USE
Year
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Salinity (ppt)
18 20 22 24 26 28 30 32 34 36 38 40
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35

Autumn


LSCE
CE
MSE
CE
Year
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Temperature (C)

Autumn


LSCE
CE
MSE
USE
Year
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Dissolved oxygen (mg//L)

<u>Appendix (xii).</u> Photographs showing the low tidal conditions in the Lower Swan-Canning Estuary in January 2024 resulting in the exposed subtidal seagrass habitat. Images provided by Dr Kerry Trayler (Department of Biodiversity, Conservations and Attractions).