ORIA STAGE II EXPANSION

POST-DEVELOPMENT KEEP RIVER AQUATIC FAUNA & TARGETED SAWFISH SURVEY - 2022

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Project ID: 22023

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Document Control

Revision	Version	Author	Date	Reviewer	Date
A	Internal Draft	M. Allen W. Fleming	13/12/2022	D. Thorburn	13/12/2022
B	Draft to Client	M. Allen D. Thorburn	15/12/2022	R. Zuks (DPIRD) D. Morgan (IRG) R. Evans (IRG)	27/01/2023
C	Draft to Client	W. Fleming D. Thorburn	16/02/2023		

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EXECUTIVE SUMMARY

This report presents the results of the 2022 Keep River Aquatic Fauna and Targeted Sawfish Survey which represents the final post-development survey required as per the project conditions of the Goomig Irrigation Development. Unlike the 2021 survey, which was affected by pandemic related travel restrictions that prohibited some sites from being surveyed, all regular monitoring sites were able to be sampled in 2022. Field work was undertaken September 2022 and sampling and analyses undertaken during the current study aligned with standardised methodologies set forth in the Ord River Irrigation Area – Weaber Plain Development Project Aquatic Fauna Management Plan.

Consistent with previous years, no evidence was found in 2022 to suggest that the Goomig Development has had any adverse impacts on the water or sediment quality within the lower Keep River. The herbicide atrazine, which was of specific concern to the project's Independent Review Group (IRG), was not present at a detectable level in any water or sediment samples. Although there were several exceedances of site-specific guideline values in 2022 for general water quality parameters, the majority were considered to be the result of natural processes, particularly tidal influence, a lack of rainfall and runoff, and increased evapoconcentration due to above average air temperatures around the time of the field survey. Nutrient concentrations in water and sediment were similar to those recorded in 2021. Sediment concentrations of metals did not increase markedly compared to the results of previous years at most sites except at K4, where the concentrations of most metal analytes were at least double those recorded in 2021. These results are not likely to be attributable to any inputs or releases from the Goomig development via Border Creek, as K4 is situated upstream of its confluence with the Keep River. The observed increases may be due to ongoing leaching of metal contaminants from roadworks and bridge construction on the nearby Legune Road, which took place in September 2020.

Consistent with all previous surveys of the Keep River, no *Glyphis* (River Shark) species were captured in 2022. A solitary *Pristis pristis* (Largetooth Sawfish) individual was captured at K3 in brackish water, while six *Pristis clavata* (Dwarf Sawfish) were captured at site K1. This was the first time this species has been recorded at a non-estuarine site in the Keep River system, a result attributable to the higher than usual salinity levels at K1 in 2022. Total numbers of *Pristis* captured in 2022 were comparable to previous surveys and were within the range of numbers expected based on the magnitude of rainfall and runoff experienced during the preceding wet season, indicating that there have been no recent adverse impacts on *Pristis* in the lower Keep River.

In 2022, the total number of fish species recorded during the survey was considerably less than in the previous two surveys due to a combination of unfavourable tides and the high abundance of saltwater crocodiles, which restricted fish sampling effort in comparison to previous years. Nonetheless, patterns of distribution, abundance and species richness of fishes were largely consistent with results of previous surveys, with richness declining as salinity decreases with increasing distance from the estuary. Differences in fish assemblages between the baseline (2011-2013) and post-development periods (2020-2022) were detected for sites K1 and K3, driven primarily by differences in abundances of a number of

species. Higher than usual salinity in the Keep River pools was identified as the probable cause of these differences, which was considered natural variation resulting from tidal ingress, a lack of freshwater runoff and evapoconcentration around the time of sampling in 2022.

With respect to macroinvertebrates, reference sites and upper Keep River pools (i.e., K4, KR1, KR2, KE1, SR4 and DR1) continue to support high diversity, whilst sites closer to the estuary (K3, K2 and K1) recorded significantly lower species richness. All taxa recorded were considered typical of the region, with no occurrences of significant or protected fauna. In accordance with previous years monitoring, variation in macroinvertebrate assemblages is primarily driven by the longitudinal salinity gradient, with species richness increasing with distance upstream from the estuary. No evidence was found to suggest that anthropogenic impacts associated with the Goomig Development have influenced macroinvertebrate assemblages.

This study brings to a close the aquatic monitoring requirements set out in the Ord River Irrigation Area – Weaber Plain Development Project Aquatic Fauna Management Plan. No evidence was found during the post-development survey period (2020-2022) to suggest that outflow from the Goomig Development area is having any adverse impacts on the water and sediment quality, or aquatic fauna assemblages of the lower Keep River system. However, a number of recommendations for any potential ongoing monitoring in the future are suggested, including:

- Water and sediment quality sampling at point of discharge into Border Creek;
- Water and sediment quality sampling to take place when connectivity exists between the irrigation channel, Border Creek and the Keep River;
- Reviewing environmental consequence assessment criteria relating to macroinvertebrate and fish assemblages;
- Considering the collection and analysis of aquatic fauna and flora tissue samples to investigate potential food web effects of introduced analytes;
- Inclusion of appropriate reference sites in estuarine habitats that are more comparable to the potentially impacted sites (K1, K2, K3, K4) in the lower Keep River; and
- Further investigation into the importance of the Keep River estuary and lower pools as habitat for *Pristis clavata* noting the high capture rates in comparison to other studies conducted in the region.

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1 INTRODUCTION

1.1 Background

In 2002, the Ord Stage 2 development, including the Goomig Development was approved by the Western Australian State Government. Approximately 7 400ha, known as Goomig farmlands was considered suitable for agricultural development, requiring 120GL irrigation supply from lake Argyle. The developmental design incorporated an irrigation tail-water management system (GHD 2010), resulting in the avoidance of dry-season discharge to the local catchment.

In June 2010, the Australian Federal Government determined that the Goomig Development required approval under the *Environment Protection and Biodiversity Conservation Act 1999 (*EPBC Act). The proposal was considered to have the potential to impact a number of Matters of National Environmental Significance (MNES). The proposal was assessed and subsequently approved (2010/5491), subject to 20 conditions, issued on 13 September 2011 (the Approval). Condition 10 of the Approval required the preparation of an Aquatic Fauna Management Plan (AFMP) to protect potentially occurring listed threatened aquatic fauna species in the Keep River, specifically the:

- critically endangered Speartooth Shark (*Glyphis glyphis*);
- endangered Northern River Shark (*Glyphis garricki*);
- vulnerable Dwarf Sawfish (*Pristis clavata*); and
- vulnerable Freshwater Sawfish (*Pristis microdon*; now referred to as *P. pristis*, Largetooth Sawfish).

Sub-conditions 10A to 10H detailed specific measures that required approval from the Minister for Sustainability, Environment, Water, Population and Communities (recently renamed to Department of Environment) to be implemented for the monitoring and protection of the listed species before the clearance of farm lots. Particular concerns related to the number of listed species potentially present in pools in the lower Keep River, the size of their populations, how the pools are used (i.e., by adults or as nursery habitat for juveniles), and how the proposed development may affect the listed species, both directly (i.e., water quality) and indirectly (i.e., through changes to habitat and the food chain). Condition 10 also specified that a baseline survey program was to be conducted over three years, and developed in consultation with the Independent Review Group (IRG). The IRG oversees hydrological aspects of the project and associated impacts on EPBC Act listed threatened species. The group consists of independent scientific and technical experts appointed under Condition 9 of the Approval.

The AFMP (Strategen 2012) was formulated to meet each requirement of condition 10 of the Approval and required:

- a targeted, non-lethal baseline survey for listed species likely to occur in the Keep River;
- measures to maintain water quality in Keep River pools; and
- a targeted aquatic fauna monitoring program to measure the AFMP's success and an adaptive management approach.

Wetland Research & Management (WRM) was commissioned by LandCorp (the proponent at the time) to design the monitoring program, including the selection of appropriate sampling methods, and undertake three pre-development baseline surveys of the Keep River between 2011 and 2013 (WRM 2013a, 2013b, 2014). The baseline survey program was designed in consultation with the Independent Review Group (IRG), of which oversee the hydrological aspects of the project and associated impacts on EPBC Act listed threatened species. The aim of these surveys was to assess surface water and sediment quality, macroinvertebrate and fish assemblages and listed species to establish the baseline ecological condition.

Additionally, the baseline macroinvertebrate surveys were used to satisfy Condition 11F of the Stormwater and Groundwater Discharge Management Plan (SEWPAC 2011), which required the development of Australian River Assessment System (AusRivAS) trigger levels for aquatic macroinvertebrates. However, these trigger values were later deemed inappropriate for assessing adverse changes in brackish, estuarine pools, as these habitats were beyond the bounds of the models. The Approval was subsequently amended with references to AusRivAS trigger values being removed from Condition 11F and replaced with the following wording: *"Use of best practice multivariate analyses on species level macro-invertebrate and fish assemblage data, within an adequate experimental design (as defined in the Aquatic Fauna Management Plan required under condition 10), using multiple indices of 'ecological condition' and a 'weight of evidence' approach, to assess any change in ecological health of Keep River pools (K1, K2 & K3) relative to baseline and upstream reference sites"*.

In October 2021, Indo-Pacific Environmental was awarded the contract by the Department of Primary Industries and Regional Development (DPIRD), acting as the proponent for the development, to undertake the second post-development survey and assessment, which took place in November 2021. The current report presents data obtained from the third and final post-development aquatic survey, which was undertaken by Indo-Pacific Environmental in September 2022.

1.2 Aims and Objectives

The aim of the third post-development survey and assessment in 2022 was to repeat the sampling program conducted during earlier baseline and post-development surveys, in order to compare the current ecological data against baseline data and identify any impacts resulting from the ORIA Stage 2 Goomig Development. The specific objectives of the survey were to undertake:

- Sediment sampling - in potentially impacted (exposed) pools;

- Targeted *Pristis* and *Glyphis* survey - to ascertain distribution and population within the potentially affected area; and
- Macroinvertebrate, fish and water quality sampling in potentially exposed and reference (control) pools.

With respect to the assessment, specific objectives were to:

- Assess sediment and water quality at potentially exposed sites against reference sites and/or trigger values derived from baseline data sets;
- Assess impacts to listed taxa (*Pristis* and *Glyphis* species) by determining the distribution and population of these species and comparing results to baseline and reference sites.
- Assess impacts to aquatic fauna (fish and macroinvertebrate communities) by statistically comparing 2022 fish and macroinvertebrate assemblages against those recorded in baseline years.

1.3 Notable Changes Since the Baseline Surveys

A series of changes and developments have taken place since the final baseline survey was completed in October 2013 that are directly relevant to the study area. These changes have the potential to adversely affect listed species and the ecological health of the Keep River downstream of the project area. The changes include construction and sealing (bituminising) of the Legune Road in September 2020 associated with the sea farms prawn aquaculture project on Legune Station and the construction of a major bridge over the Keep River at the old Legune Road Crossing between the K4 and K3 sites on the Keep River (Figure 1). Although unrelated to the expansion of the ORIA, the potential exists for the Keep River to be affected for a number of years through increased siltation, potential hydrocarbon spills/releases, and chemical run-off from the bitumen.

WRM (2021) also noted that some irrigation drainage water from Ord Stage 1 flows through the Goomig Development and is released into Border Creek where it subsequently drains into the Keep River immediately upstream of site K3. Although this tail water is not strictly from the Goomig Development, M2 supply water has been released previously into Border Creek/Keep River to provide a flushing/dilution flow in accordance with operational requirements of the Goomig Development. As such, should any adverse impacts on the river be detected, it may be difficult to ascertain the true source given these two different run-off sources. However, it is understood that Kimberley Agricultural Investment (KAI), the entity that manages farming operations at the Goomig Development, installed a pumping station in 2021 and as a result no irrigation water was released into Border Creek in that year (Jo-Anne Ellis, DPIRD, pers. comm).

2 METHODS

2.1 Sample Sites

A total of 12 sites (including 26 sub-sites) that had previously been established were surveyed in 2022 (Table 1; Figure 1). Sampling was undertaken at potentially exposed sites in the Keep River, as well as reference sites to create a classic BACI design (Before/After: Control/Impact). Potentially exposed sites were designated by KBR (2006) and included the four main pools on the lower Keep River (i.e., K1, K2, K3, K4). Five replicate locations (sub-sites) were sampled at K1, K2 and K3, and three replicate locations were sampled at K4 due to its smaller size (Figure 1). Additional sites established by WRM (2013a) that were sampled included three potentially exposed sites in the Keep River estuary (EST01, EST02 and EST03) and the reference sites KE1 (Milligan's Lagoon), KR1 (Alligator Waterhole), KR2 (Policeman's Waterhole), SR4 (Augustus Waterhole) and DR1 (Dunham River at Sugarloaf Hill) (Figure 1).

2.2 Sampling Methods

The current survey followed the methodology of WRM (2013a, 2013b, 2014 and 2021) including the collection of abiotic samples and the deployment of nets at the same locations and for the same duration, to ensure comparability to baseline data. The sampling methods utilised at each sub-site are summarised in Table 1. In brief, water quality sampling was undertaken at all sub-sites, whilst sediment sampling was only conducted at potentially exposed sites in the lower Keep River, including the estuary. The Aquatic Fauna Ecological Health Assessment, which includes the sampling of macroinvertebrates and fish, was undertaken at all sub-sites within each of the potentially exposed lower Keep River pools, in addition to all sub-sites at reference pools. Targeted surveys for *Pristis* and *Glyphis* species were undertaken at one sub-site within each of the potentially exposed lower Keep River pools and each of the Keep River estuary sites, although any incidental captures of these species at other sub-sites were also recorded.

2.2.1 Water Quality

At each sub site, undisturbed filtered and unfiltered water samples were collected in a variety of containers provided by the laboratory depending on the analysis required. Retained samples were immediately labelled and placed on ice before being refrigerated or frozen as quickly as practicable. Water samples were delivered within designated holding times to Australian Laboratory Services (ALS), a NATA-accredited laboratory, and analysed for a suite of physico-chemical, ionic and nutrient parameters, in addition to Atrazine which was specifically requested by the IRG (Appendix 1). The herbicide Atrazine was added to the suite in 2020 given the discharge of irrigation return water into the Keep River via Border Creek. One sample was collected from each potentially exposed site which was analysed for Atrazine. Additionally, various in situ water quality parameters were also measured at the time of sampling (Appendix 1), whilst profiles of dissolved oxygen (DO), electrical conductivity (EC) and temperature were measured at 0.5 m intervals throughout the water column.

2.2.2 Sediment

At each sub site, sediment samples were collected from the left bank, mid-channel and right bank using an Ekman-Birge grab sampler before being transferred via a washed glass-nylon trowel directly into high-density polyethylene (HDPE) press-seal bags or glass jar depending on the analysis required. Retained samples were immediately labelled and placed on ice before being refrigerated or frozen as quickly as practicable. Sediment samples were delivered to ALS holding times and analysed for a suite of physico-chemical, major ion, metal and nutrient parameters, whilst one sample from each site was also analysed for Atrazine (Appendix 2). In relation to the analysis of total metals, samples were homogenised in-sample jar, if possible, with a clean spatula prior to weighing out for acid digestion. Between 0.8-1.2 g was subsequently digested for half an hour with a mix of 2 mL 1:1 HNO_3 and 10 mL 1:4 HCl. Samples were then allowed to cool before adding 2 mL H_2O_2 and digested for a further 30 minutes. Samples were then allowed to cool before being bulked to 50 ml with reagent grade water and poured off for analysis by ICP-MS and ICP-AES. Results were moisture corrected before reporting.

It should be noted that analysis of sediment samples in 2020 was undertaken by a different laboratory (i.e. ChemCentre) to that used in 2021 and 2022 (i.e. ALS). Specific treatment and analytical methods of sediment samples were not described in the report by WRM. Furthermore, analytical methods used in baseline sampling years (2011 – 2013) are also unknown. As such, sediment analyses are likely to have involved differing analytical methods in comparison to those used in 2021 and 2022. The inconsistency in methods therefore limits the ability to accurately assess potential sediment quality impacts between current results and previous years.

2.2.3 Targeted Pristis (Sawfish) and Glyphis (River Shark) Surveys

The sampling and processing of *Pristis* and *Glyphis* species aligned with the Protocols for Surveying and Tagging Sawfishes and River Sharks (Kyne and Pillans 2014). At each sampling site, two 30 m long single panel gill nets with a 2 m drop, composed of 6 inch stretched monofilament mesh, were deployed perpendicular to the shore and anchored at both ends to prevent the nets from moving for up to eight hours. To minimise the potential for death and injury of aquatic fauna, nets were closely monitored for movement and regularly cleared (at least every hour) to ensure entangled animals could be removed and released alive. For each net set, the number of each species captured, net length and duration of time deployed were recorded. This information was used to derive the catch per unit of effort (CPUE) as an indirect measure of abundance by dividing the total number of individuals captured at a sample site by the combined total of net length (m) deployed at the sub-site per hour.

Any listed species captured were processed as rapidly as possible, whilst remaining submerged off the side of the vessel, in the following manner:

- Total length (TL) was recorded, with total rostrum length (TRL) and left and right rostral tooth counts also recorded for *Pristis* species;
- Sex was determined (based on presence or absence of claspers); and

- A fin clip was taken and placed immediately in 100% ethanol to provide tissue samples for future DNA analyses.

Additionally, to align with the Protocols for Surveying and Tagging Sawfishes and River Sharks (Kyne and Pillans 2014) and after discussion with the NT Department of Industry, Tourism and Trade – Fisheries, the current study utilised Passive Integrated Transponder (PIT) tags as opposed to the conventional cattle-style tags that were utilised during previous surveys. PIT tags have no external parts and are the preferred tag type to individually identify animals as they circumvent the biofouling and abrasion issues of external conventional tags. PIT tags were applied internally (in the body musculature, just under the skin) via a stainless-steel needle attached to an applicator gun to the left side of the first dorsal fin. Each PIT tag has a unique serial number that can be read with an electronic scanner allowing for the identification of recaptured individuals.

Other fish species captured whilst netting for *Pristis* and *Glyphis* spp. were identified to species and a total length recorded before being returned to the water alive.

2.2.4 Fish

Sampling for fish as part of the Aquatic Fauna Ecological Health Assessment was undertaken using a standardised methodology that has been used extensively in the Northern Territory (Larson 1999) and Kimberley (Storey 2003; WRC 2003). Two 30 m multi-panel gill nets were deployed at each location, with each net consisting of 6 x 5 m panels, with a 2 m drop, and panels increasing in size from 25mm to 150mm stretched mesh. The nets were set perpendicular to the bank, with the smallest mesh set against and secured to the bank, and the largest mesh positioned mid-channel with a float and weight to keep the net in place for approximately 2.5 hours. To minimise the potential for death and injury of aquatic fauna, nets were closely monitored for movement and regularly cleared to ensure entangled animals could be removed and released alive. Individual fish were identified to species and total length (mm) and weight (g) measured, before being released back into the water alive. For each net set, the number of each species captured, net length and duration of time deployed were recorded. Catches from both nets were combined to form one replicate sample from each sampling location.

2.2.5 Aquatic Fauna Pest Monitoring

Within the AFMP there was a requirement for annual surveys to be undertaken for aquatic pest animals introduced to Border Creek and Keep River (e.g., *Cherax quadricarinatus*, Red Claw Crayfish). In 2021, baited opera house traps were deployed near each set of gill nets at each sub-site for up to seven hours. The entry size into each trap was restricted to exclude larger air-breathing fauna (e.g., turtles) in order to mitigate the risk of drowning. No *C. quadricarinatus* were captured in that year and no records of the species presence were attained (e.g. shell remnants on the banks). *C. quadricarinatus* are largely considered freshwater species with the ability to tolerate brackish conditions (< 15ppt), therefore their presence in saline water within the Keep River is highly unlikely (Prymaczok et al. 2008). As such, opera house traps were not utilised in 2022 ,although, if present, juvenile *C. quadricarinatus* can generally be collected via macroinvertebrates sweeps.

2.2.6 Macroinvertebrates

Sampling for macroinvertebrates as part of the Aquatic Fauna Ecological Health Assessment was undertaken using a standard methodology used extensively in rivers of northern Australia, including the Ord Stage 2 project (NCTWR 2005; Storey and Lynas 2007; WRM 2010 and 2011) and the WA (van Looij 2009) and NT (Lloyd and Cook 2002) Australian River Assessment System (AusRivAS) programmes. Edge samples were collected from habitat along the banks of each pool, typically consisting of root mat, leaf litter/detritus, and occasionally submerged macrophytes or floating vegetation. Samples were collected using a cultivator rake to disturb the substrate along a 10 m transect and a standard macroinvertebrate net (250-micron mesh) to collect dislodged material. As riffle habitat was not present at any of the sites during the current study, riffle samples were not collected. For edge samples, litter and other coarse debris were washed and removed by hand with the remaining material preserved in 70% ethanol and transported to the Indo-Pacific Environmental laboratory in Perth for processing.

In the laboratory, macroinvertebrates were removed from samples by sorting under a low power dissecting microscope and then identified to the lowest possible level (genus or species level) using available keys and identification guides. Specimens were enumerated to log^{10} scale abundance classes (i.e., 1 = 1 individual, 2 = 2-10 individuals, 3 = 11-100 individuals, 4 = 101-1000 individuals, 5 = >1000 individuals).

2.2.7 Limitations of Methods

A number of limitations were encountered by field personnel during sampling that had the potential to influence survey results. At multiple sub-sites within the K1 and K2 pools, high abundances of Saltwater Crocodiles (*Crocodylus porosus*) resulted in multiple gill nets being withdrawn early to avoid the entanglement and subsequent risks associated with capturing these animals in gill nets. Results from all nets that were withdrawn early were adjusted accordingly for CPUE. Additionally, gill netting was not undertaken at sites KR2, KR1 and EST01 for various reasons, as follows. Survey personnel were advised by Keep River National Park staff to not enter the waterhole due to the presence of a large Saltwater Crocodile at KR2; whilst no viable access for a boat was present at site KR1. Low tides resulting in very shallow water depth (<0.5 m) at EST01 also prevented the use of a boat, therefore gill netting was not possible. Discussion with visitors to the area outlined that EST01 only contains water of any depth on macro-tides.

2.3 Data Analysis

2.3.1 Limitations and Assumptions

A comparison of water quality, sediment quality and fauna between sites within years in the lower Keep River was not considered appropriate due to the pronounced longitudinal gradient in tidal influence (i.e., prominent at K1 and negligible at K4) and its potential to cause significant variation in data across those sites. As such, comparisons were made between data collected during baseline years and the current survey for each site separately. Additionally, there was a requirement to discuss natural variability in ecosystem health whilst having regard to reference site survey results. Whilst this was done and considered appropriate for K4, the results from the tidally influenced K1, K2 and K3 should be treated with caution as none of the current reference sites are tidally influenced. Furthermore, the results presented in this report represent a snapshot of the environmental conditions and fauna present at the time of sampling. As environmental conditions and fauna can vary considerably depending on the time of year and the climatic conditions around the time of sampling, these factors should be taken into account when interpreting results.

While some raw data from the 2020 study by WRM were provided by DPIRD, baseline macroinvertebrate, fish and *Pristis* abundance data were not available and, therefore needed to be extracted from tables within previous reports (WRM 2013a, 2013b, 2014). Based on data reported by WRM (2013a, 2013b, 2014, 2021) it appeared that specimen observations of fish were attributed an abundance value of one, so this was applied to the current data. For the extracted macroinvertebrate data, it was noted that there were discrepancies between the taxonomic level of identification between years, and a number of in-house (WRM) names were used to identify some species. As such, to allow for accurate comparisons and statistical analyses to be made between years, the taxonomic level of identification was adjusted so as to be consistent across all years. Additionally, as only log^{10} scale abundances were presented, when taxa were combined, the highest log^{10} abundance value was allocated.

For abiotic data, water quality data were only available for 2011 and 2012 and no sediment data were presented for any years in the WRM reports. As such, the only interannual data comparisons that could be undertaken were between water quality and fauna abundance data for 2011, 2012, 2020, 2021 and 2022. Whilst additional data for 2013 would have been beneficial, results from statistical analyses are still considered valid. Summary statistics for water and sediment baseline data were, however, provided by WRM (2014 and 2021) and extracted for assessing against data collected during the current study. Analytical methodology for metals in sediments in baseline surveys is unknown, 2020 sediment analysis methodologies differed due to the use of differing analysis labs (ChemCentre in 2020, ALS in 2021 and 2022). These discrepancies have resulted in invalid statistical analysis regarding nutrient and metal concentrations in sediments between years.

2.3.2 Water and Sediment Quality

Whilst the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (2018) contains guideline values for a number of the water and sediment parameters measured, guideline values do not exist for the majority of parameters. Furthermore, ANZG (2018) indicates that the use of local reference data for the development of site-specific guidelines is preferential. As such, the methodology outlined in ANZG (2018) for the development of site-specific guideline values for water (SS-WQGV) and sediment (SS-SQGV) quality was adopted. Based on the definitions provided in ANZG (2018), the lower Keep River would be considered a slightly to moderately disturbed ecosystem. For such ecosystems, ANZG (2018) indicates the 80th (or 20th for oxygen saturation) percentile values should be adopted as the site-specific guideline values and these values were derived for each site from the baseline survey data sets (i.e., 2011, 2012, 2013) These site specific guidelines were also adopted in the 2020 WRM and 2021 Indo-Pacific Environmental reports. (WRM 2021; IPE 2022) Median values of replicate samples collected at each site in 2022 were compared against site-specific guideline values for each parameter.

Additionally, 2022 median water quality values were also compared to the Interim Local Trigger Values (ILTVs) developed for the Keep River pools by Bennett and George (2014). Comparisons were also made between water quality at potentially exposed and reference (control) sites to determine if any changes occurred in 2022 throughout the region and, if so, whether these were widespread as a result of naturogenic processes, or if they were unique to the lower Keep River.

While statistical analyses on water and sediment data in the Keep River have been undertaken in some previous reports (e.g., WRM 2014, 2021), they were not undertaken in 2021 (IPE 2022) or in the current study, which aligns with the nationally accepted methodology outlined in ANZG (2018) for water and sediment quality assessments.

2.3.3 Pristis (Sawfish) Population Assessment

In northern Australian rivers, the magnitude and duration of flood levels during the previous wet season has been correlated to recruitment success (and hence abundance) of *P. pristis* (Lear *et al.* 2019). During the current study, the influence of hydrology was taken into account when assessing whether the Goomig Development was impacting on *P. pristis* numbers in the lower Keep River by performing a correlation analysis between CPUE data and water level recorded at the Legune Road Crossing gauging station (G8100225) during the previous wet season. Additionally, individuals less than a year old (<1300 mm TL), i.e., young-of-year (YOY) (Morgan *et al.* 2011; Thorburn *et al.* 2007), were examined separately to assess recruitment of *P. pristis*. Regression analyses were undertaken between baseline data (2011-2013) and data collected post-development (2020-2022) to determine if the results fell within the expected range for assessment.

2.3.4 Fish and Macroinvertebrates

As previously mentioned, the AusRivAS trigger values identified in the 2013 report were deemed inappropriate for assessing adverse changes in brackish, estuarine pools of the lower Keep River. As such, baseline and post-development data for aquatic fauna were compared using several routines in PRIMER/PERMANOVA+. Unless specified, default values or procedures recommended in PRIMER-7 (Clarke and Gorley 2006) and PERMANOVA+ (Anderson *et al.* 2008) were used for all analysis routines.

For the analysis of species level assemblage data, fish abundance data were transformed (log [x+1]) prior to the analysis, whilst untransformed log^{10} scale abundance classes were used for macroinvertebrates. Water quality data collected during all years were also transformed (log [x+1] and normalised to account for various measurement scales and to correct asymmetric (positive) distribution (Clarke and Gorley 2006). Additionally, water quality parameter values below the limit of reporting (LOR) were allocated a value of half of the LOR for statistical analyses.

Ordination of assemblage data was by non-metric Multi-Dimensional Scaling (nMDS) depicted as two-dimensional (2D) plots based on annual site by site Bray – Curtis similarity matrices (Clarke and Warwick 2001). Pair-wise comparisons were undertaken using the permutational multivariate analysis of variance (PERMANOVA) routine to test for statistically significant ($p < 0.05$) differences between:

- each potentially exposed site and combined reference sites (DR1, KE1 and SR4) in 2022;
- combined 2011-2013 baseline and 2020-2022 post-development data sets for each site; and
- individual baseline years and 2020-2022 post-development data sets for each site.

In some cases, there were low numbers of unique permutations for comparisons in the PERMANOVA analysis due to the limitations associated with the distribution and availability of sites in the design. As a result, Monte-Carlo *p*-values were also generated, as these may provide a more accurate assessment where unique permutation numbers are less than 100 (Anderson *et al.* 2008).

Similarity percentage analysis (SIMPER) was used to calculate the contribution of each species (%) to the dissimilarity between each group, in order to identify species that were the major contributors to any differences detected in PERMANOVA pair-wise testing.

Relationships between the water quality variables and both fish and macroinvertebrate assemblage data were explored using the distance-based linear models (DistLM) routine (AIC and step-wise comparisons) (Clarke and Gorley 2006; Anderson *et al.* 2008). DistLM was chosen over other models as it takes into account the potential overlap of different predictors and finds linear combinations of the abiotic variables that best predict patterns in the biotic data set.

For macroinvertebrates, a 'sensitivity analysis' was also undertaken as per the Stream Invertebrate Grade Number – Average Level (SIGNAL) 2 biotic indices for river macroinvertebrate methodology (Chessman 2003). A SIGNAL 2 score provides an indication of water quality at the site from which the sample was collected. Sites with high SIGNAL 2 scores are likely to have low levels of salinity, turbidity and nutrients such as nitrogen and phosphorus. When considered together with macroinvertebrate diversity, this can indicate the types of pollution and other physical and chemical factors that may be affecting the macroinvertebrate community.

3 RESULTS AND DISCUSSION

3.1 Water quality

Water quality parameters measured during the 2022 survey for all replicate sub-sites are presented in Appendix 1, whilst median values for each site along with ANZG (2018) default water quality guidelines, SS-WQGVs and dry season ILTVs are presented in Table 2. As the recommended method for assessing environmental water quality utilises site-specific water quality guidelines (ANZG 2018; see section 2.3.3), ANZG default water quality guidelines will not be discussed further in this report. It was understood that Farm stormwater discharge to the Keep River via Border Creek and the Goomig Development stormwater outlet occurred in March 2022

Consistent with previous surveys, stratification of temperature, electrical conductivity and dissolved oxygen was pronounced at site K2 in the lower Keep River, with evidence of a halocline and thermocline formation between 1 m and 1.5 m below the surface (Figure 2). Stratification of these parameters was also evident to a lesser extent at K1, K3 and estuary sites (Figure 2). Oxygen levels decreased with depth at all sites except K1, with hypoxia (≤25% DO) recorded in depths between ~2 m and 3.5 m at sites K2, K3 and K4 (Figure 2). Hypoxic conditions were not recorded in the relatively shallow waters of the estuary and the strongly tidal K1 site, which appeared to be well mixed (Figure 2).

3.1.1 General Parameters

In 2022, median water temperatures exceeded the SS-WQGV at 50%, 40% and 100% of potentially impacted sites, reference sites and estuarine sites, respectively (Table 2). The current survey took place at the same time of year as the baseline surveys, however, daily maximum air temperatures recorded during the 2022 survey were over 3°C higher on average than the long-term average recorded for the month of September at the nearby Kununurra Aero weather station (BOM, 2022). Median pH values were below guideline values at all potentially impacted and reference sites (except DR1), but were above guideline values at all estuary sites (Table 2). At the majority of sites, median DO% was outside respective guideline values, but in many cases only just so, with the exception of reference sites which were mostly well outside guideline values (Table 2). Turbidity values were not recorded during the current survey due to an issue with the turbidity meter.

Median TDS values exceeded guideline values at all potentially impacted (except K4) and estuarine sites, but were within guideline values at all reference sites (Table 2). These results contrasted those recorded in 2021, when TDS guideline values were only exceeded at site K2. For TSS, the LOR (5 mg/L) was actually higher than the SS-SQGV at potentially impacted Keep River sites (1.5 mg/L), making it difficult to interpret the results and compare to surveys prior to 2021 which used a lower LOR (1 mg/L). In any case, ILTVs were not exceeded for TSS at any of these sites in 2022 (Table 2). At all estuary sites, TSS results were within guideline values, however, for the majority of reference sites the high LOR in relation to the SS-WQGV again confounded an accurate interpretation of results except at KR1 and KR2, which were found to be outside and within their guideline values, respectively (Table 2).

3.1.2 Salinity and Ionic Composition

In 2022, median conductivity values at potentially impacted sites exceeded SS-WQGV and ILTVs at K1, K2 and K3, but were within guideline values at K4 (Table 2). Elsewhere, conductivity also exceeded guideline values at all estuary sites, but were within guideline values at all reference sites (Table 2). Conductivity at the surface of sites K2 and K3 was almost half that recorded below ~1 m depth (Figure 2), indicating that a distinct halocline had formed at these sites. This is a reflection of the negligible effect of tidal mixing in these pools as well as the lack of any significant rainfall or freshwater runoff immediately prior to or during the survey. On the contrary, a distinct halocline was not recorded at site K1 or in the estuary (Figure 2) indicating that tidal mixing is more prevalent at these sites.

Similar to the results recorded for conductivity, measurements of a number of ionic composition analytes exceeded SS-WQGVs at the lowermost Keep River sites (K1, K2, K3) and estuary sites, while measurements recorded at reference sites and site K4 were mostly within their respective guideline values (Table 2). The ionic parameters that were most consistently recorded in excess of guideline values during the study were chloride, sulphate, calcium, magnesium, sodium, potassium and water hardness.

3.1.3 Nutrients

The majority of nutrient parameter values at potentially impacted Keep River sites were below their respective SS-WQGVs and ILTVs, with the exception of total soluble phosphate, total phosphate and DOC (Table 2). In contrast, most of the estuary and reference sites (except KE1 and SR4) recorded nutrient concentrations that exceeded guideline values (Table 2). This mirrored the results recorded in 2021, although only two reference sites (DR1 and KR1) were able to be sampled in that year due to pandemic related border closures. Across the six sites that were sampled in 2021, a comparison of data between 2021 and 2022 revealed similar trends in surface water nutrient concentrations with only minor differences in the values that were recorded (see IPE 2022).

Phosphate and DOC concentrations recorded in excess of guideline values at potentially impacted sites in 2022 are unlikely to have resulted from any significant recent inputs from the Goomig development as they were also elevated at most reference sites (Figure 3). These results may have been caused by high prevailing water temperatures (above the SS-WQGV at ~58% of sites), which are known to accelerate the release process for phosphate (Li *et al.* 2013) and DOC (Winterdahl *et al.* 2016) at the sediment and water interface.

3.1.4 Atrazine

The concentration of atrazine in surface water samples was below the Limit of Reporting (LOR) (i.e., <0.5 µg/L) during the current study, suggesting that atrazine was not entering the environment, or that it was present in negligible concentrations. These results were consistent with the findings of 2020 and 2021 (WRM 2021; IPE 2022). Furthermore, the high surrogate recoveries indicate matrix compatibility for the method of analysis, as matrix interference is not suppressing the recovery of the analyte of interest, and that results are not biased low.

Aditionally, Kimberley Agriculture Investment conducted water quality sampling on 16 March 2022 and 19 May 2022, the latter date being after all flows (including flow at the Keep River GS) had ceased. Atrazine was undetected on both dates, therefore it was expected that Atrazine was undetected in September 2022, aligning with the results attained in this survey (R. Zuks, DPIRD, pers. comm).

3.2 Sediment quality

Raw data from the analysis of sediment samples collected in 2022 at all sub-sites are presented in Appendix 2. Median values for analyte concentrations recorded at each site between 2020 and 2022 are presented in Table 3 along with SS-SQGVs and ANZG (2018) default sediment quality guidelines. The recommended method for assessing sediment quality utilises site-specific sediment quality guidelines (ANZG 2018; see section 2.3.3), therefore ANZG default sediment quality guidelines will not be discussed any further in this report.

3.2.1 Ionic Composition

In 2022, instances where ionic concentrations in sediments exceeded SS-SQGVs predominantly occurred at estuary sites and the potentially impacted sites K1, K2 and K3 (Table 3). These sites are all tidally influenced to some degree with naturally higher salinity and thus higher ionic concentrations in their sediments than non-tidal sites. Not surprisingly, sediment ions were recorded within guideline values for all analytes except potassium at the non-tidal K4 site (Table 3).

3.2.2 Metals

As discussed in Section 2.2.2, accurate assessment of sediment quality impacts based on comparisons between results collected in 2021 and 2022 and the SS-SQGVs derived from baseline results was not considered appropriate. This is due to the fact sediment analysis methodologies applied during the baseline surveys are unknown, though likely to differ to those used in recent years. In addition, the methods implemented by ALS in 2021 and 2022 appear to be different to those used by ChemCentre in 2020. This is indicated by, for example, the fact limits of reporting (LOR) in 2021 and 2022 were higher on occasion than applied SQGVs and concentrations of some metals in 2020. Attempts to ascertain the specific methods used in 2020 were unsuccessful. As such, any comparison of results against the SS-SQGVs or 2020 data were done so with caution. Furthermore, the SS-SQGVs derived from baseline results may not be considered appropriate for the purpose of impact assessment.

Consistent with results of 2021, median concentrations for the majority of metals at each site were below their respective SS-SQGVs in 2022 (Table 3). It was not possible to accurately interpret the results for a number of metals (Sb, Be, B, Bi, Cd, Mo, Ag) because the LOR for the current analysis was higher than SS-SQGVs at some sites. Site specific guideline values for these analytes were originally determined during baseline surveys and made use of a more sensitive LOR. It is unclear from baseline reports of WRM what method was used to treat (digest) sediment samples prior laboratory analysis. As such, this may explain why post-development sediment quality show some variation from the SS-SQGVs

Regardless, during the current study the LOR for each of these analytes was well below concentrations that are known to have detrimental effects.

The metal analytes that exceeded site specific guideline values most prevalently during the current study were titanium (all sites), selenium (all sites) and vanadium (~70% of sites) (Table 3). However, the concentrations of these metals were only marginally outside the respective SS-SQGVs in all instances. Metal concentrations in Keep River pools were not considered to be markedly different to results of 2021 at most sites, suggesting that there have been negligible inputs of heavy metals to potentially impacted sites in the lower Keep River from the Goomig Development over the past 12 months. The one exception was at site K4, which recorded increased concentrations of almost every metal analyte to levels above the SS-SQGV (Table 3). In 2022, concentrations of most metal analytes at K4 were at least double those recorded during the previous year, with some increasing by several orders of magnitude (e.g., selenium) (Table 3). However, these results are not considered attributable to any inputs or releases from the Goomig Development area via Border Creek, as the pool at K4 is situated upstream of its confluence with the Keep River. The observed increases may be due to ongoing leaching of metal contaminants from roadworks and bridge construction on the nearby Legune Road (see inset in Figure 1), which took place in September 2020.

3.2.3 Nutrients

Consistent with the results of the 2021 survey, the majority of sediment nutrient concentration values were within SS-SQGVs in 2022, with the exception of ammonium, which exceeded guideline values at all sites except EST02 and EST03 (Table 3). As hypothesised previously, ammonium concentrations in excess of guideline values at the study site may be an artefact of underestimated SS-SQGVs for this analyte. Ammonium can break down into other compounds if, for example, the seven-day holding period of sediment samples for nutrient analysis is exceeded. It is suspected that this may have occurred during baseline surveys when SS-SQGVs were initially determined, however, it is not possible to determine with absolute certainty if this is the true explanation for the observed trends in the ammonium data. In any case, ammonium concentrations are unlikely to be associated with any inputs from the Goomig Development or any releases of water via Border Creek.

Total phosphorus, total nitrogen and total organic carbon in sediments during the current study were generally below their respective SS-SQGVs and median concentrations were comparable to baseline data (Figure 4). The only other instances where guideline values were exceeded for nutrients in 2022 were for total nitrogen at EST02 and total phosphorous at K3, which in both cases were only slightly above the SS-SQGV (Table 3). These data suggest that there has been no appreciable accumulation of nutrients in the study area over the past year. It is noteworthy that the nutrient data at site K4 showed the same trend as for metals, with most analytes increasing in concentration at least twofold compared to 2021 data (Table 3).

3.2.4 Atrazine

Consistent with the results of previous surveys, sediment concentrations of atrazine were below the LOR (i.e., <0.05 mg/kg) at all sites that were sampled (Table 3), suggesting that this chemical is not entering the study area. Furthermore, the high surrogate recoveries indicate matrix compatibility for the method of analysis, as matrix interference is not suppressing the recovery of the analyte of interest, and that results are not biased low.

3.3 *Pristis* (Sawfish) and *Glyph*is (River Shark) Populations

A total of seven sawfish were captured during the 2022 survey, comprising six *Pristis clavata* (Dwarf Sawfish) and one *Pristis pristis* (Largetooth Sawfish) (Table 4). All six *P. clavata* were recorded from the saline reaches of the lower Keep River at site K1, whilst the single *P. pristis* was recorded from K3, a site with brackish water that ranged between 552 and 645 mS/cm. The *P. pristis* was likely a young-of-year (YoY) juvenile (TL 972mm) (*sec.* Peverell 2008; Thorburn *et al.* 2007), while multiple age cohorts of subadult *P. clavata* were captured, including one YoY juvenile (TL = 1020 mm), four individuals of at least 2+ years of age (TL 1321 – 1747 mm) and one larger individual, likely 5+ years of age (TL = 2357 mm) (*sec.* Thorburn *et al.* 2008; Peverell, 2008).

Plate 1. *P. clavata* specimens captured at K1 in 2022; 5+ year old (left) and young-of-year (right).

A number of factors limited the effectiveness of gill netting for sawfish and sharks during the 2022 survey including unfavourable tides at some of the estuary sites which resulted in some pools becoming shallow and disconnected during the time of sampling. Also, the high abundance of estuarine crocodiles impacted the ability to deploy gill nets effectively at a number of lower Keep River sub-sites (see section 2.2.7).

Despite this, the total numbers of *Pristis* captured during the current survey were comparable to previous surveys (Figure 5). However, it should be noted that the overall numbers captured would likely have been higher if sampling had taken place when tides were higher.

Historically, all occurrences of *P. clavata* within the Keep River catchment have been recorded from estuary sites (Larson 1999; WRC 2003; WRM 2011, 2013a, 2013b, 2014, 2021). The 2022 survey was the first time that *P. clavata* has been recorded from the Keep River pools (Figure 5), which was probably due to the elevated conductivity (= salinity) at site K1 in 2022 (Figure 3). The capture of a juvenile *P. pristis* from site K3 during the current study continued an established trend in the Keep River system whereby the majority of juveniles of this species have been recorded in brackish to freshwater pools (i.e., sites K2, K3 and K4) where food sources are abundant and the density of large predators is substantially lower than in habitats located further downstream.

Notwithstanding the previously mentioned limitations on sawfish sampling in 2022, an inter-annual comparison of capture rates for *P. clavata* was considered appropriate, as the nearshore marine and estuarine habitats that are preferred by this species are generally well connected throughout the year and water quality, particularly salinity, is consistent between years. Conversely, a degree of caution needs to be exercised when comparing and interpreting inter-annual capture data for *P. pristis*, as this species prefers freshwater reaches of rivers that experience highly variable seasonal flow, which is known to influence recruitment and dispersal (IPE 2020, 2021a and 2021b; Lear *et al.* 2019).

Despite the limited amount of capture data for *P. pristis* in the Keep River, a regression analysis shows that CPUE of YOY juveniles is positively correlated to the magnitude of the preceding wet season (Figure 6). Results from the current study continue this previously reported trend (IPE 2020, 2021a, b) and provide evidence to support the conclusions of other researchers (e.g., Lear *et al.* 2019). Specifically, the number of days the water level at the Legune Road Crossing (G8100225) stream gauge was above 5.5 m was found to have the strongest relationship with YOY CPUE data (Figure 6). Data on age cohorts of *P. pristis* captured in 2011 show that recruitment was high during this high magnitude wet season, with the age class of individuals increasing in subsequent years (Figure 7), which suggests that recruitment was limited during these low magnitude wet seasons. Based on the regression lines fitted in Figure 6, the CPUE of YOY and total numbers obtained in both between 2020 and 2022 fitted the models and could be considered within the expected range based on the magnitude of the previous wet season. The numbers of *P. pristis* and *P. clavata* recorded in 2022 suggest that there have been no discernible negative impacts on *Pristis* populations in the lower Keep River from the Goomig Development.

Appendix 3 indicates the CPUE for captures of *P. pristis* and *P. clavata* by year and site surveyed. In relation to *P. clavata*, CPUE values ranged from 0.00467 to 0.01458 individuals per net metre per hour throughout the study. In 2022, a combined CPUE of 0.00189 *P. clavata* per net metre per hour was recorded from estuarine sites (i.e. EST02 and EST03) and sites within K1 and K2 which would be considered to be estuarine environment at that time (despite the lack of tide). In relation to other studies from the Kimberley region, that of Stevens *et al.* (2008) reported a CPUE of 0.00001 and 0.00041 *P.*

clavata per net metre per hour from coastal waters of King Sound, whilst that of Morgan *et al.* (2020) reported a combined CPUE of 0.0067 *P. clavata* per net metre per hour for sampling undertaken in King Sound and estuarine waters of the lower Fitzroy River. Considering that at the time of sampling in 2022 EST02 and EST03 were isolated pools and that no sampling could be undertaken in EST01, the combined CPUE for *P. clavata* from sampling undertaken in the Keep River in 2022 is considered to be high in comparison to results attained by Stevens *et al* (2008). Morgan *et al.* (2020) considered the high occurrence of dwarf sawfish in the Fitzroy River region to be of global significance for *P. clavata*. Considering the comparatively high capture rate of *P. clavata* at individual survey sites throughout the study and combined value for 2022, the Keep River may also represent a regionally important habitat for the species.

Pristis zijsron (Green Sawfish) was not captured during the current survey. This species has only been recorded once within the Keep River, with a single individual captured at site EST01 in 2011. *Pristis zijsron* typically inhabits shallow nearshore marine waters rather than estuary interfaces or freshwater rivers and is therefore not expected to occur within the survey area (Morgan *et al.*, 2017). Likewise, no *Glyphis* species were captured during the current study, a result that was consistent with baseline and historic surveys of the Keep River (WRM 2013a, 2013b, 2014, Larson; 1999; NCTWR 2005; WRC 2003). In contrast, *Carcharhinus leucas* (Bull Shark) was reasonably common, with eight individuals captured during the current survey.

3.4 Fish Assemblages

3.4.1 Species Richness and Abundance

In total, 22 fish species were recorded in 2022, with the equal highest species richness (n=11 spp.) recorded at sites K1 and K3 (Table 4). Of the three reference sites sampled, DR1 and SR4 recorded the highest species richness with nine species each, while five species were recorded at KE1 (Table 4). Species richness was much lower at the two estuary sites with only three species recorded at EST02 and a solitary species at EST03 (Table 4). In 2022, the total fish species richness was considerably less than in 2021 (n=47 spp.) and 2020 (n=42 spp.). This was due to a combination of unfavourable tides and safety concerns pertaining to the abundance of saltwater crocodiles, which restricted fish sampling effort in comparison to previous years.

Consistent with previous surveys (WRM 2021; IPE 2022), the most widespread fish species in 2022 was *Nematalosa erebi*, which was recorded at all sub-sites and reference sites (Table 4). Other commonly encountered species included *L. calcarifer*, *E. vaigiensis* and *N. graeffei* (Table 4). Multiple species were recorded at only a single site, including *P.pristis*, *Pomadasys kaakan* (Barred Javelinfish), *Neosilurus ater* (Narrow-fronted Tandan), *Neoarius midgleyorum* (Shovel-nosed Catfish), *Moolgarda buchanani* (Bluetail Mullet), *Lutjanus argentimaculatus* (Mangrove Jack) and *Glossogobius spp.* (Goby) (Table 4).

In the Keep River pools, species richness was generally highest at the lowermost sites, with the close proximity to the estuary facilitating the presence of a mixed assemblage of freshwater and estuarine-marine species (Table 4). The majority of species recorded to date are considered common throughout estuarine and riverine habitats in northern Australia, with the exception of the two *Pristis* species, already discussed in section 3.3.

In total, 538 individual fish were recorded in 2022, the most numerous of which was *Nematalosa erebi* (Bony Bream), followed by *Ellochelon vaigiensis* (Diamondscale Mullet), *Neoarius graeffei* (Blue Catfish), *Planiliza ordensis* (Diamond Mullet), and *Lates calcarifer* (Barramundi) (Table 4). The percentage composition of species abundance in 2022 was similar to results obtained during the two most recent reporting periods (WRM 2021; IPE 2022). Of The potentially impacted Keep River pools, the mean fish abundance was highest at site K3 (38.6 individuals per sub-site), followed by K4 (29.5), K2 (23.6) and K1 (15.4) (Figure 8). In comparison, the mean abundance of fishes sampled across the three reference sites was 23.3 individuals per site.

3.4.2 Statistical Analysis of Fish Assemblages

An n-MDS ordination suggested that there have been no substantial changes in fish assemblages at the four potentially impacted Keep River sites between the baseline (2011-2013) and post-development periods (2020-2022) (Figure 9). However, PERMANOVA pair-wise testing found significant differences in fish assemblages between 2022 and baseline data at sites K1 (p=0.0014) and K2 (p=0.0239), but not at K3 (p=0.403), K4 (p=0.1494) or reference sites (p=0.1524) (Table 5). For site K1, it is apparent that species richness is comparable between baseline and 2022 data (Figure 8), suggesting that the disparity in abundance primarily contributed to the significant difference detected by PERMANOVA testing. Distance-based redundancy analysis plots (dbRDA) confirmed that *N. erebi* abundance was responsible for over 17% of the total variation between baseline and 2022 data (Figure 10). A reduction in abundance in *P. ordensis* also contributed over 10% of the variation, whilst increased abundance of *C. leucas, E. vaigiensis, E. tetradactylum*, amongst other species, accounted for 8%- 6.14% of the variance (Figure 10). The presence of *P. clavata* for the first time at this site also accounted for 7.47% of the total variation.

Continuing with site K1, results of the DistLM (stepwise AIC) sequential test indicated that alkalinity and calcium were significant variables in explaining ~24% of the variation of fish assemblages between years, with pH and N-NOx contributing an additional ~12% of the variation (Figure 11). Salinity (=conductivity) was much higher at site K1 in 2022 than in previous years (Figure 3), indicating that intrusion of salty water from the marine/estuarine interface had penetrated inland to this site at the time of sampling. It was expected, therefore, that variation in fish assemblage data would be largely driven by water quality parameters associated with higher salinity (e.g., alkalinity, calcium, pH). There was no evidence that the observed variation in fish assemblages at site K1 was due to anthropogenic impacts on water quality arising from the Goomig development in 2022.

At site K2, the significant difference detected between the fish assemblage data for 2022 and baseline years was primarily driven by differences in the abundances of *N. graeffei*, *E. vaigiensis*, *L. calcarifer* and *N. erebi*, which together contributed ~57% of the overall variation (Figure 10). Abundances of *L. calcarifer* and *E. vaigiensis* were marginally higher in 2022 compared to baseline years, while a slight reduction in abundance was recorded for *N. graeffei* and *N. erebi*. Results of the DistLM (stepwise AIC) sequential test indicated that total nitrogen, calcium and chloride were significant variables in explaining ~30% of the variation of fish assemblages between years (Figure 11). Consistent with results in 2021, values for conductivity (= salinity) at site K2 were higher in 2022 than during the baseline years (Figure 3), which helps to explain why parameters such as calcium and chloride (and pH to a lesser extent) contributed to the detected differences in fish assemblages. However, an increase in salinity does not account for the contribution of total nitrogen concentration to the observed differences at K2. Values for total nitrogen at K2 recorded in 2022 were within the range that was recorded during baseline years (Figure 3). Therefore, despite this parameter being identified as potentially contributing to the observed variation in fish assemblages, it unlikely that variation or trends in total nitrogen are due to any inputs or impacts on water quality arising from the Goomig development. The same interpretation can be made for total nitrogen concentrations at the other potentially impacted Keep River sites (K3 and K4), which also recorded values within or very close to those recorded during baseline surveys (Figure 3).

Pair-wise testing of the fish assemblage data for 2022 in isolation from other years, revealed a significant difference between both K1 (p=0.0451) and K3 (p=0.0217) in comparison to reference sites, whilst no significant differences to reference sites were detected for K2 or K4 (p=0.06 and p=0.1436, respectively) (Table 5). The differentiation of reference sites from the Keep River sites was primarily driven by disparities in abundances of the freshwater specialist *Melanotaenia australis* and to a lesser extent *N. graeffei*, whilst the Keep River sites, particularly K1 and K3 were differentiated by higher abundances of marine-estuarine species such as *E. vaigiensis*, *C. leucas* and *L. calcarifer* (Figure 12a). These differences in species distributions between Keep River sites and reference sites are consistent with data recorded in previous sampling years (WRM 2021; IPE 2022). The ionic concentrations of chloride and magnesium combined to account for ~28% of the observed variability in the fish assemblage data between Keep River sites and reference sites in 2022. This result was expected as these ions are associated with higher salinities such as those found in the lower Keep River, whereas salinities are much lower at the freshwater reference sites. As expected, there was no significant difference detected between reference sites and K4, which is the potentially impacted site located furthest upstream, and is minimally influenced by saline intrusion from the Keep River estuary.

3.5 Aquatic Fauna Pest Monitoring

Cherax quadricarinatus (Redclaw) was not recorded from macroinvertebrate sweeps at any sites in 2022. As conductivity levels at K1 and K2 exceeded the mortality threshold for this species (i.e., 2900 mS/m; Jones 1995), it was expected that *C. quadricarinatus* would be absent from these sites, therefore no opera house traps were deployed. The absence of the species from pools further upstream in the Keep River and at reference sites suggests that it is yet to establish a robust population within the Keep River system.

3.6 Macroinvertebrates Assemblages

3.6.1 Species Richness and Abundance

A total of 154 macroinvertebrate taxa (Table 6) were recorded from edge habitats across all sites during 2022 sampling. Of these, multiple taxa could not be identified to species level due to the absence of suitable identification keys for various life phases (e.g., juvenile, larvae or early instar) and sex (some keys require male specimens). In order to perform accurate statistical comparisons, some taxa were assigned to a higher taxonomic level to remain consistent with data from previous years. The total number of taxa recorded in 2022 was comparable to previous years monitoring, which previously ranged from 106 to 140 (Appendix 5). Species richness was highest at reference sites (except KR2) and upstream sites in the Keep River, and much reduced at in the lower Keep River (Table 6). Consistent with previous years monitoring, increased salinity and proximity to the estuary appeared to drive the macroinvertebrate community assemblage at each site, with a reduction in species richness and fewer freshwater species occurring at sites occurring along a longitudinal gradient towards the estuary. As per baseline and previous years sampling, no taxa collected are listed under Commonwealth or State legislation, with the majority of macroinvertebrates recorded considered common species with distributions extending throughout Australia and/or Australasia. The percentage composition of macroinvertebrate classes was also comparable to previous years, with insects comprising 87.18% of total taxa recorded, followed by gastropods (4.49%), malacostracans (3.85%), and bivalves (1.28%), with remaining classes contributing less than 1% of the total (Table 7).

3.6.2 Statistical Analysis of Macroinvertebrate Assemblages

An nMDS ordination of macroinvertebrate assemblage data showed that sub-sites were typically grouped together in each sampling year (Figure 13). During 2022 sampling, assemblages at K3 and K4 grouped fairly closely with reference sites, and were separated from assemblages at K1 and K2, which also grouped closely together (Figure 13). In general, assemblages at the majority of sites (Ref, K2, K3 and K4) in 2022 appeared to be somewhat distinct from previous years monitoring, although some similarity was apparent between 2022 reference sites and reference sites surveyed in 2020 and 2013 (Figure 13). Macroinvertebrate assemblages at site K1 displayed the greatest variability both within and between years (Figure 13).

PERMANOVA pair-wise testing confirmed some of the aforementioned similarities and differences (Table 8, Table 9). For 2022 data only, significant differences were found between reference sites and K1 ($p=0.047$), K2 ($p=0.022$) and K3 ($p=0.034$), but no significant difference was found between reference sites and K4 ($p=0.054$) (Table 8). When data for 2022 were compared to the combined baseline data set (2011-2013), significant differences in macroinvertebrate assemblages were found at sites K1 ($p=0.001$), K2 ($p=0.002$) and K4 ($p=0.013$) (Table 8). Although appearing distinct in the MDS ordination (Figure 13), no significant differences were detected for K3 ($p=0.404$) or references sites ($p=0.168$) compared to baseline data (Table 8). PERMANOVA pair-wise testing results between individual baseline years within sites (e.g., K2 2012 baseline vs K2 2013 baseline) indicated significant differences in macroinvertebrate assemblages at all sites except K4, with significant differences also apparent between baseline and post-development survey years and between individual post-development survey years (Table 9). These results suggest that at K2, K3, K4 and reference sites, there is significant inter-annual variation of macroinvertebrate assemblages. There were no significant differences in macroinvertebrate assemblages at site K1 between any of the survey's years prior to 2022, with the assemblage recorded in 2022 proving to be significantly different. Results attained prior to 2022 suggest that macroinvertebrate assemblages are more uniform from year to year in the lower Keep River Pools.

SIMPER analysis on species level data indicated that the differences in macroinvertebrate assemblages between baseline and 2022 data were driven by multiple small changes of numerous taxa, with the majority of taxa contributing less than 3% of the variation at most sites. Greater abundances of estuarine taxa (e.g., Corophiidae, Polychaeta, and Bithyniidae) and significantly fewer freshwater taxa at downstream sites were the primary drivers of variance. An analysis of nMDS at site K1 indicated that the increased presence of *Corophiidae spp*. recorded in 2022 was the main contributor to the significant difference observed between years.

With respect to water quality, DistLM (stepwise AIC) sequential test results from site K1 indicated that magnesium, total phosphorus, alkalinity and pH explained 56% of assemblage variation between 2022 and baseline surveys (Figure 16). Phosphorus concentration appeared to be the most influential variable when comparing 2022 results to baseline. As discussed in Section 3.1.3, the elevated phosphorus concentrations were attributed to high prevailing water temperatures, which may accelerate the release of phosphate (Li *et al.* 2013). As such, the influence of the increased phosphorus concentrations on macroinvertebrate communities in 2022 is not likely to be attributable to the Goomig Development.

DistLM (stepwise AIC) sequential test results for K2 indicated that magnesium and chloride accounted for 51% of the total variation of assemblages between years (Figure 16). Elevated magnesium and chloride at this site are likely the result of tidal influence, rather than any impacts associated with the Goomig Development. Similar results were also acquired for site K3, with water quality variables associated with saline water (i.e., magnesium, calcium, alkalinity) accounting for 53% of variation between years (Figure 16).

DistLM (stepwise AIC) sequential testing at site K4 indicated that NOx, NH3 and dissolved oxygen percentage were variables that explained 45% of the total variation between years (Figure 16). Increased NOx and NH3 concentrations are often associated with anthropogenic impacts, including agricultural practices. However, as similarly high concentrations of these variables were also recorded at reference sites (Appendix 1), this suggests that high concentrations of these parameters are naturally occurring.

When the 2022 data for macroinvertebrate assemblages were investigated in isolation, DistLM (stepwise AIC) sequential test results again indicated that parameters related to salinity (i.e., magnesium, conductivity, alkalinity and chloride) were the primary drivers of variation, accounting for 60% of the total variation (Figure 17a). These results compliment those indicated by PERMANOVA pair-wise tests and support the notion that salinity is the main driver of differences in macroinvertebrate assemblages in the study area. As such, the spatial variation observed in the macroinvertebrate assemblage data is considered natural and not attributable to any influence from the Goomig Development.

SIGNAL 2 Score analysis indicated that in 2022, the majority of sub-sites at K2, K3, K4 and Reference sites fell within quadrant one (Figure 18), indicating favourable habitat conditions with pollutants only present in negligible concentrations. This also suggests that the increased NOx and NH3 concentrations at site K4 are having negligible impacts on macroinvertebrate fauna.

A single sub-site at K2 and two sub-sites in K1 fell within quadrant four (Figure 18), which often indicates anthropogenic impacts such as industrial or agricultural pollution. However, water quality data recorded at K2 and K1 did not show evidence of pollution, but rather reflected the intrusion of saline water from the estuary. Estuarine macroinvertebrate assemblages typically comprise low species richness and are dominated by saline tolerant taxa, which was evident at all K2 and K1 sub-sites in 2022 (Table 4). It is understood that sites typically appear in quadrant three as a result of a lower species richness but maintain a high SIGNAL 2 score due to toxicity tolerances in resident taxa. Although SIGNAL Score analysis suggests that sites with high salinity should fall in quadrant two, this analysis is usually conducted in freshwater habitats. It is apparent that the SIGNAL 2 analysis on the aforementioned sub-sites may be misinterpreting the naturally occurring high salinities of these estuarine sites as suffering from anthropogenic impacts.

One reference sub-site fell within quadrant three (KR2) in 2022 (Figure 18), which usually indicates the presence of harsh physical conditions or toxic pollution. In situ testing and laboratory analyses suggests that water quality at this stie was comparable to other reference sites, with no signs of toxicant pollution. The placement of KR2 in quadrant three was likely due to spatial restrictions on sweep netting at this site owing to the presence of a large Saltwater Crocodile, which is likely to have resulted in the under-representation of resident macroinvertebrate fauna.

Similar to temporal comparisons, SIGNAL 2 score analysis undertaken on 2022 data in isolation indicated that freshwater sites (i.e., Reference, K4 and K3) generally fell within quadrant 1, whilst estuarine sites fell within quadrants three and four (Figure 19).

4 CONCLUSION AND RECOMMENDATIONS

This report presents the findings of the third (and final) post-development survey in line with sampling frequency defined in Table 7 of the Ord River Irrigation Area – Weaber Plain Development Project Aquatic Fauna Management Plan (AFMP). The analyses presented in this report compared data collected in 2022 to baseline survey data (2011-2013). Unlike previous years which were impacted by pandemic-related travel restrictions, all regular monitoring sites were able to be sampled in 2022.

No evidence was found in the current study to suggest that the Goomig Development has had any adverse impacts on either water or sediment quality within the lower Keep River in the previous 12 months. In all instances, the herbicide atrazine was below the LOR. While there were several exceedances of site-specific guideline values in 2022, there appeared to be no adverse effects on the biota present, and most were the result of natural processes, particularly tidal influence, a lack of rainfall and runoff, and increased evapoconcentration due to above average air temperatures around the time of the field survey. Nutrient concentrations in water and sediment were similar to those recorded in previous years. Metal concentrations in sediments were also consistent with results of previous years at all sites except K4. This site recorded concentrations of most metal analytes that were at least double those recorded in 2021. However, it is unlikely that these results are attributable to any inputs or releases from the Goomig Development via Border Creek, as K4 is situated upstream of its confluence with the Keep River. The observed increases may be due to ongoing leaching of metal contaminants from roadworks and bridge construction on the nearby Legune Road, which took place in September 2020.

Consistent with all previous surveys of the Keep River, no *Glyphis* (River Shark) species were captured in 2022. A solitary *Pristis pristis* (Largetooth Sawfish) individual was captured and six *Pristis clavata* (Dwarf Sawfish) were captured, with the latter species being captured at site K1 for the first time. All previous records of this species had been from estuarine sites. This result was attributed to much higher salinity levels in the lower Keep River than in previous years. Total numbers of *Pristis* captured in 2022 were comparable to previous surveys and were within the range of numbers expected based on the magnitude of rainfall and runoff experienced during the preceding wet season, indicating that sawfish populations remain functional in the lower Keep River.

The total number of fish species recorded during the 2022 survey was considerably less than in the previous two surveys. It is believed this is due to the combination of unfavourable tides and the high abundance of saltwater crocodiles, which restricted fish sampling effort in comparison to previous years. Despite these challenges, the patterns of distribution, abundance and species richness of fishes were largely consistent with results of previous surveys, with richness found to decline as salinity decreases with increasing distance from the estuary. For macroinvertebrates, current results indicate that the Keep River pools continue to support a high species diversity. Consistent with previous survey results, variation in macroinvertebrate assemblages was primarily driven by the longitudinal salinity gradient, with species richness increasing with distance upstream from the estuary.

Consistent with the previous reporting period, no evidence was found in the current study to suggest there have been any anthropogenic impacts associated with the Goomig Development that have impacted the water and sediment quality, or the aquatic fauna assemblages of the lower Keep River. The current study brings to a close the aquatic monitoring requirements set out in the AFMP, and while the nature of any future monitoring is currently unclear, outlined below are several recommendations that may assist in defining practical assessment criteria and identifying potential future impacts on the receiving Keep River environment.

- Inclusion of water and sediment quality sampling at the point of discharge into Border Creek and along Border Creek. No analytical results of irrigation water or sediment samples collected at the discharge point were made available at the time of the study. Collection of water and sediment samples at the discharge point would allow specific analytes of concern originating from the Weaber Plains Development to be identified and a target analytical suite for investigation in the Keep River to be defined. Furthermore, benefit exists in collecting and analysing water and fluvial sediment samples along Border Creek. This data would provide an indication of whether analytes of concern originating from the Weaber Plains Development dissipate or accumulate prior to entering the Keep River;
- Sediment and water analytical methodologies should be standardised to ensure results are comparable between successive sampling events. This is essential for meaningful interpretation of monitoring results and identification of potential impacts. As discussed, the comparison of concentrations from 2021 and 2022 with previous data sets was not considered appropriate for the purpose of assessing impact;
- Future monitoring should consider the inclusion of water and sediment sampling when connectivity exists between the irrigation channel, Border Creek and the Keep River. Historically, sampling has been undertaken several months after the cessation of flow in the late dry season when there is no discharge from the Weaber Plains Development and Border Creek is dry. As a result, the discharge event and input of potentially impacting analytes may be missed. In addition, tidal flushing of pools below the confluence of Border Creek and the Keep River may results in impacting analytes being removed from the system prior to sampling;
- Consideration should be given to the collection and analysis of aquatic fauna and flora tissue samples to investigate potential food web effects of introduced analytes. As discussed above, the timing of the current sampling regime may have meant the introduction of analytes into the Keep River was missed and that its affects on sediment and water quality were not captured. However, uptake by fauna and flora may have occurred. Noting also the proposed expansion of agriculture in the region and that the Keep River may receive additional discharge from that proposal, a food web study would be beneficial to provide baseline understanding and how future inputs may affect it. This data may also assist in understanding whether consumption of higher order species (e.g. *Lates calcarifer*) represent any health risk to people consuming fish;

- Assessment criteria, including the environmental consequence ratings outlined in Table 8 of the AFMP, relating to macroinvertebrate and fish species richness of composition require review as they were not considered practical for monitoring health or identifying impact. Data collected during the baseline (pre-construction) surveys indicated that macroinvertebrate and fish species diversity was highly variable at respective survey sites between years and also between survey sites in the same year. As a result, the percentages used to define the consequence ratings outlined in Table 8 were consistently exceeded during the baseline survey period alone. The subsequent application of those consequence ratings for the purpose of assessing post-development impact was therefore considered inappropriate;
- Macroinvertebrate taxa composition was particularly variable in the Keep River due to the fact sites downstream of its confluence with Border Creek were largely considered to be estuarine at the time of the survey, having elevated salinities (i.e. close to that of sea water) and at times being tidally influenced. In contrast, reference sites located upstream and off-river reference sites were largely isolated inland water holes containing freshwater derived from rainfall. Future monitoring should consider the inclusion of appropriate reference sites, including those within an estuarine habitat; and
- The fact that capture rates of *Pristis clavata* were comparatively high when compared to other studies undertaken in the region suggested that the Keep River may represent a regionally important habitat for the species. This may warrant further investigation to identify how the species utilises estuarine waters and downstream pools (e.g. KR1) of the Keep River. This will assist in identifying potential impacts in response to water being released into the Keep River from the Goomig Development and future sources. While the current study utilised PIT tags which will allow tagged individuals to be identified if recaptured, the use of acoustic tags and installation of receivers in the river would allow the passive collection of data in a labour efficient manner.
- The methodology used in the sediment analysis do not include or refer to bioavailability across any year reporting. Particle size distribution analysis would be beneficial in determining the percentage of bioavailable particulates in sediments (e.g., sediments < 63 µm)

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TABLES

Table 1. List and location of the monitoring programs sampling sites and sub-sites. Type refers to whether the site is a potentially exposed (PE) or reference (R) site. Y = sampled in 2022, NA = not accessible in 2022 and blank = not a component of the sampling program undertaken at the site or sub-site.

Site Information				Sediment	water quality				Macroinvertebrates		Elasmobranchs	Small fish
Code	Easting	Northing	Type		In situ water quality	Do + T profiles 0.5 m intervals	water samples	Atrazine	Edge habitats	Riffle habitats	6” & 7” x 30 m up to 8 hrs	x2 30 m multi-pane for 2.5 hours
EST01	512679	8305571	PE	Y	Y	Y	Y	NA			NA	NA
EST02	512545	8313129	PE	Y	Y	NA	Y	Y		NA	Y	NA
EST03	513091	8316246	PE	Y	Y	NA	Y	NA			Y	NA
K1-1	509484	8305651	PE	Y	Y	Y	Y		Y		×	Y
K1-2	510312	8304733	PE	Y	Y	Y	Y		Y		×	Y
K1-3	508853	8303530	PE	Y	Y	Y	Y	Y	Y	NA	Y	Y
K1-4	509064	8302722	PE	Y	Y	Y	Y		Y		Y	Y
K1-5	508988	8301745	PE	Y	Y	Y	Y		Y		Y	Y
K2-1	509147	8300892	PE	Y	Y	Y	Y		Y			Y
K2-2	509256	8300705	PE	Y	Y	Y	Y		Y			Y
K2-3	509276	8300457	PE	Y	Y	Y	Y	Y	Y	NA	NA	Y
K2-4	509141	8300123	PE	Y	Y	Y	Y		Y			Y
K2-5	509004	8300012	PE	Y	Y	Y	Y		Y			Y
K3-1	508553	8299522	PE	Y	Y	Y	Y		×		×	Y
K3-2	508512	8298897	PE	Y	Y	Y	Y		×		Y	Y
K3-3	508377	8298346	PE	Y	Y	Y	Y	Y	×	NA	Y	Y
K3-4	508350	8297859	PE	Y	Y	Y	Y		×		×	Y
K3-5	508132	8297681	PE	Y	Y	Y	Y		×		×	Y
K4-1	506892	8296907	PE	Y	Y	Y	Y		Y			Y
K4-2	506816	8296830	PE	Y	Y	Y	Y	Y	Y	NA	Y	Y
K4-3	506977	8296457	PE	Y	Y	Y	Y		Y			Y
KE1	500794	8272943	Ref		Y	Y	Y		Y			Y
KR1	504078	8265707	Ref		Y	NA	Y		Y			NA
KR2	507481	8260867	Ref		Y	NA	Y	NA	Y	NA	NA	NA
SR4	534621	8283769	Ref		Y	Y	Y		Y			Y
DR1	433967	8216059	Ref		Y	Y	Y		Y			Y

Table 2. Median water quality values (mg/L unless indicated), obtained from reference sites, potentially impacted lower Keep River sites and estuary sites in 2022. Highlighted median values indicate an exceedance of the applicable SS-WQGV and/or ILTV. ANZG (2018) default trigger values for tropical Australian lowland rivers (LR) and estuaries (E) are also displayed.

	Analyte	LOR	ANZG (2018)		Keep River (potentially impacted sites)												Estuary	
					K4			K3			K2			K1			EST01	
			LR	E	SS-WQGV	ILTV	Median	SS-WQGV	ILTV	Median	SS-WQGV	ILTVs	Median	SS-WQGV	ILTVs	Median	SS-WQGV	Median
Miscellaneous	TDS-calc	1			2416		302	2440		3740	12200		17200	27000		35000	31600	36800
	TSS	5			1.5	62	<5	1.5	29	<5	1.5	21	<5	1.5	27	12	66.8	41
	Temp (°C)				28	31	27.6	29.4	31	30.4	32.5	32	30.1	30.4	33	32.3	31.4	33.6
	Turbid (NTU)		15	20	13.2	120		15	17		10	15		9.7	15		34.8	
	pH (units)		6-8	6-8.5	8	6.0–8.0	7.6	8.1	6.0–8.2	8.0	8.4	6.0–8.4	8.26	8.4	6.0–8.4	8.4	8.2	8.4
	DO (%)		90	80	52	23	52.9	79	22	78.2	91	35	87.5	85	28	96.2	88	84.4
	Econd (mS/m)	0.1	250		121	85	46.5	427	434	575	2176	2158	2640	4566	4166	5390	5444	5660
Ionic composition	Alkalinity	1			145		111	151		111	160		139	174		177	187	184
	Acidity	1			11.8		4	12		4	16.4		3	1.6		<1	15.4	5
	Hardness	1			328		131	540		685	2400		3120	5300		6950	6400	7350
	CO3	1			<1		<1	<1		<1	<1		<1	9		<1	11	<1
	Cl	1			251		76	1122		1650	7152		8560	15440		19100	19960	20100
	F	0.1			0.21		<0.1	0.28		0.2	0.48		0.5	0.74		0.7	0.8	0.8
	SO4-S	1			105		20	146		207	1002		1060	2340		2560	2740	2790
	HCO3	1			175		111	179		111	185		139	200		177	228	184
	Ca	1			45		26	65		78	189		248	361		492	439	519
	Mg	1			36		16	91		119	456		606	1030		1390	1294	1470
	Na	1			366		39	625		814	3518		4330	8816		10200	11400	10900
	K	1			12		3	19		37	117		208	296		512	397	554
Nutrients	DOC	1			2.8		4	3.8		5	4.3		5	4.7		6	4.3	4
	N-NH3	0.005			0.007	0.32	0.008	<0.01	0.32	0.006	0.006	0.32	0.017	0.022	0.32	0.013	0.07	0.044
	N-NOx	0.002	0.01	0.03	<0.01	0.017	0.031	<0.01	0.017	<0.002	<0.01	0.017	0.003	<0.01	0.017	<0.002	<0.01	0.009
	N-org.	0.025/0.01*			0.27		0.16	0.31		0.30	0.35		0.246	0.47		0.427	0.57	0.513
	N-tot.sol.	0.025/0.01*			0.22		0.19	0.22		0.20	0.32		0.236	0.48		0.360	0.57	0.442
	N-total	0.05/0.01*	0.3	0.25	0.24	0.44	0.20	0.3	0.39	0.30	0.35	0.35	0.260	0.5	0.4	0.44	0.66	0.566
	P-tot.sol	0.005			<0.005		0.019	<0.005		0.011	<0.005		0.008	<0.005		0.014	<0.005	0.019
	P-total	0.005	0.01	0.02	0.01	0.04	0.022	<0.005	0.013	0.015	<0.01	0.01	0.012	<0.01	0.01	0.021	0.03	0.07
Herbicide	Atrazine (µg/L)	0.5					<0.5						<0.5			<0.5		<0.5
	Dibromo-DDE (%)*	0.5					73.5						69.1			63.9		62.0
	DEF (%)*	0.5					106.5						100.2			89.1		86.1

*Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018), Site-Specific Water Quality Guideline Values (SS-WQGV) as the 80th, or 20th for oxygen saturation, percentile value of baseline data and Bennett and George (2014) lower Keep River Interim Local Trigger Values (ILTV) for aquatic environmental stressors and toxicants.

	Analyte	LOR	ANZG (2018)		Estuary				Reference sites									
					EST02		EST03		DR1		KR1		KR2		KE1		SR4	
			LR	E	SS-WQGV	Median	SS-WQGV	Median	SS-WQGV	Median	SS-WQGV	Median	SS-WQGV	Median	SS-WQGV	Median	SS-WQGV	Median
Miscellaneous	TDS-calc	1			33200	41000	31600	41900	200	206	146	75	110	72		52		190
	TSS	5			704	50	582	20	0.9	<5	6.6	70	6.6	<5	1.5	<5	1.5	<5
	Temp (°C)				29.6	31.3	29.4	30.9	31.2	29.1	29.1	29.2	29.1	28.8	28.1	27.9	30.4	30.8
	Turbid (NTU)		15	20	624		444		5.3		6.2		6		19.1		1.8	
	pH (units)		6-8	6-8.5	8.2	8.4	8.1	8.3	8.2	8.8	7.6	7.6	8.2	7.2	7.5	7.1	7.9	6.9
	DO (%)		90	80	95	93.2	91	89.5	84	69.2	67	68.5	88	50.3	39	19.4	74	56.3
	Econd (mS/m)	1	250		5848	6300	5720	6450	42.5	31.7	27.6	11.6	35.4	11.1	41.4	8	30.9	29.2
Ionic composition	Alkalinity	1			171	166	147	183	207	173	106	55	135	49	135	41	150	157
	Acidity	1			13.8	10	14	3	4.8	<1	3.8	4	3.8	2	9.2	5	5	1
	Hardness	1			7100	8210	6920	8460	156	124	104	39	75	40	136	29	144	
	CO3	1			9	<1	9	<1	3	13	<1	<1	<1	<1	<1	<1	<1	<1
	Cl	1			21860	22500	20200	23200	16	8	15	4	18	6	44	3	5	5
	F	0.1			0.92	0.9	0.93	0.9	0.29	0.2	0.1	<0.1	0.07	<0.1	0.16	<0.1	0.13	
	SO4-S	1				3010		3170	21	<1		3	2.5	3		<1	5.2	5
	HCO3	1			206	166	180		218	161	132	55	114	49	169	41	178	157
	Ca	1			465	551	453	568	28	20	21	9	26	8	24	5	27	25
	Mg	1			1448	1660	1404	1710	26	18	14	4	18	5	17	4	21	17
	Na	1				12500		12900	17	19		6	30	5		4	4	5
	K	1				683		700	12	3	8	4	8	3	8	2	3	4
Nutrients	DOC	1			2.3	3	1.6	2	3.1	5	4.5	5	4.2	4	11.5	7	2.3	3
	N-NH3	0.005			0.014	<0.005	<0.01	0.006	<0.01	<0.005	<0.01	0.018	<0.01	0.041	0.032	<0.005	<0.01	<0.005
	N-NOx	0.002	0.01	0.03	<0.01	0.002	0.017	<0.002	<0.01	<0.002	<0.01	0.011	0.014	0.084	<0.01	<0.002	<0.01	<0.002
	N-org.	0.025/0.01*			0.24	0.56	0.2	0.332	0.31	0.44	0.39	0.74	0.38	0.32	0.95	0.62	0.15	0.13
	N-tot.sol.	0.025/0.01*			0.22	0.297	0.16	0.181	0.21	0.22	0.38	0.40	0.3	0.53	0.83	0.44	0.15	0.10
	N-total	0.05/0.01*	0.3	0.25	0.33	0.562	0.47	0.338	0.29	0.44	0.38	0.77	0.37	0.44	0.94	0.62	0.16	0.13
	P-tot.sol	0.005			<0.005	0.024	<0.005	0.018	<0.005	0.025	<0.005	0.018	<0.005	0.017	0.01	0.014	<0.005	0.016
	P-total	0.005	0.01	0.02	<0.005	0.09	0.032	0.049	0.016	0.038	<0.005	0.067	<0.005	0.039	0.022	0.032	<0.005	0.02
Herbicide	Atrazine (µg/L)	0.5				<0.5												
	Dibromo-DDE (%)*	0.5				62.0												
	DEF (%)*	0.5				86.1												

*Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018), Site-Specific Water Quality Guideline Values (SS-WQGV) as the 80th, or 20th for oxygen saturation, percentile value of baseline data and Bennett and George (2014) lower Keep River Interim Local Trigger Values (ILTV) for aquatic environmental stressors and toxicants.

Table 3. Median sediment quality values (mg/kg unless indicated), obtained from potentially impacted lower Keep River sites and estuary sites between 2020 and 2022. Median values highlighted purple = SS-SQGV exceedance. ANZG (2018) sediment default guideline values (DVG) and default guideline values-High (GV-H) are also displayed. N.B. values in red typeface indicate that the limit of reporting (LOR) was greater than the SS-SQGV.

					Estuary												Keep River															
	Analyte	LOR	ANZG (2018)		EST01				EST02				EST03				K1				K2				K3				K4			
			DGV	GV-H	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022
Major Ions	Si	1			154	180	10	8	160			6	178			6	190	130	8	10	160	160	7	7	182			11	190	190	13	22
	Cl	10			8800	3230	10200	9960	11000			13000	10900			10200	10400	2600	8640	13200	5840	85	4910	5870	694			1410	850	15	20	30
	SO4	10			1580	2000	1610	1590	2020			2080	2580			1590	1820	2000	950	1950	812	30	780	690	308			50	384	200	15	10
	Na	50			6560	10000	7520	8200	7020			8750	7420			7830	8080	8100	7560	12700	5160	590	3980	5600	920			1640	936	230	90	140
	K	50			2900	4100	2290	2280	1680			1940	2220			1860	2640	3200	2900	3370	2200	1700	1560	2200	1400			2560	1300	1200	500	1580
	Ca	50			48600	31000	47000	47800	59800			63000	68200			90800	11200	7000	4200	2230	4720	2900	2350	3120	4020			3860	4140	2600	1370	3510
	Mg	50			7980	9600	7820	7840	7120			8030	7700			8760	6520	7900	5810	6630	6720	3700	4000	5590	5940			6350	5900	3100	1280	4360
Nutrients	NO3-N	0.1			1	<1	<0.1	<0.1	1			<0.1	<1			<0.1	1	1	<0.1	<0.1	1	1	<0.1	<0.1	1			<0.1	<1	<1	<0.1	<0.1
	N-Total	20			344	300	240	160	168			180	176			130	460	590	410	420	522	360	430	440	596			480	732	440	150	620
	P-Total	2			210	200	201	200	240			220	264			256	150	130	143	122	160	90	95	123	140			148	150	76	40	142
	NH4-N	0.2			2	2	23.2	7.2	1			0.9	2			1.5	4.2	5	14.4	13.4	7.2	4	18.4	20	9			37.8	35	6	10.2	51.7
	TOC%	0.02			0.71	0.38	0.13	0.16	0.52			0.19	0.5			0.12	0.7	0.65	0.26	0.43	0.7	0.46	0.5	0.51	0.8			0.45	1	0.59	0.24	0.71
Total Metals	Al	50			10520	21900	7780	6800	6098			5090	7370			4770	17000	26200	12200	14800	17300	24500	6850	14700	16340			19100	16620	16400	4440	16300
	Sb	0.5	2	25	0.06	0.07	<0.5	<0.5	<0.05			<0.5	0.07			<0.5	0.09	0.09	<0.5	<0.5	0.12	0.08	<0.5	<0.5	0.12			<0.5	0.13	0.08	<0.5	<0.5
	As	1	20	70	3.6	4.4	3.31	3.69	5.2			6.07	8.6			7.62	2.5	2.9	2.06	2.27	2.3	2.2	1.61	1.93	2			2.03	2.1	1.7	0.5	2.14
	Ba	10			17	23	10	10	12			10	12			10	114	80	100	120	172	150	80	130	160			160	170	140	90	190
	Be	1			0.34	0.44	<1	<1	0.19			<1	0.23			<1	0.75	0.57	<1	1	0.76	0.51	<1	<1	0.67			<1	0.73	0.53	<1	<1
	Bi	0.1			<0.05	0.14	<0.1	0.1	<0.05			<0.1	<0.05			<0.1	0.14	0.16	0.2	0.2	0.16	0.12	0.1	0.2	0.15			0.3	0.16	0.13	<0.1	0.3
	B	50			23	36	<50	<50	22			<50	24			<50	13.2	21	<50	<50	6.2	6	<50	<50	2.5			<50	2.5	5	<50	<50
	Cd	0.1	1.5	10	<0.05	<0.05	<0.1	<0.1	<0.05			<0.1	<0.05			<0.1	<0.05	0.05	<0.1	<0.1	<0.05	0.05	<0.1	<0.1	<0.05			<0.1	<0.05	<0.05	<0.1	<0.1

Analyte	LOR	ANZG (2018)		Estuary												Keep River															
				EST01				EST02				EST03				K1				K2				K3				K4			
		DGV	GV-H	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022	SQGV	2020	2021	2022
Cr	**1**	80	370	18	27	16	15	13			12.8	15			12.2	27	32	23	28.2	29	26	17	27	29			33.3	29	21	10	26.4
Co	**1**			10	11	8	7.6	10			8.3	12			8.5	21	18	19	16.7	23	20	18	20.8	22			19.8	23	20	12	24.8
Cu	**1**	65	270	9	11	7	6.8	5.6			4.9	5.6			4.5	15	18	13	18	19	16	13	20.3	18			22.8	18	15	6	19.8
Ga	**0.1**			4.3	6.9	2.6	2.5	2.8			2.1	3.3			2	7.7	7.4	4	5.3	8.3	8.9	2.6	5.4	7.8			7.3	8.2	6	1.6	6.3
Fe	**50**			18000	23000	14400	13200	15000			14000	17000			14100	29400	31000	24400	27800	33200	25000	17400	28700	32000			36900	32000	27000	11100	32300
La	**0**			12	14	10	11.1	12			12.6	12			15	18	17	14	17.2	20	19	15	18.8	19			23.7	20	15	8	22.2
Pb	**1**	50	220	6	7.6	4.7	4.8	4			4.8	5			5	10	11	9.2	10.7	11	12	9.4	11	10			12.8	11	9.8	5.2	13.3
Li	**0.1**			8	18	6.7	6.4	6			5.6	7			5.3	7	16	4.9	6.3	7	9.8	2.7	5.6	6			5.8	6	6.1	1.3	4.8
Mn	**10**			290	310	249	260	388			438	546			523	630	590	504	332	1100	620	619	495	740			505	748	630	522	696
Mo	**2**			0.23	0.19	<2	<2	0.21			<2	0.3			<2	0.32	0.28	<2	<2	0.28	0.13	<2	<2	0.22			<2	0.22	0.14	<2	<2
Hg	**0.01**	0.15	1	0.21	<0.02	<0.01	<0.01	0.662			<0.01	0.896			<0.01	0.45	<0.02	<0.01	<0.01	0.49	<0.02	<0.01	<0.01	0.31			<0.01	0.286	<0.02	<0.01	<0.01
Ni	**1**	21	52	10	14	8.8	9	7			8.4	8			8.4	17	18	13.9	16.6	19	22	14.4	17.9	18			19.2	18	14	6.8	16.5
Se	**0.1**			0.06	0.09	0.05	0.1	<0.05			0.1	0.05			0.2	0.11	0.12	0.2	0.2	0.11	0.12	0.1	0.2	0.1			0.2	0.11	0.11	0.05	0.3
Ag	**0.1**	1	4	<0.05	<0.05	<0.1	<0.1	<0.05			<0.1	<0.05			<0.1	<0.05	<0.05	<0.1	<0.1	<0.05	<0.05	<0.1	<0.1	<0.05			<0.1	<0.05	<0.05	<0.1	<0.1
Sn	**0.1**			<0.5	1	0.5	0.5	<0.5			0.4	0.6			0.4	0.6	1.1	0.8	1	0.7	1	0.5	1	0.7			1.4	0.8	0.8	0.4	1.1
Ti	**10**			220	460	360	320	224			270	258			260	112	280	210	190	100	280	150	200	99.2			250	73.4	130	80	190
U	**0.1**			0.5	0.72	0.5	0.4	0.4			0.5	0.4			0.5	0.8	0.94	0.7	0.8	1	0.99	0.7	1	0.9			1	1	0.75	0.3	1
V	**2**			29	43	27	25.6	24			27.6	30			26.4	56	65	54	67.3	66	87	68	74.8	66			79	66	62	36	78.4
Zn	**1**	200	410	18	24	15.6	15.3	15			13.3	15			12.7	25	26	20.7	24.9	31	20	13.4	25.5	29.2			28.9	29	19	7.4	22.8
Herbicide																															
Atrazine	**0.05**				<0.01	<0.05					<0.05						<0.01	<0.05	<0.05		<0.01	<0.05	<0.05				<0.05		<0.01	<0.05	<0.05
Dibromo-DDE	**0.05**					114					89.4							94.3	85.2			108	77.7				90.7			113	77.55
DEF	**0.05**					74.6					94.7							95.2	91.6			111	86.65				93.2			111	78.35

*Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018), Site-Specific Sediment Quality Guideline Values (SS-SQGV) as the 80th percentile value of baseline data.

Table 4. Fish species and numbers recorded from each sub-site sampled in 2022.

Species	Common Name	Life-cycle Category	Keep River K1-1	K1-2	K1-3	K1-4	K1-5	K1	K2-1	K2-2	K2-3	K2-4	K2-5	K2	K3-1	K3-2	K3-3	K3-4	K3-5	K3	K4-1	K4-2	K4-3	K4	Estuary EST02	EST03	Reference KE1	DR1	SR4	Total
Carcharhinus leucas	Bull Shark	EE	1		2	1	2	**6**								2				**2**										8
Eleutheronema tetradactylum	Blue Threadfin	MM	1	5				**6**	4					**4**																10
Ellochelon vaigiensis	Diamondscale Mullet	MM	4	2		7	6	**19**	4	12	3	6	2	**27**	6		4	1	3	**14**	3	12	8	**23**	**4**					87
Glossogobius spp.	Goby	EV/P																										*		1
Hephaestus jenkinsi	Western Sooty Grunter	P																										**1**	**1**	2
Lates calcarifer	Barramundi	Sc			1	2	1	**4**	4	4		2		**10**	4		3			**7**	2	1	1	**4**	**2**	**4**			**1**	32
Lutjanus argentimaculatus	Mangrove Jack	MM																											**2**	2
Marilyna meraukensis	Merauke Toadfish	MV/EV									*		2	**3**			*			**1**										4
Megalops cyprinoides	Oxeye Herring	MM																			1	1		**2**			9		**1**	12
Melanotaenia australis	Western Rainbowfish	P																									*	*	*	3
Moolgarda buchanani	Bluetail Mullet	MM					1	**1**																						1
Nematalosa erebi	Bony Bream	P	1	8	10	1	2	**22**	4	18	7	36	2	**67**	53	28	9	15	12	**117**	9	8	4	**21**			2	**6**	**1**	236
Neoarius graeffei	Blue Catfish	MV/EV/P	2	1	1	2		**6**			1	4		**5**		8		11	2	**21**	6	1	2	**9**	**1**		3	**1**	**1**	47
Neoarius midgleyorum	Shovel-nosed Catfish	P																										**21**		21
Neosilurus ater	Narrow-fronted Tandan	P																											**1**	1
Planiliza ordensis	Diamond Mullet	MM	1			1	1	**3**				2		**2**	20	2	1		2	**25**							5	**5**		40
Pomadasys kaakan	Barred Javelinfish	MM														2				**2**										2
Pristis clavata	Dwarf Sawfish	EE	1	1		1	3	**6**																						6
Pristis pristis	Largetooth Sawfish	EE													1					**1**										1
Strongylura krefftii	Freshwater Longtom	P							2					**2**			1		1	**2**								*		5
Thryssa sp.	Anchovy	MM	2	1		1		**4**																						4
Toxotes chatareus	Seven-spot Archerfish	P		1	1			**2**		2	*		1	**4**			1	1		**2**								**3**	*	12
	Species Richness		8	7	5	8	7	**11**	5	4	5	5	4	**9**	5	5	7	4	5	**11**	5	5	4	**5**	**3**	**1**	**5**	**9**	**9**	22
	Total Number		13	19	15	16	16	**79**	18	36	13	50	7	**124**	85	42	20	28	20	**195**	21	23	15	**59**	**7**	4	**20**	**40**	**10**	**538**

Life-cycle categories: EE = euryhaline elasmobranch, MM = marine migrants, MV = marine vagrants, EV = estuarine vagrants, Sc = semi-catadromous, and P = potamodromous fishes (but includes those freshwater obligate species for which migratory information is unavailable). Yellow cells indicate adjusted data, * indicates sighting only

Table 5. Results of the PERMANOVA (permutational multivariate analysis of variance, Type 1 sequential) pair-wise testing undertaken on fish abundance data (Bray-Curtis similarity) recorded during baseline surveys (2011-2013) and post-development (2021 and 2022) at potentially impacted sites and reference sites. N.B. Significant values ($p < 0.05$) are highlighted green and in instances when the number of permutations was below 100 (highlighted yellow) the Monte Carlo p-value should be referred to.

Pair	t	P(perm)	Unique perms	P(MC)
K1 Baseline, K1 2022	1.8017	0.0014	7368	0.0066
K2 Baseline, K2 2022	1.4496	0.0239	7346	0.0603
K3 Baseline, K3 2022	1.0287	0.4032	7393	0.3831
K4 Baseline, K4 2022	1.3046	0.1494	220	0.1693
Reference Baseline, Reference 2022	1.2376	0.1524	220	0.1943
K1 2022, Reference 2022	1.714	0.018	56	0.0451
K2 2022, Reference 2022	1.6004	0.0189	56	0.06
K3 2022, Reference 2022	1.9106	0.019	56	0.0217
K4 2022, Reference 2022	1.4713	0.1005	10	0.1436
K1 Baseline, K1 2021	1.9476	0.001	965	0.005
K2 Baseline, K2 2021	1.7873	0.002	977	0.009
K4 Baseline, K4 2021	1.2521	0.176	218	0.195
Reference Baseline, Reference 2021	1.5644	0.255	4	0.199
K1 2021, Reference 2021	1.961	0.178	6	0.046
K2 2021, Reference 2021	1.8689	0.174	6	0.05
K4 2021, Reference 2021	1.3376	0.49	4	0.253

Table 6. Edge macroinvertebrate species abundance data from each sub-site sampled in 2022. N.B. Data are log[10] abundance classes; 1 = 1 individual, 2 = 2-10 individuals, 3 =11-100 individuals, 4 = 101-1000 individuals, 5 = >1000 individuals.

					Keep River																			Reference				
					K1					K2					K3					K4								
PHYLUM	**Class**	**Order**	**Family**	**Lowest Taxon**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**KE1**	**KR1**	**KR2**	**SR4**	**DR1**
ANNELIDA	Oligochaeta			Oligochaeta spp.				2	2				2	2		2			2	2	2	2	3	2		2	2
	Polychaeta			Polychaeta spp.	3	3	3	3	3	4	4	4	4	3												2	2
ARTHROPODA	Arachnida			Acarina spp.																2			2	2		2	2
	Branchiopoda	Diplostraca	Cyzicidae	Eocyzicus spp. (juv)																			4				
	Insecta	Coleoptera	Carabidae	Carabidae spp.									1									1					
			Chrysomelidae	Chrysomelidae spp.													1	1									
			Dytiscidae	*Bidessus* spp.																	2	1		2			
				Clypeodytes feryi																	3	1					
				Clypeodytes larsoni																1	2	1				1	1
				Clypeodytes weiri																	2						
				Copelatus nigrolineatus																					1	2	2
				Hydroglyphus godeffroyi																		2					
				Hydroglyphus grammopterus																	2	2				1	1
				Hydroglyphus leai																1	3	3		3		1	1
				Hydroglyphus mastersii																	3						
				Hydrovatus ovalis														1		2		1	2	2			
				Hydrovatus parallelus																1	2	2					
				Hyphydrus elegans																2	1		3	2		1	1
				Hyphydrus lyratus																			2				
				Laccophilus cingulatus																				1			
				Laccophilus clarki							1	1								1	3	3			1		
				Laccophilus religatus																2							
				Laccophilus sharpi												1				2	2	2		2			
				Laccophilus spp. (L)																		1					
				Laccophilus transversalis																	2	2					
				Limbodessus compactus																				2			
				Megaporus ruficeps														1		2			1	2			
				Megaporus spp.													2						1	2			
				Tiporus demmaculatus																				1		1	1
				Tiporus josepheni																				1			
				Tiporus undecimmaculatus															1								
			Elmidae	Elmidae (L)																						3	3
			Georissidae	*Georissus* spp.											1											1	1
			Hetericeridae	*Heterocerus* spp.				1																			2
			Hydraenidae	*Hydraena* spp.					1	2	2	1		2				2	2	2	2	2	2	3		2	
				Limnebius spp.											2	2	3	1	1								
				Ochthebius spp.																		1					
			Hydrochidae	*Hydrochus* spp.								1			2	2	2	2	2	2	3	2	3	4		2	2
			Hydrophilidae	*Amphiops australicus*									1			1		1	2					3	1		
				Amphiops micropunctatus																				1			
				Anacaena spp.													2										
				Coelostoma fabricii											1												

					Keep River																		Reference				
					K1					K2					K3					K4							
PHYLUM	Class	Order	Family	Lowest Taxon	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	KE1	KR1	KR2	SR4	DR1
ARTHROPODA	Insecta	Coleoptera	Hydrophilidae	*Enochrus deserticola*																				2			
				Enochrus eyrensis																					1	1	1
				Helochares clypeatus															1		1						
				Helochares marreensis							1				1						2				1		
				Helochares tatei																					1		
				Hydrobiomorpha bovilli																				2			
				Hydrophilidae (L)																		1					
				Laccobius billi																						1	1
				Paracymus spenceri																2					2	1	1
				Regimbartia attenuata			1			3	2	2	3	2	2	2	2	2		1	2	2		3	1		
			Limnichidae	Limnichidae spp.													1										
			Noteridae	*Hydrocanthus waterhousei*												1	1			1	2		3				
				Neohydrocoptus subfasciatus									1			2			1	2	2	2					
				Notomicrus tenellus													1	1				1				1	1
			Scirtidae	Scirtidae spp.																		1		2	1	2	2
			Staphylinidae	Pselaphinae spp.																	1						
				Staphylinidae spp.													1										
				Austroconops spp.																2							
		Diptera	Ceratopogonidae	Ceratopogoninae spp.				2	2	2			2	3	1	2	2	2	2	4	3	3	3	2	4	3	3
				Dasyheleinae spp.																2	1		2				
			Chironomidae	Chironominae spp.								2	2	2	3	3	4	3	3			3	4	4	4		
				Orthocladiinae spp.																3	3	2	4			3	3
				Tanypodinae spp.											2	2	2	3	3	4	3	3	4	3	3	4	4
			Culicidae	*Anopheles* spp.		2										2	2				3					4	4
			Simuliidae	Simuliidae spp.											1												
			Tabanidae	Tabanidae spp.																1					1	1	1
		Ephemeroptera	Baetidae	Baetidae spp.													1			3							
				Cloeon fluviatile											2	2	3										
				Cloeon sp. NT2											1	2	2	2									2
				Cloeon sp. Red Stripe											1					2	2			1			
				Cloeon spp.				2							2	3	2	3			3	4	2		3	2	
			Caenidae	*Tasmancoensis* spp.											1	1	1									4	4
				Tasmanocoenis sp. E													1	2	2						1		
				Tasmanocoenis sp. M																						4	4
				Tasmanocoenis sp. P/arcuata																2			1	2			
		Hemiptera	Belostomatidae	*Diplonychus eques*																			2	2			
			Gelastocoridae	*Nerthra* spp.																		1					
			Gerridae	Gerridae spp.													1										
				Limnogonus fossarum gilguy						1	1								1			1					
				Limnogonus spp.																						1	1
				Rhagadotarsus anomalus																	1	3		1			
				Tenagogerris pallidus						1	1	2	2														
			Hydrometridae	*Hydrometra* spp.																			1				
			Meenoplidae	Meenoplidae spp.							3	4	3														
			Mesoveliidae	*Mesovelia horvathi*													1				1	2			1		
				Mesovelia spp.							1	2				1					2	1			2		
				Mesovelia vittigera												1							2	1			
			Micronectidae	*Micronecta adelaidae*																2	2					2	2
				Micronecta annae														2		2	3						

					Keep River																		Reference				
					K1					K2					K3					K4							
PHYLUM	Class	Order	Family	Lowest Taxon	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	KE1	KR1	KR2	SR4	DR1
ARTHROPODA	Insecta	Hemiptera	Micronectidae	*Micronecta robusta*											1	2	2										
				Micronecta spp.															2				2		2		
				Micronecta virgata																			1				
			Microvelidae	*Microvelia* spp.													1				1				1	1	1
			Nepidae	*Austronepa angusta*												1											
				Laccotrephes tristis																					1		
				Ranatra diminuta						2	1	1			2	2	2		1	1							
				Ranatra spp.																1							
			Notonectidae	*Anisops* spp.														1								3	3
				Enithares atra																			2				
				Enithares loria																		1	2				
				Notonectidae spp.																			1	2			
				Nychia sappho											1			2	1	3	3	3		3	4		
			Ochteridae	*Ochterus* spp. (Juv)																1							
			Pleidae	*Paraplea* spp.				2		2	1	2		2	3	3	3	4	4	4	4	4	4	4	4	1	1
			Veliidae	*Microvelia herberti*																	2	2					
				Veliidae spp.																				2			
		Lepidoptera		Lepidoptera spp.																			1				
		Odonata	Coenagrionidae	*Argiocnemis rubescens*						1										2							
				Austroagrion spp.												1											
				Coenagrionidae spp.												3	1		2								
				Ischnura aurora												2	1				1		2				
				Ischnura spp.																		1	2				
				Pseudagrion aureofrons											1		2										
				Pseudagrion lucifer						1	1	2															
				Pseudagrion microcephalum						3	2	3	2	2	1	2	1	2	2			1					
				Argiocnemis pygmaea																1		1					
			Gomphidae	*Antipodogomphus neophytus*																						1	1
			Libellulidae	*Crocothemis nigrifrons*																			2				
				Hydrobasileus brevistylus																			1				
				Libelulidae spp.													1		2								
				Neurothemis stigmatizans															2							2	2
				Potamarcha congener																						2	2
				Rhodothemis lieftincki																			2				
				Tramea spp.																			3				
				Zyxomma elgneri																				1			
			Lindeniidae	*Ictinogomphus australis*																			2	2		1	1
			Platycnemididae	*Nososticta* spp.																1							
				Anisoptera spp.																2			2	2		2	2
				Zygoptera spp.										2			1						2	2			
		Trichoptera	Leptoceridae	*Oecetis* spp.															1	2			2	2		2	2
				Triaenodes spp.											1												
				Triplectides australicus																2			2			2	2
				Triplectides australis													2					1					
				Triplectides ciskus seductus																				2			
				Triplectides parvus																		1					
				Triplectides spp.															1	2		1					
	Malacostraca	Amphipoda	Corophiidae	Corophiidae spp.		2	3	3	2	4	4	4	4	4				4	3								
			Melitidae	Melitidae spp.											3	3	3										

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					Keep River																		Reference				
					K1					K2					K3					K4							
PHYLUM	**Class**	**Order**	**Family**	**Lowest Taxon**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**KE1**	**KR1**	**KR2**	**SR4**	**DR1**
ARTHROPODA	Malacostraca	Decapoda	Atyidae	*Caridina* spp.	3								2						1			3	2	2			
			Hymenosomatidae	*Amarinus* spp.	2																						
			Palaemonidae	*Macrobrachium rosenbergii*	3						2		1								2	3	2				
				Macrobrachium spp.												3	1						3				
MOLLUSCA	Bivalvia	Cardiida	Cyrenidae	*Corbicula* spp.													1			4						4	4
		Unionoida	Hyriidae	*Lortiella* spp.				3		3	4	4	4	3		2			2	1				2	3		
	Gastropoda	Hygrophila	Planorbidae	*Ferrissia petterdi*																				1	1	1	1
				Gyraulus spp.		1		2	3	3	2	2	2	2	1	1				3		2	3	2		2	2
				Hygrophila spp.																			2	1			
		Hypsogastropoda	Bithyniidae	Bithyniidae spp.																				1			
				Gabbia spp.	3				2	2	3	2	2	2		1		2									
			Thiaridae	*Thiara* spp.																					2	2	2
			Viviparidae	*Notopala* spp.																			2	1		2	2
NEMATODA				Nematoda spp.																			2				
				Taxa Richness	**5**	**4**	**3**	**9**	**7**	**15**	**18**	**17**	**17**	**13**	**24**	**31**	**36**	**22**	**26**	**43**	**39**	**45**	**46**	**46**	**25**	**43**	**43**

Table 7. Percentage composition of macroinvertebrate classes and total taxonomic richness recorded within edge samples collected during baseline (2011-2013) and post-development (2020 , 2021 and 2022) surveys from sites sampled in 2022 (K1, K2, K3 K4, KE1, KR1, KR2, SR4 and DR1).

Phylum	Class	2011	2012	2013	2020	2021	2022
ANNELIDA	OLIGOCHAETA	0.63	0.57	0.57	0.61	0.83	0.64
	POLYCHAETA	0.63	0.57	0.57	0.61	0.83	0.64
ARTHROPODA	ACARINA	0.63	1.72	0.57	0.61	2.50	0.64
	BRANCHIOPODA	0.00	0.00	0.00	0.00	0.00	0.64
	ENTOGNATHA	1.27	0.57	0.57	0.61	0.00	0.00
	INSECTA	82.28	82.18	85.80	86.67	80.00	87.18
	MALACOSTRACA	6.96	6.90	4.55	4.24	7.50	3.85
CNIDARIA	HYDROZOA	0.63	0.57	0.57	0.61	0.83	0.00
MOLLUSCA	BIVALVIA	1.27	1.72	1.14	1.21	1.67	1.28
	GASTROPODA	4.43	4.60	3.98	4.24	4.17	4.49
NEMATODA		0.63	0.00	0.57	0.61	0.83	0.64
NEMERTEA		0.63	0.00	0.57	0.00	0.00	0.00
PLATYHELMINTHES	TURBELLARIA	0.00	0.57	0.57	0.00	0.83	0.00
	Grand Total	**158**	**174**	**176**	**165**	**120**	**156**

Table 8. Results of the PERMANOVA (permutational multivariate analysis of variance, Type 1 sequential) pair-wise testing undertaken on edge macroinvertebrate abundance data (Bray-Curtis similarity) recorded during baseline surveys (2011-2013) and post-development (2021 and 2022) at potentially impacted sites and reference sites. N.B. Significant values ($p < 0.05$) are highlighted green and in instances when the number of permutations < 100 (highlighted yellow) the Monte Carlo p-value should be referred to.

Pair	t	P(perm)	Unique perms	P(MC)
K1 Baseline, K1 2022	2.2846	0.001	971	0.001
K2 Baseline, K2 2022	2.6123	0.002	973	0.001
K3 Baseline, K3 2022	1.0287	0.404	968	0.374
K4 Baseline, K4 2022	2.2508	0.013	214	0.008
Reference Baseline, Reference 2022	1.2734	0.149	55	0.168
K1 2022, Reference 2022	1.879	0.052	21	0.047
K2 2022, Reference 2022	1.9983	0.06	21	0.022
K3 2022, Reference 2022	1.9305	0.048	21	0.034
K4 2022, Reference 2022	2.1105	0.102	10	0.054
K1 Baseline, K1 2021	2.3297	0.001	965	0.003
K2 Baseline, K2 2021	2.977	0.001	967	0.001
K4 Baseline, K4 2021	1.3614	0.022	220	0.074
Reference Baseline, Reference 2021	1.5005	0.043	28	0.091
K1 2021, Reference 2021	2.9022	0.049	21	0.007
K2 2021, Reference 2021	3.1128	0.051	21	0.003
K4 2021, Reference 2021	1.1315	0.301	10	0.395

Table 9. Results of the PERMANOVA (permutational multivariate analysis of variance, Type 1 sequential) pair-wise testing undertaken on edge macroinvertebrate abundance data (Bray-Curtis similarity) recorded in individual years during baseline surveys (2011-2013) and post-development (2020-2022). N.B. Significant values ($p < 0.05$) are highlighted green and in instances when the number of permutations was below 100 (highlighted yellow) the Monte Carlo p-value should be referred to.

Site	Pair	Year	t	P(perm)	Unique perms	P(MC)
K1	Baseline, Baseline	2011, 2012	1.8227	0.009	126	0.012
		2011, 2013	3.2584	0.007	126	0.001
		2012, 2013	2.532	0.009	126	0.002
	Baseline, Post-Development	2011, 2020	2.284	0.009	126	0.002
		2011, 2021	3.9432	0.007	126	0.000
		2011, 2022	3.1388	0.008	126	0.001
		2012, 2020	2.4418	0.007	126	0.002
		2012, 2021	3.4232	0.009	126	0.000
		2012, 2022	2.6214	0.009	126	0.001
		2013, 2020	3.1554	0.010	126	0.001
		2013, 2021	1.941	0.007	126	0.013
		2013, 2022	1.4822	0.022	126	0.079
	Post Development, Post-Development	2020, 2021	4.0044	0.010	126	0.000
		2020, 2022	2.8173	0.008	126	0.001
		2021, 2022	2.1867	0.008	126	0.007
	Baseline, Reference	2011, Ref 2011	2.5239	0.007	126	0.001
		2012, Ref 2012	3.1727	0.008	126	0.001
		2013, Ref 2013	3.7225	0.009	126	0.000
K2	Baseline, Baseline	2011, 2012	1.6856	0.007	126	0.020
		2011, 2013	3.6745	0.007	126	0.000
		2012, 2013	3.0302	0.008	126	0.001
	Baseline, Post-Development	2011, 2020	2.3458	0.007	126	0.003
		2011, 2021	4.4403	0.008	126	0.000
		2011, 2022	4.541	0.008	125	0.000
		2012, 2020	2.0627	0.008	126	0.007
		2012, 2021	3.9547	0.008	126	0.000
		2012, 2022	4.2005	0.008	126	0.000
		2013, 2020	3.4831	0.009	126	0.000
		2013, 2021	3.2072	0.009	126	0.001
		2013, 2022	4.2577	0.008	126	0.000
	Post Development, Post-Development	2020, 2021	4.0695	0.010	126	0.000
		2020, 2022	4.2341	0.008	126	0.000
		2021, 2022	3.7206	0.008	126	0.000
	Baseline, Reference	2011, Ref 2011	1.7218	0.007	126	0.019
		2012, Ref 2012	2.0279	0.007	126	0.004
		2013, Ref 2013	3.3277	0.010	126	0.000
K3	Baseline, Baseline	2011, 2012	1.7221	0.008	126	0.019
		2011, 2013	2.4564	0.009	126	0.002
		2012, 2013	2.0165	0.008	126	0.005
	Baseline, Post-Development	2011, 2020	2.4823	0.008	126	0.002
		2011, 2022	2.8639	0.009	126	0.001
		2012, 2020	2.216	0.006	126	0.003
		2012, 2022	2.8079	0.007	126	0.001
		2013, 2020	2.1446	0.008	126	0.005
		2014, 2022	2.5006	0.006	126	0.002

	Post Development, Post-Development	2020, 2022	2.9026	0.008	126	0.001
	Baseline, Reference	2011, 2011 Ref	1.7844	0.011	126	0.016
		2012, 2012 Ref	1.8336	0.008	126	0.010
		2013, 2013 Ref	1.8539	0.007	126	0.014
K4	Baseline, Baseline	2011, 2012	1.5847	0.098	10	0.086
		2011, 2013	1.6593	0.100	10	0.063
		2012, 2013	1.1498	0.100	10	0.289
	Baseline, Post-Development	2011, 2020	1.7397	0.101	10	0.059
		2011, 2021	1.5959	0.101	10	0.080
		2011, 2022	2.0552	0.099	10	0.027
		2012, 2020	1.4473	0.102	10	0.124
		2012, 2021	1.5197	0.097	10	0.104
		2012, 2022	2.073	0.102	10	0.025
		2013, 2020	1.2872	0.100	10	0.198
		2013, 2021	1.3486	0.099	10	0.164
		2013, 2022	1.9085	0.100	10	0.039
	Post Development, Post-Development	2020, 2021	1.4751	0.100	10	0.115
		2020, 2022	2.0824	0.102	10	0.029
		2021, 2022	2.0844	0.097	10	0.027
	Baseline, Reference	2011, Ref 2011	1.5089	0.037	56	0.070
		2012, Ref 2012	1.1925	0.053	56	0.238
		2013, Ref 2013	0.9751	0.602	56	0.464
Reference	Baseline, Baseline	2011, 2012	1.3639	0.007	126	0.096
		2011, 2013	1.4204	0.009	126	0.066
		2012, 2013	1.3254	0.008	126	0.116
	Baseline, Post-Development	2011, 2020	1.7028	0.007	126	0.017
		2011, 2021	1.4999	0.043	21	0.085
		2011, 2022	2.1222	0.008	126	0.006
		2012, 2020	1.7222	0.008	126	0.023
		2012, 2021	1.5683	0.047	21	0.065
		2012, 2022	2.1556	0.006	126	0.004
		2013, 2020	1.6593	0.006	126	0.024
		2013, 2021	1.4516	0.093	21	0.100
		2013, 2022	2.1308	0.009	126	0.004
	Post Development, Post-Development	2020, 2021	1.6328	0.049	21	0.060
		2020, 2022	2.0411	0.008	126	0.006
		2021, 2022	1.5276	0.049	21	0.090

FIGURES

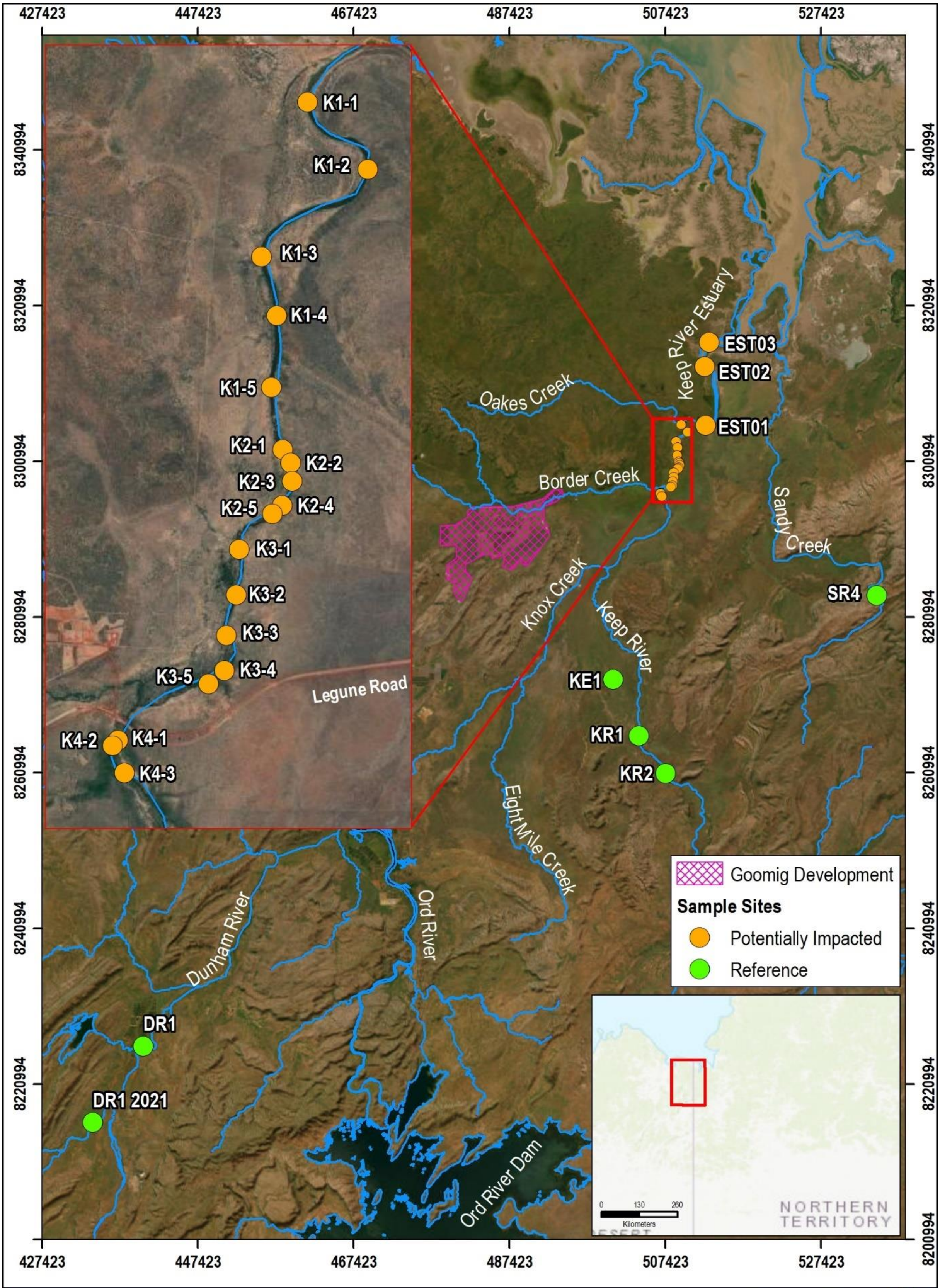

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Figure 1. Keep River Aquatic Fauna and Targeted Sawfish Post-development Survey sampling sites.

0 10 20
Kilometers

Project: 22023 DPIRD Keep River
Client: DPIRD
Coordinate System: GCS GDA 1994
Scale: 20,000,000
Author: J. Keleher

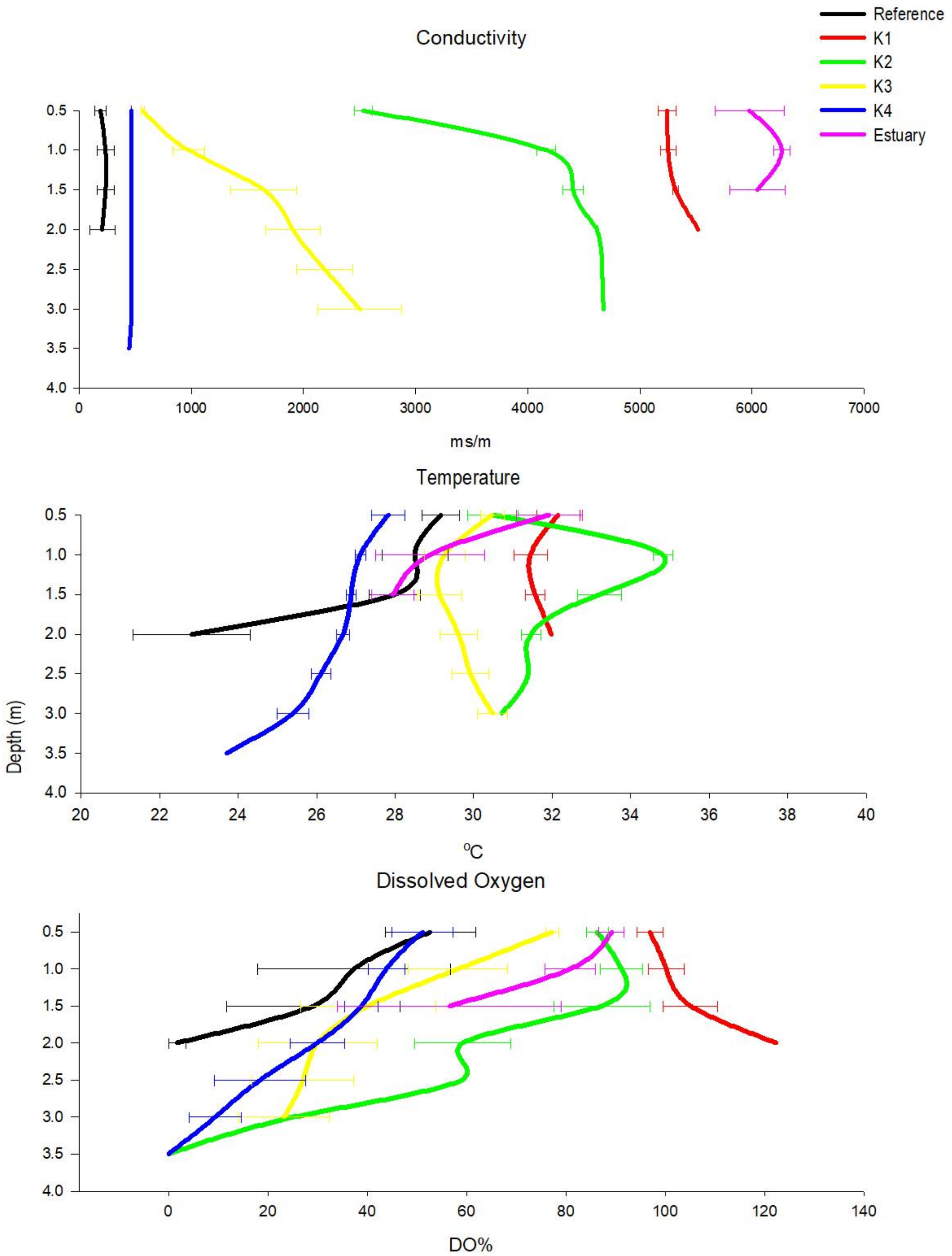


Figure 2. Mean (±SE) conductivity, temperature and dissolved oxygen (saturation) depth profiles recorded from each site sampled in 2022.

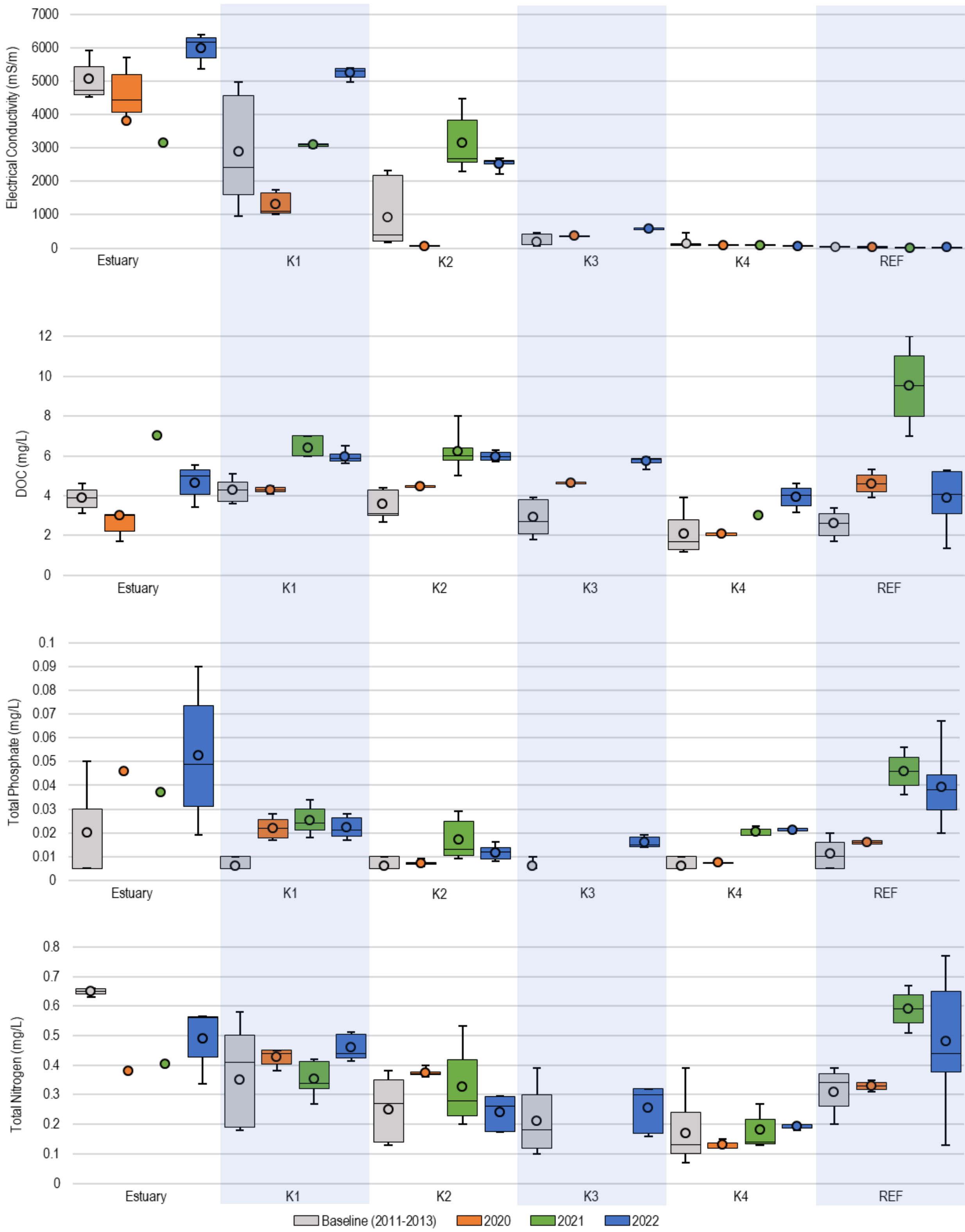


Figure 3. Box plots displaying minimum, 20%ile, median, 80%ile, maximum and mean (circle) of select water quality parameters within the Keep River (K1, K2 K3 and K4), Keep River estuary (EST01, EST02 and EST03) and reference (DR1, KR1, KR2, SR4 and KE1) sites recorded during combined baseline surveys (2011-2013) and post-development surveys (2020, 2021 and 2022).

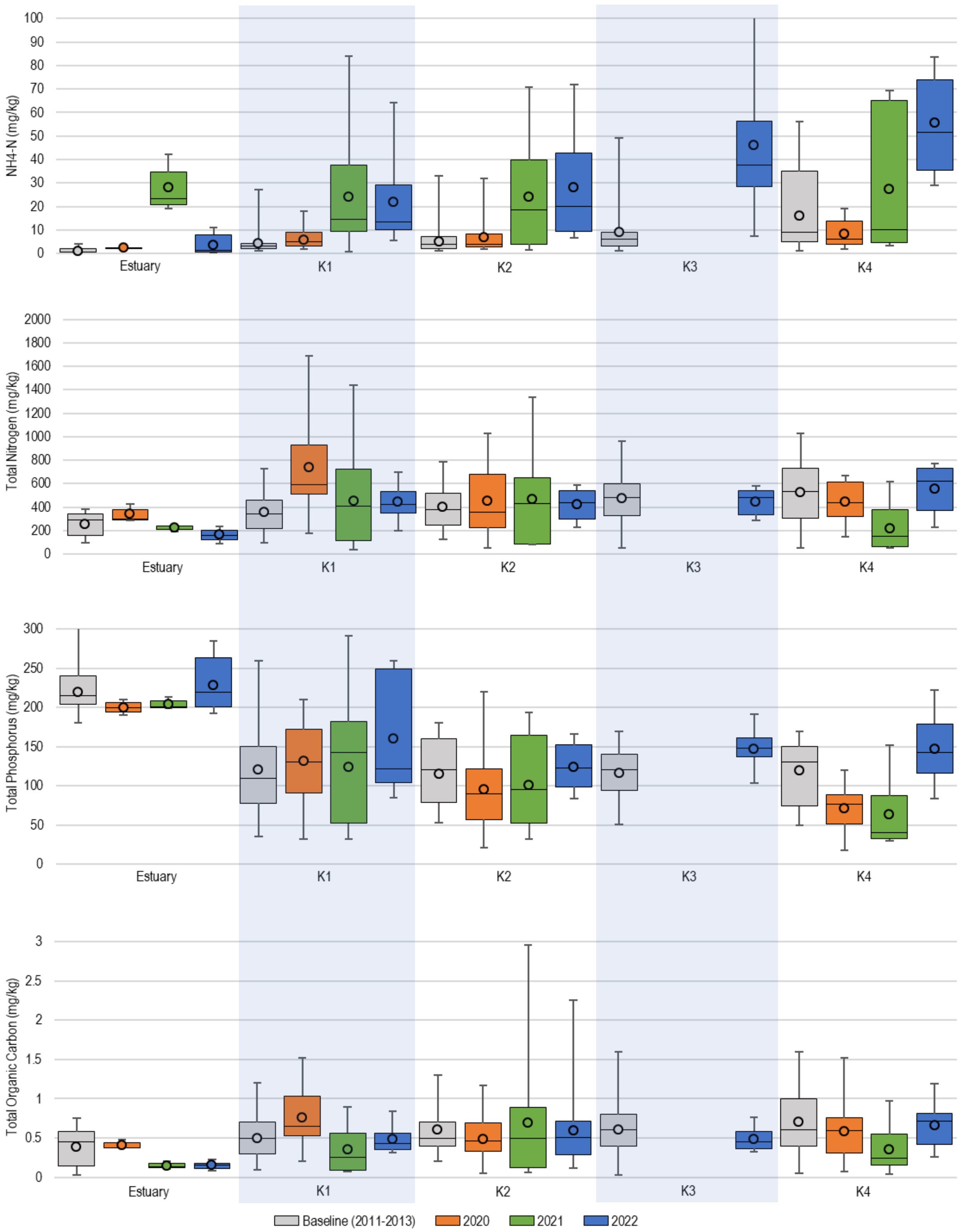


Figure 4. Box plots displaying minimum, 20%ile, median, 80%ile, maximum and mean (circle) of select sediment quality parameters within the Keep River (K1, K2, K3 and K4) and Keep River estuary sites (EST01, EST02 and EST03) recorded during combined baseline surveys (2011-2013) and post-development surveys (2020, 2021 and 2022).

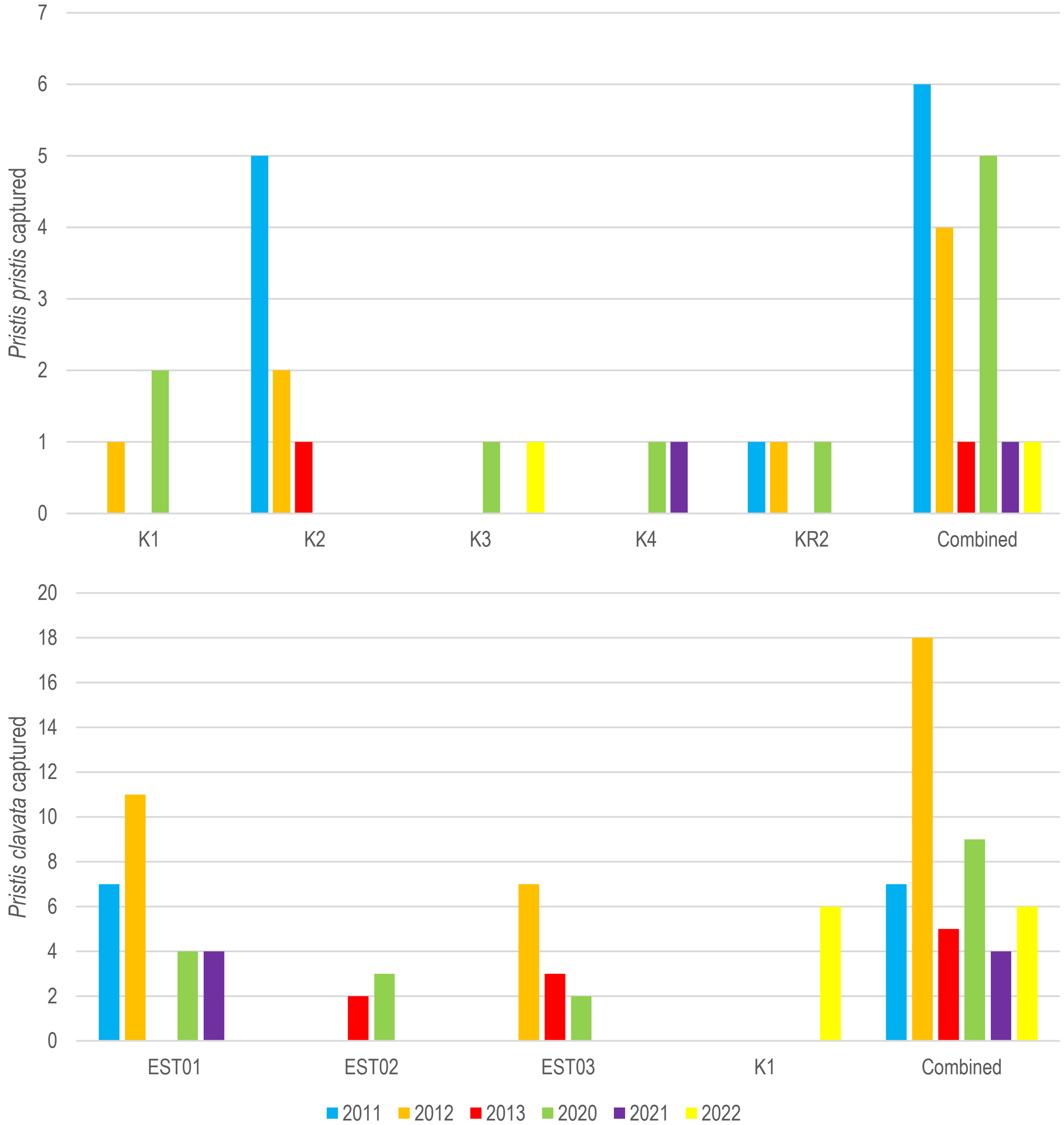


Figure 5. The total number of *Pristis pristis* (top) and *Pristis clavata* (bottom) captured during baseline (2011-2013) and post-development (2020-2022) surveys.

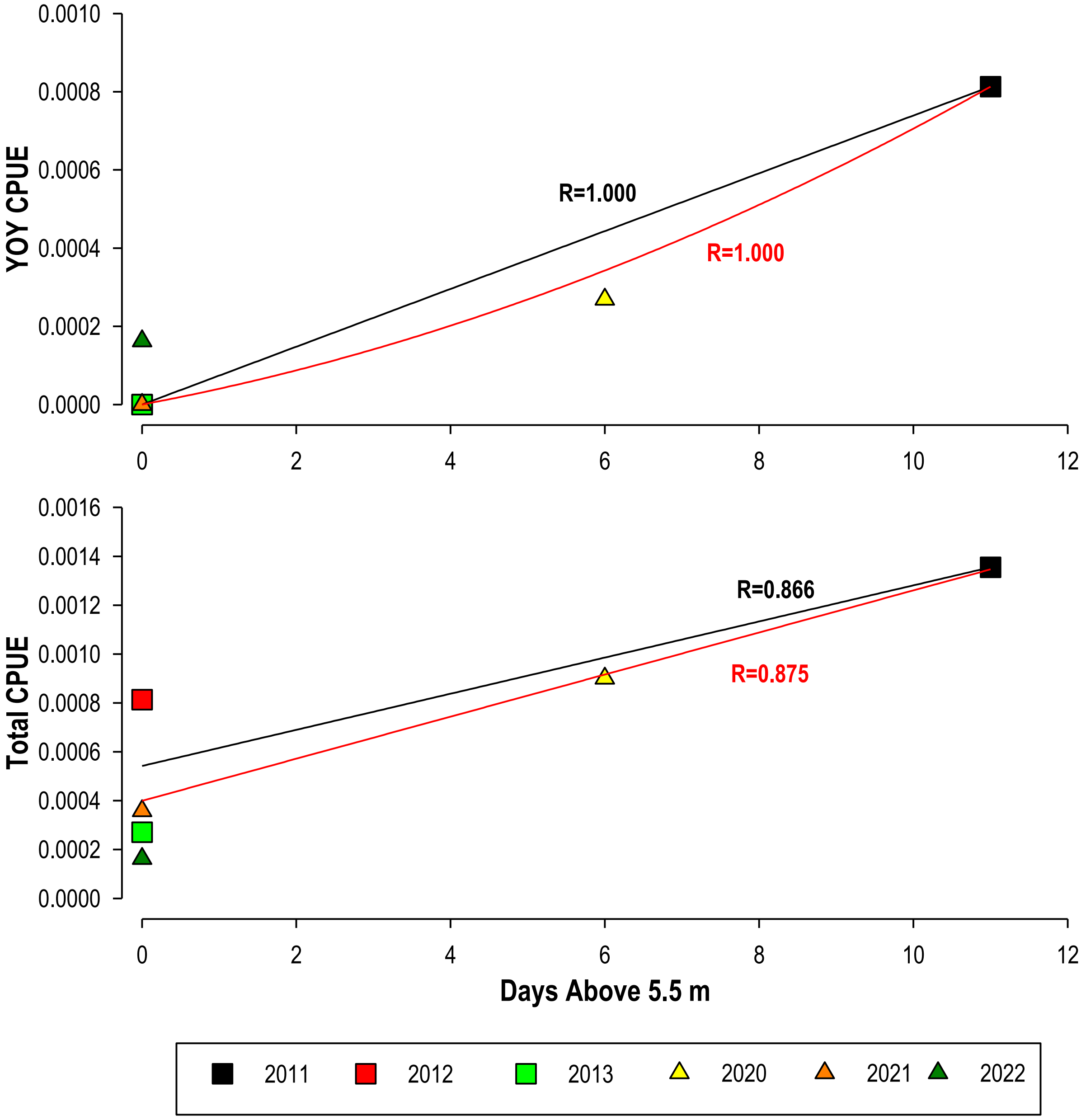


Figure 6. Regression analysis results produced from 2011 to 2013 (black) and 2011 to 2022 (red) for mean Catch Per Unit of Effort (CPUE) data of young-of-year (YOY) (top) and total (bottom) *Pristis pristis* captured with number of days the water level at the Legune Road Crossing (G8100225) was above 5.5 m during the previous wet season.

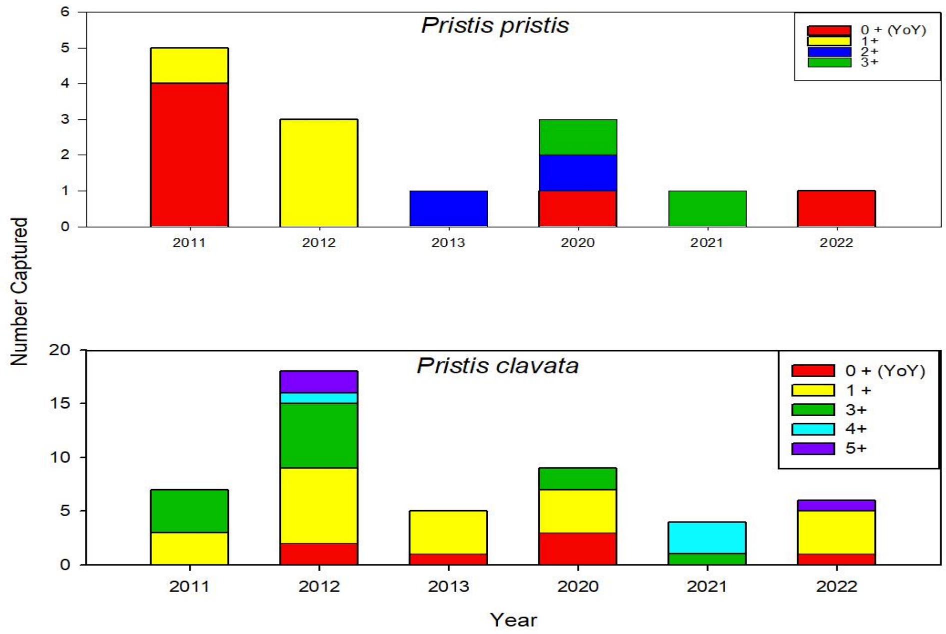


Figure 7. Age classes (cohort data) of *Pristis pristis* and *P. clavata* captured during each survey event in the Keep River system.

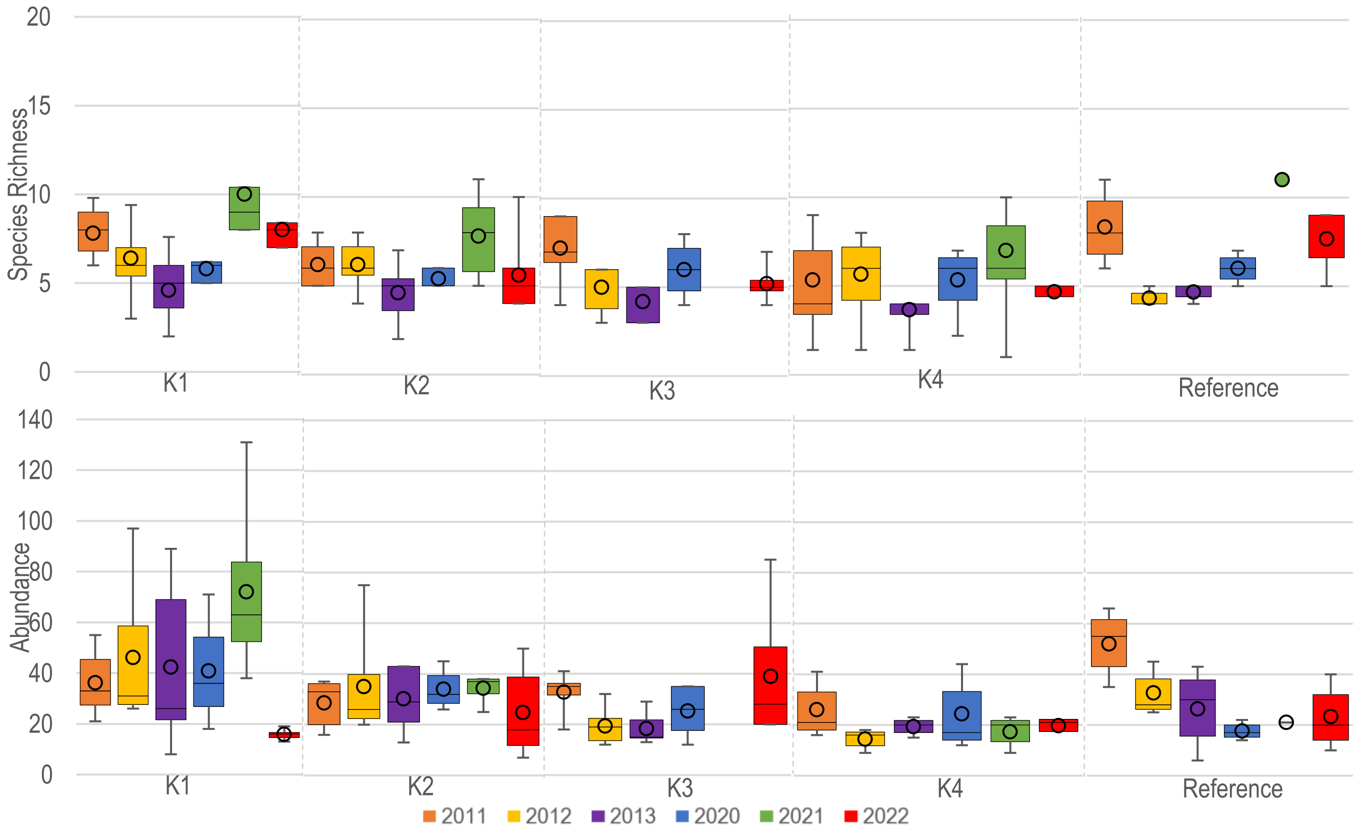


Figure 8. Box plots displaying minimum, 20%ile, median, 80%ile, maximum and mean (circle) of fish species richness and abundance within Keep River (K1, K2, K3 and K4) and reference (DR1, KE1 and SR4) sites recorded during individual baseline survey years (2011-2013) and post-development surveys (2020-2022).

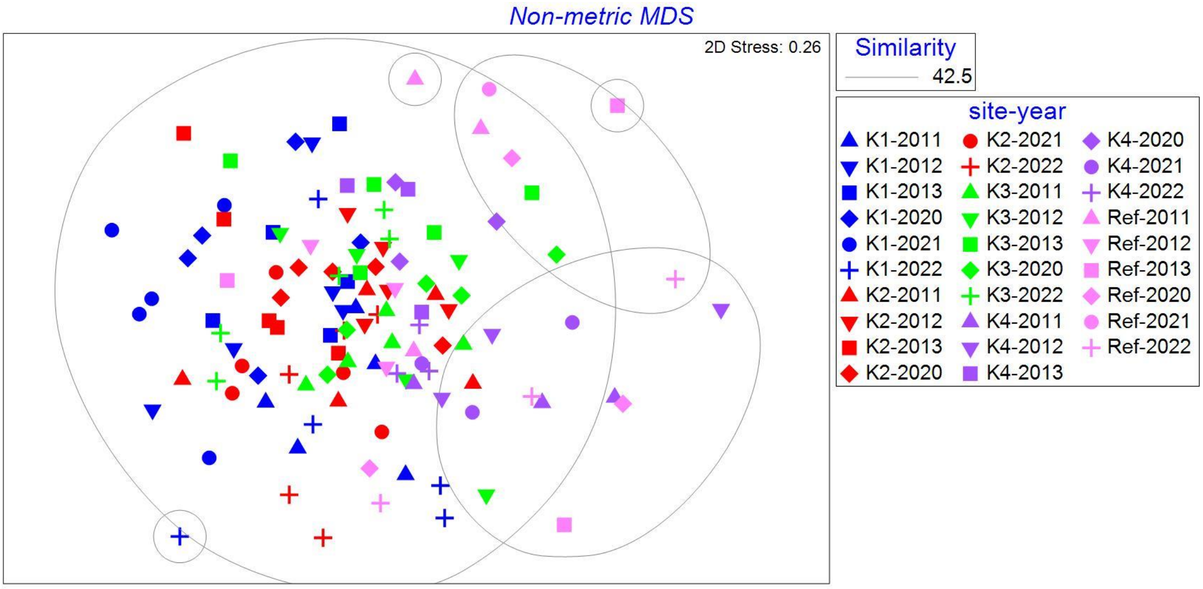


Figure 9. Non-metric MDS plots of fish assemblage data (transformed) within Keep River (K1, K2, K3 and K4) and reference (DR1, KE1 and SR4) sites sampled during baseline (2011-2013) and post-development (2020, 2021 and 2022) surveys separated by year and site.

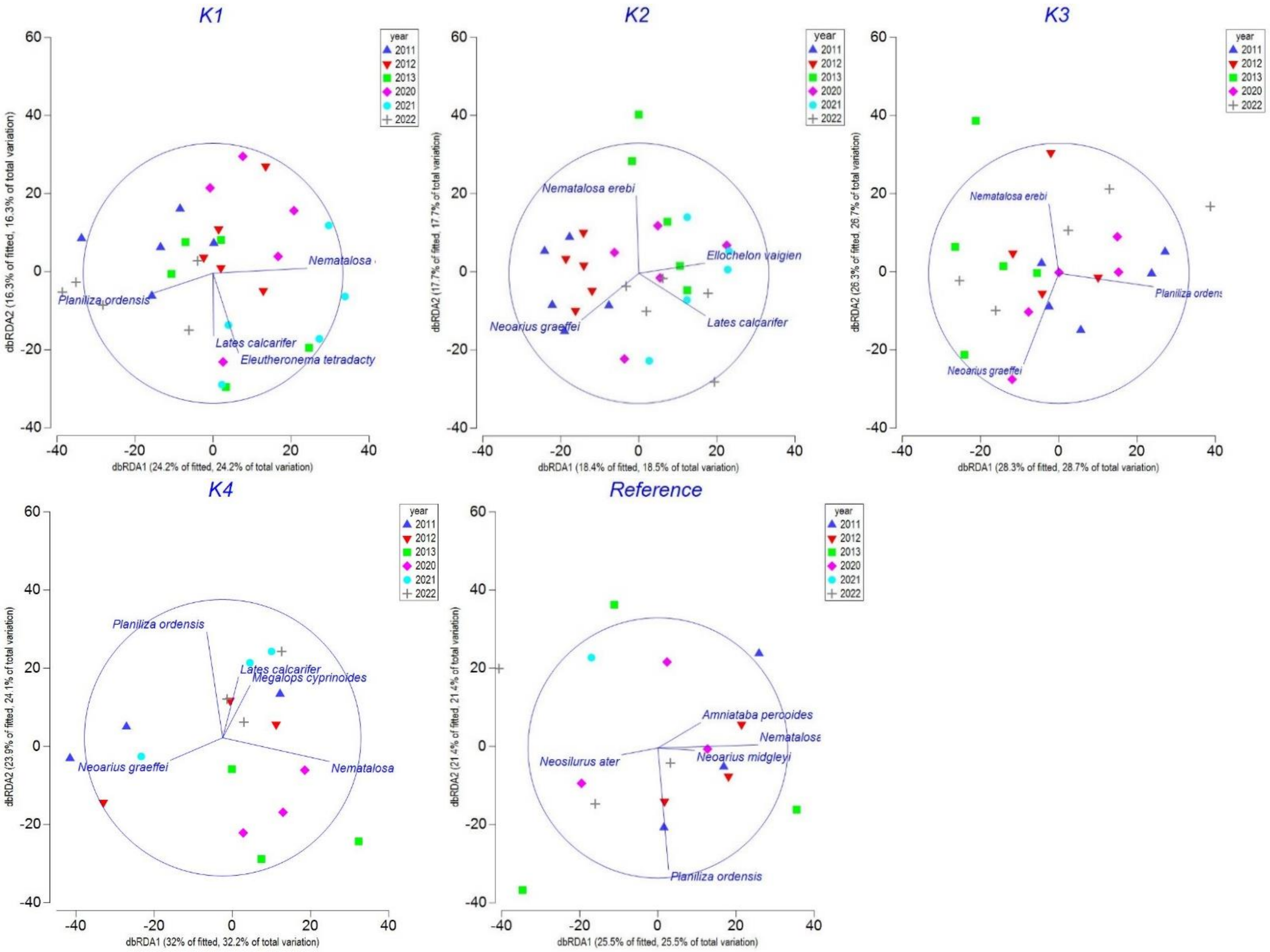


Figure 10. Distance-based redundancy analysis (dbRDA) plots of fish assemblage data for Keep River (K1, K2, K3 and K4) and reference (DR1, KE1, SR4) sites sampled during baseline (2011-2013) and post-development (2020-2022) surveys overlaid with transformed fish species abundance data. Vectors indicate the strength and direction of the species effect in the ordination plot.

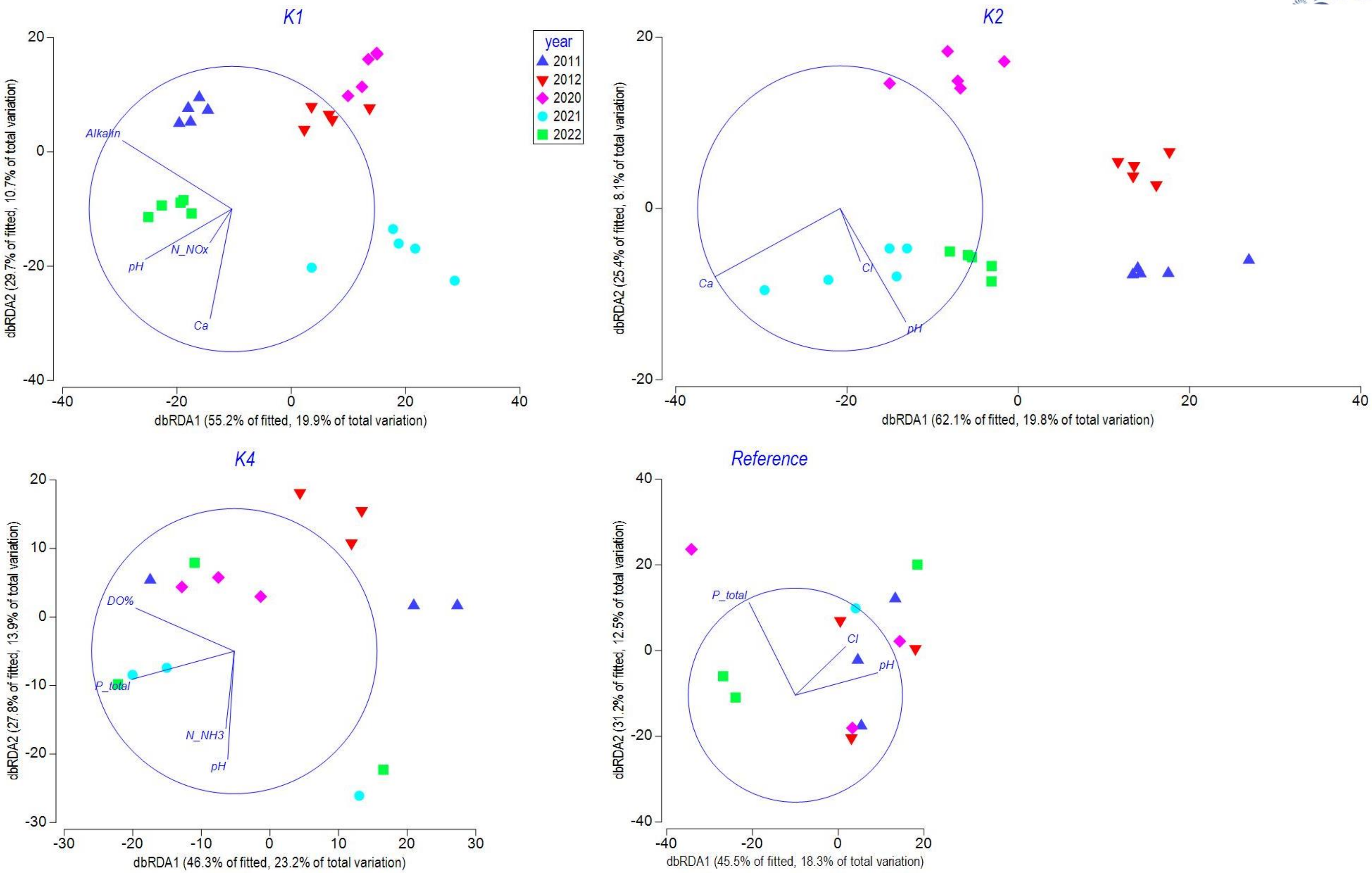
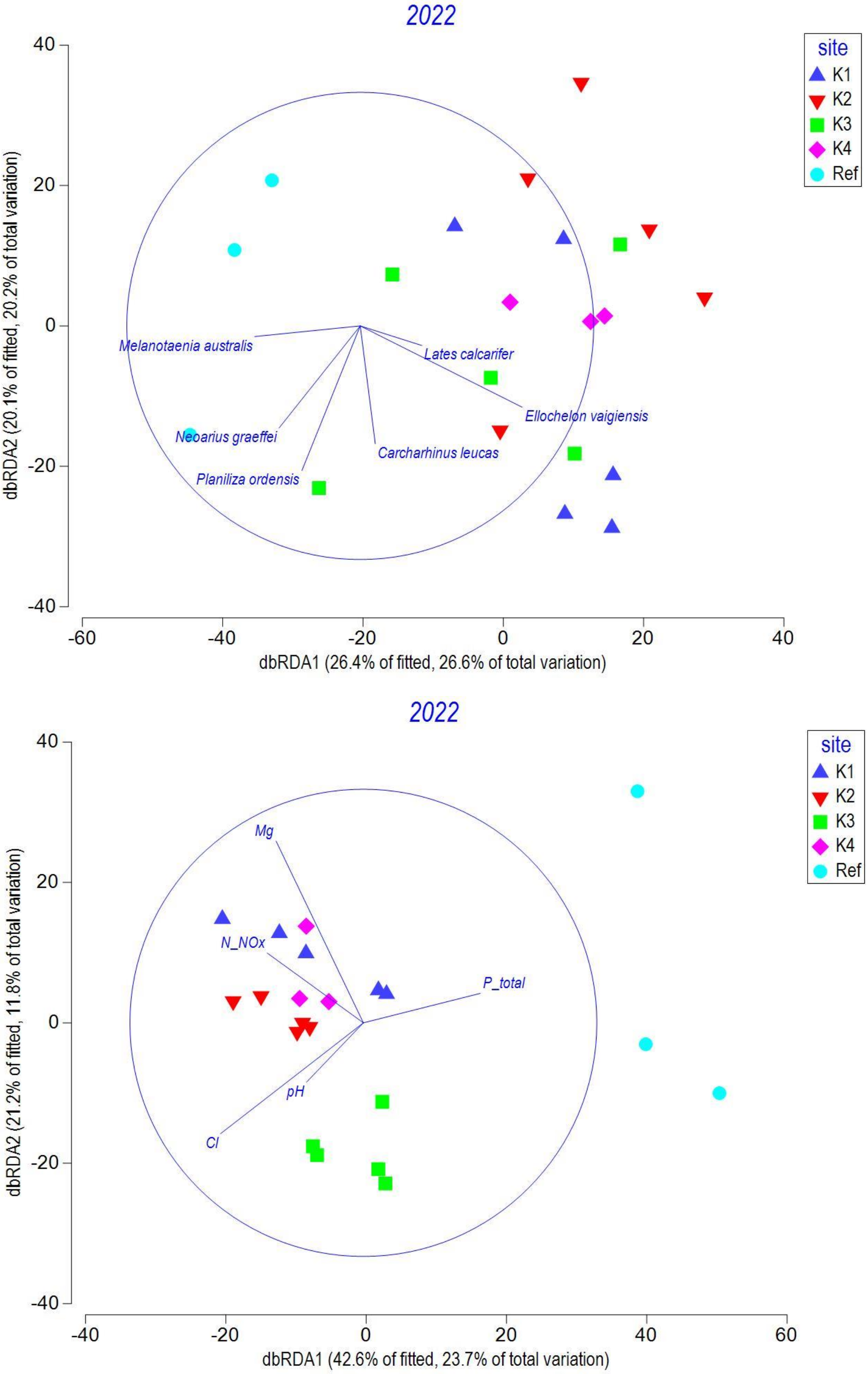


Figure 11. Distance-based redundancy analysis (dbRDA) plots of fish assemblage data for Keep River (K1, K2 and K4) and reference (DR1, KE1 and SR4) sites sampled during baseline (only 2011 and 2012 available for water quality data) and post-development (2020-2022) surveys overlaid with transformed and normalised predictor water quality variables (based on distLM analysis). Vectors indicate the direction and strength of the parameter effect in the ordination plot.

A)



B)

Figure 12. Distance-based redundancy analysis (dbRDA) plots of fish assemblage data for Keep River (K1, K2, K3 and K4) and reference (DR1, KE1, SR4) sites sampled in 2022, A) overlaid with transformed fish species abundance data (vectors indicate the strength and direction of the species effect in the ordination plot); B) overlaid with transformed and normalised predictor water quality variables (vectors indicate the direction and strength of the parameter effect in the ordination plot).

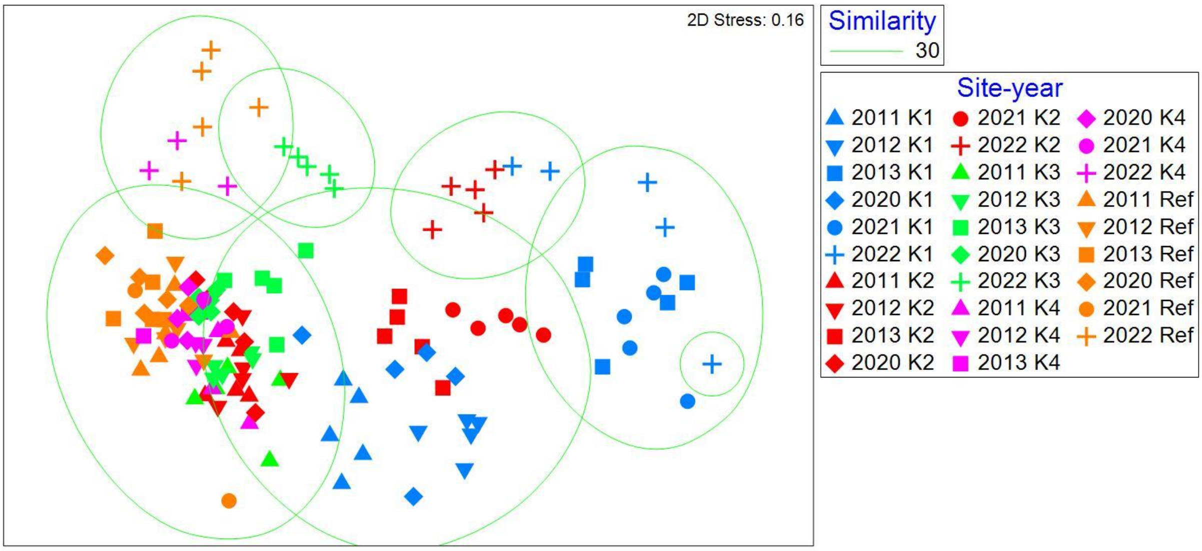


Figure 13. Non-metric MDS plots of edge macroinvertebrate assemblage data (log^{10} scale) within Keep River (K1, K2, K3 and K4) and reference (KR1, KR2, KE1, SR4 and DR1) sites sampled during baseline (2011-2013) and post-development (2020-2022) surveys separated by year and site.

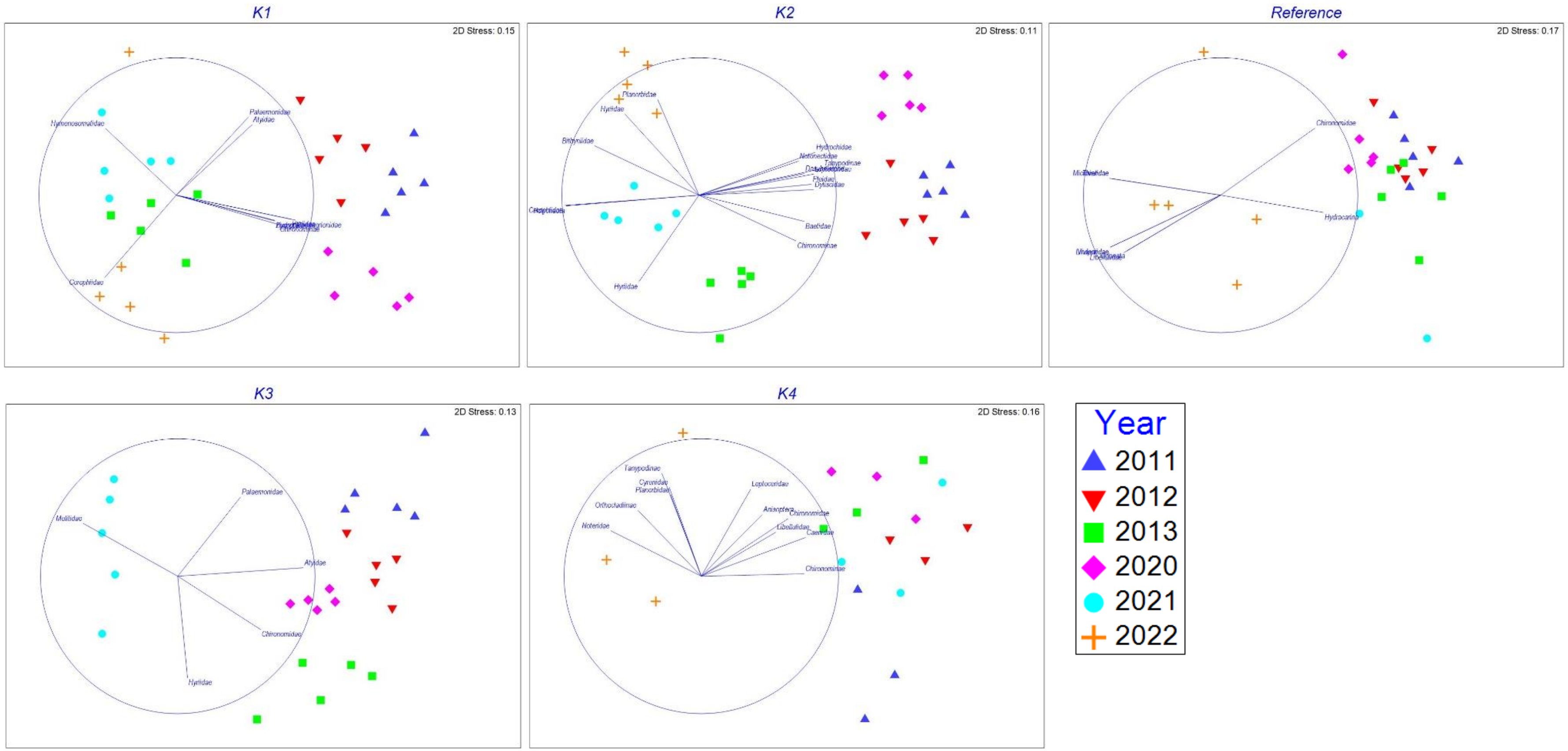


Figure 14. Non-metric MDS plots of edge macroinvertebrate assemblage data (log^{10} scale) within Keep River (K1, K2, K3 and K4) and reference (KR1, KR2, KE1, SR4, DR1) sites sampled in 2022 during baseline (2011-2013) and post-development (2020 -2022) surveys separated by year and site, with overlaid correlation (>0.7) vectors displaying the macroinvertebrate families that best distinguish the distribution sub-site samples within sites and between years.

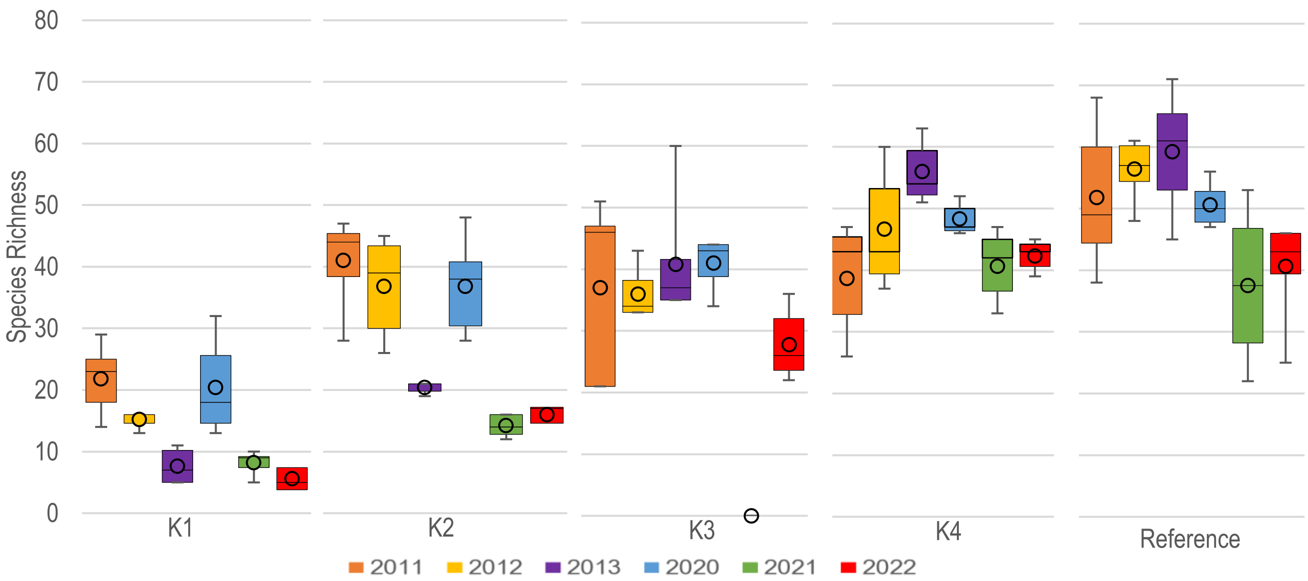


Figure 15. Box plots displaying minimum, 20%ile, median, 80%ile, maximum and mean (circle) of macroinvertebrate species richness within Keep River (K1, K2, K3 and K4) and reference sites recorded during individual baseline survey years (2011-2013) and post-development surveys (2020, 2021 and 2022).

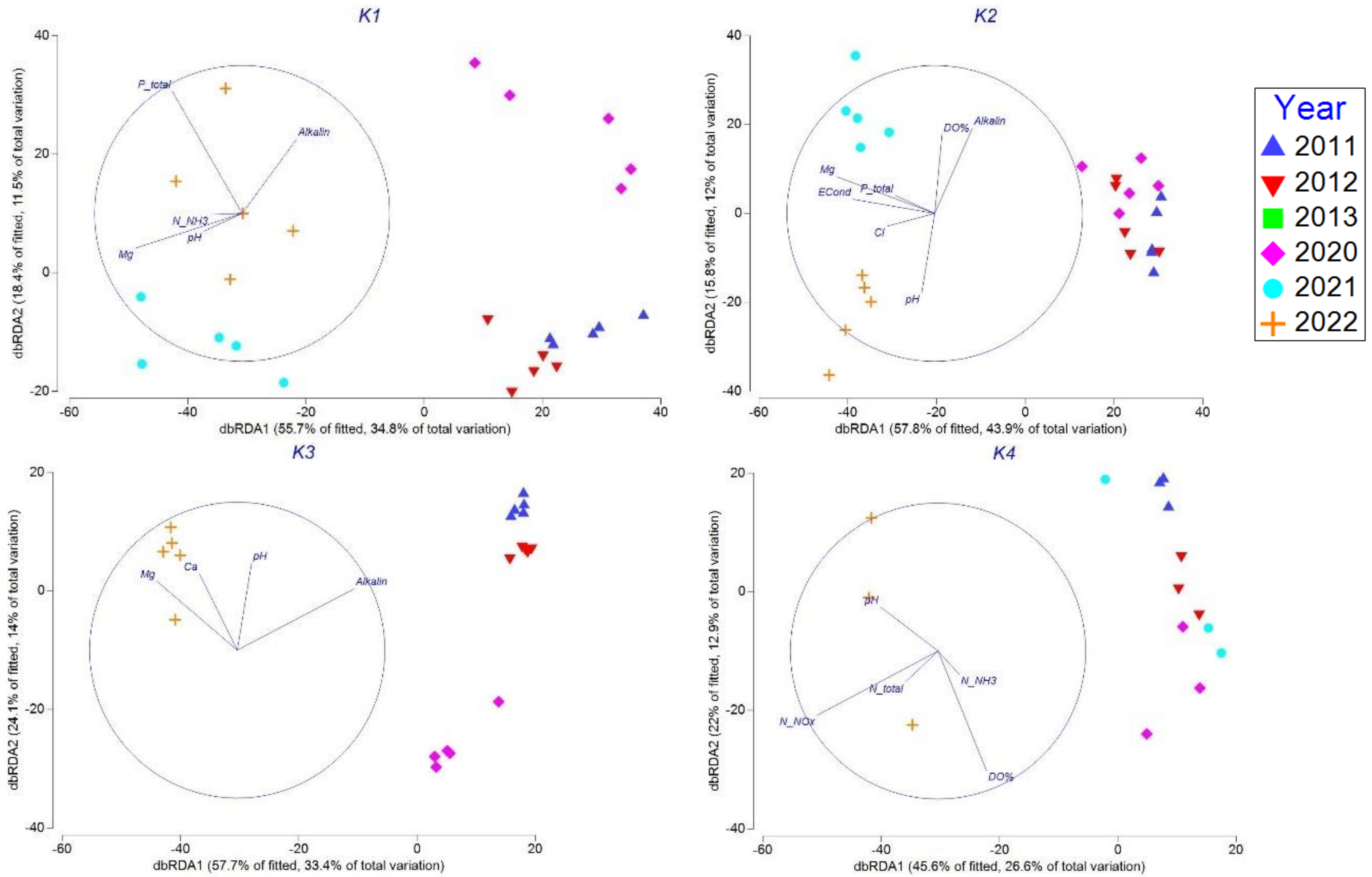
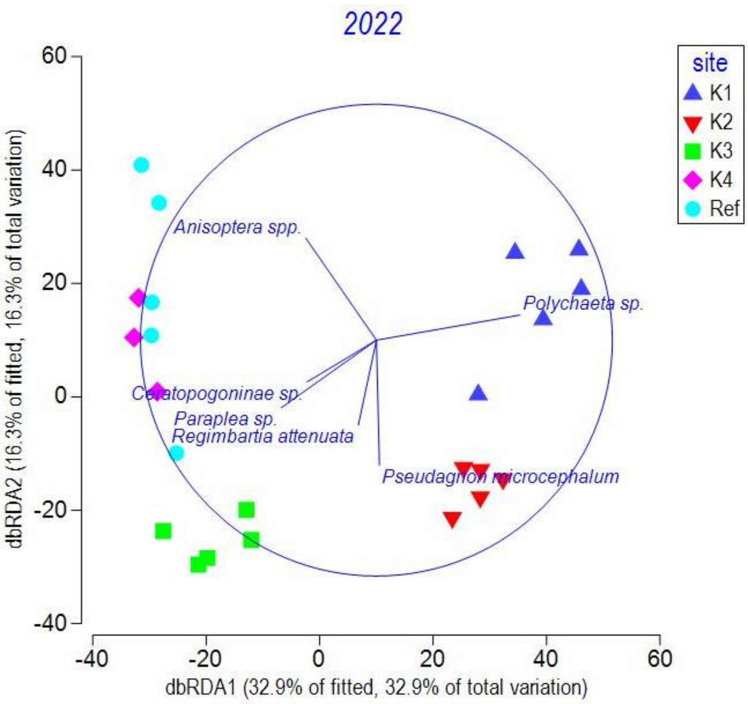


Figure 16. Distance-based redundancy analysis (dbRDA) plots of macroinvertebrate species assemblage data for Keep River (K1, K2, K3 and K4) sites sampled during baseline (only 2011 and 2012 available for water quality data) and post-development (2020, 2021 and 2022) surveys overlaid with transformed and normalised predictor water quality variables (based on distLM analysis). Vectors indicate the direction and strength of the parameter effect in the ordination plot.

A)



B)

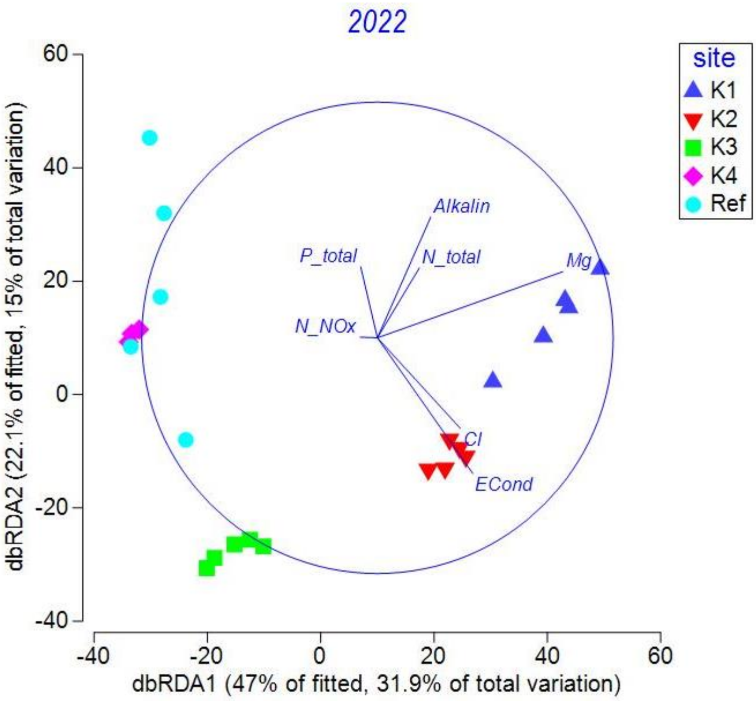


Figure 17. Distance-based redundancy analysis (dbRDA) plots of macroinvertebrate assemblage data for Keep River (K1, K2, K3 and K4) and reference (DR1, KE1, SR4) sites sampled in 2022, A) overlaid with transformed species abundance data (vectors indicate the strength and direction of the species effect in the ordination plot); B) overlaid with transformed and normalised predictor water quality variables (vectors indicate the direction and strength of the parameter effect in the ordination plot).

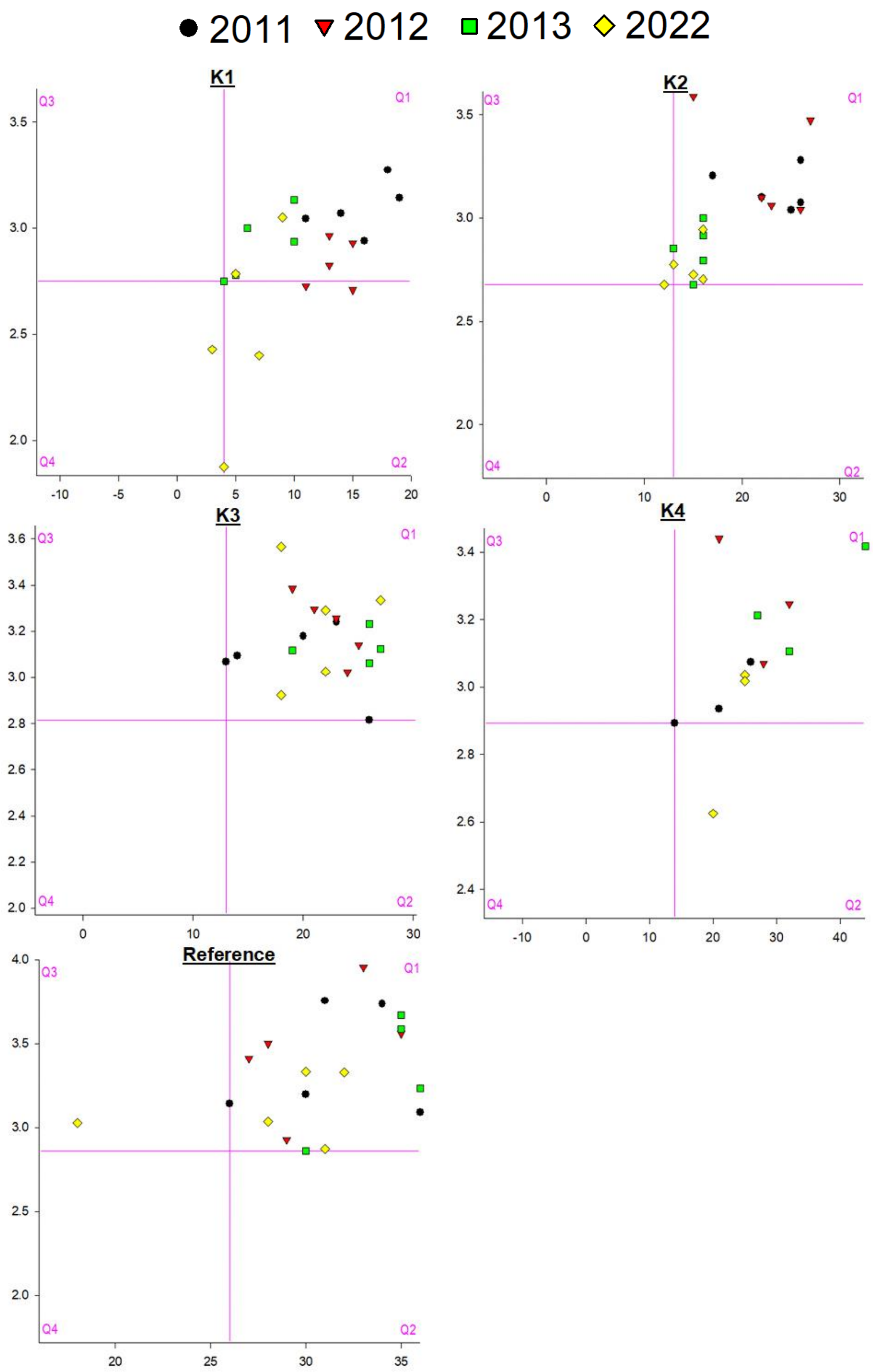


Figure 18. Bi-plots of SIGNAL2 (family) scores from Keep River (K1, K2, K3 and K4) and reference sites for 2022 and respective baseline (2011-2013) edge macroinvertebrate assemblages. The pink lines represent quadrant boundaries based on baseline (2011-2013) or reference site values.

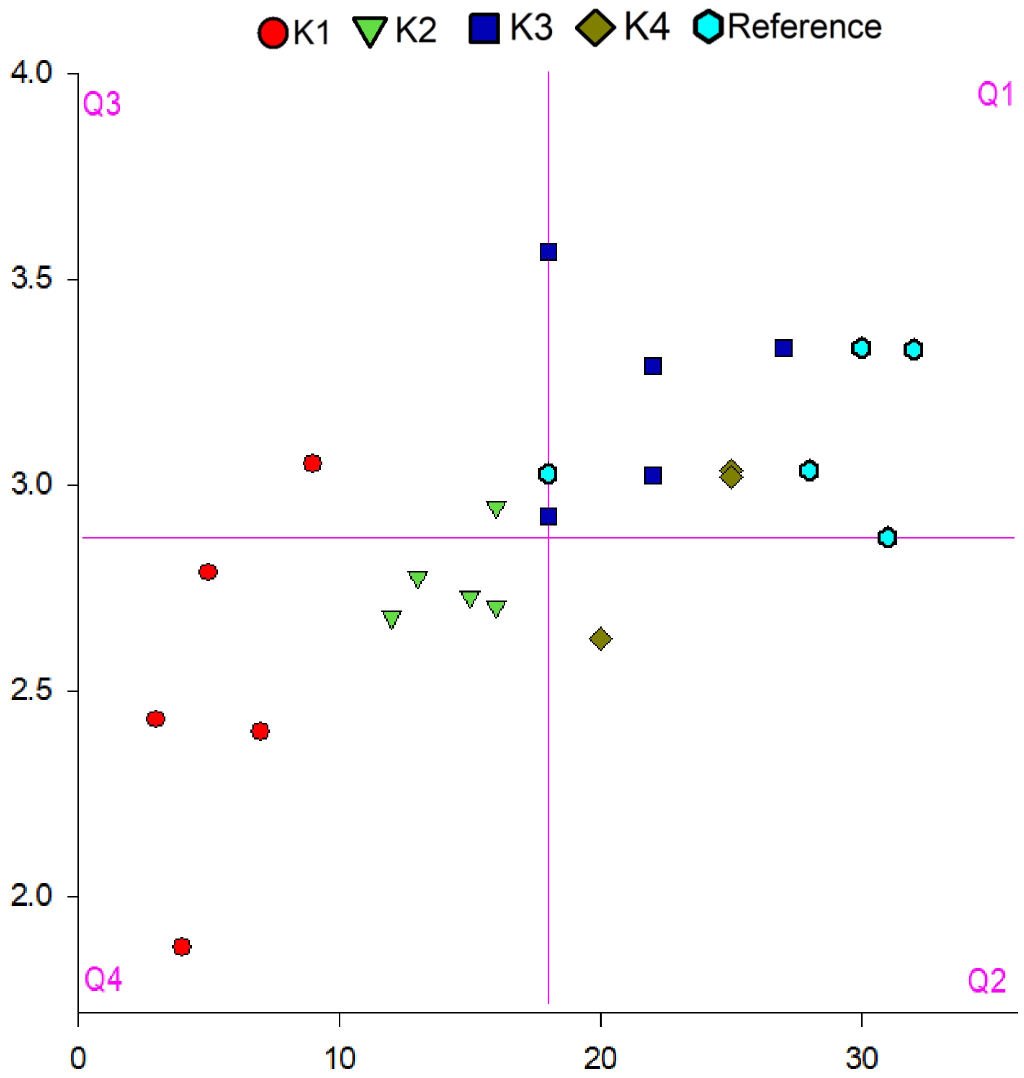


Figure 19. Bi-plots of SIGNAL2 (family) scores from Keep River (K1, K2, K3 and K4) and reference sites for 2022 edge macroinvertebrate assemblages. The pink lines represent quadrant boundaries based on reference site values.

APPENDICES

Appendix 1. Water quality values (mg/L unless indicated), obtained from reference, potentially impacted lower Keep River and estuary sub-sites in 2022. Values highlighted purple = SS-WQGV or ILTV exceedance, yellow = ILTV and SS-WQGV exceedance. ANZG (2018) default trigger values for tropical Australian lowland rivers (LR) and estuaries (E) are also displayed.

					Keep River																									
	Analyte	LOR	ANZG (2018)		K4					K3							K2							K1						
			LR	E	SS-WQGV	ILTV	1	2	3	SS-WQGV	ILTV	1	2	3	4	5	SS-WQGV	ILTVs	1	2	3	4	5	SS-WQGV	ILTVs	1	2	3	4	5
Miscellaneous	TDS-calc	1			2416		298	302	303	2440		4190	3910	3740	3600	3590	12200		17200	17000	17000	17400	17400	27000		35500	35300	35000	34500	33800
	TSS	5			1.5	62	<5	<5	<5	1.5	29	<5	6	<5	<5	<5	1.5	21	<5	<5	14	<5	<5	1.5	27	12	11	12	7	16
	Temp (°C)				28	31	27.61	28.65	27.22	29.4	31	31.1	31.16	29.5	30.4	30.23	32.5	32	30.09	28.54	30.05	31.66	32.1	30.4	33	31.22	32.27	33.29	30.62	33.31
	Turbid (NTU)		15	20	13.2	120				15	17						10	15						9.7	15					
	pH (units)		6-8	6-8.5	8	6.0–8.0	7.11	7.69	7.57	8.1	6.0–8.2	8.08	8	8.11	8.02	7.33	8.4	6.0–8.4	8.23	8.36	8.26	8.3	8.25	8.4	6.0–8.4	8.48	8.42	8.35	8.38	8.39
	DO (%)		90	80	52	23	52.9	60.3	39.8	79	22	80	78.2	76.9	78.7	72.3	91	35	83.6	79.4	89.4	87.5	91.7	85	28	96.2	106.4	98.2	91.9	91.7
	Econd (mS/m)	1	250		121	85	45.9	46.5	46.6	427	434	645	601	575	554	552	2176	2158	2640	2610	2610	2680	2680	4566	4166	5460	5430	5390	5310	5200
Ionic composition	Alkalinity	1			145		109	111	111	151		112	110	111	111	109	160		134	132	140	141	139	174		177	178	177	175	170
	Acidity	1			11.8		4	4	4	12		4	4	4	4	4	16.4		3	3	3	3	3	1.6		<1	<1	<1	1	<1
	Hardness	1			328		131	131	131	540		747	710	685	662	658	2400		3140	3120	3080	3090	3130	5300		7300	6950	6910	6670	6970
	CO3	1			<1		<1	<1	<1	<1		<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	9		<1	<1	<1	<1	<1
	Cl	1			251		76	76	77	1122		1880	1750	1650	1580	1590	7152		8560	8490	8520	8650	8650	15440		19800	19500	19100	18600	18300
	F	0.1			0.21		<0.1	<0.1	<0.1	0.28		0.2	0.2	0.2	0.2	0.2	0.48		0.5	0.5	0.5	0.5	0.5	0.74		0.7	0.8	0.7	0.7	0.7
	SO4-S	1			105		20	20	21	146		230	218	207	198	197	1002		1070	1060	1060	1080	1060	2340		2660	2610	2560	2460	2470
	HCO3	1			175		109	111	111	179		112	110	111	111	109	185		134	132	140	141	139	200		177	178	177	175	170
	Ca	1			45		26	26	26	65		83	80	78	77	77	189		251	249	246	245	248	361		516	490	492	477	500
	Mg	1			36		16	16	16	91		131	124	119	114	113	456		611	606	598	601	609	1030		1460	1390	1380	1330	1390
	Na	1			366		39	39	40	625		909	861	814	773	773	3518		4380	4330	4270	4320	4380	8816		10700	10200	10100	9810	10200
	K	1			12		3	3	3	19		42	39	37	36	35	117		210	208	205	206	209	296		543	520	512	488	511
Nutrients	DOC	1			2.8		4	2	4	3.8		5	5	6	5	5	4.3		5	6	5	5	6	4.7		6	6	6	5	6
	N-NH3	0.005			0.007	0.32	0.008	0.006	0.012	<0.01	0.32	<0.005	0.012	<0.005	0.019	0.006	0.006	0.32	0.011	0.013	0.017	0.027	0.025	0.022	0.32	0.034	0.01	0.041	<0.005	0.013
	N-NOx	0.002	0.01	0.03	<0.01	0.17	0.033	0.031	0.031	<0.01	0.017	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01	0.17	0.003	0.003	0.005	0.002	0.005	<0.01	0.17	0.003	<0.002	0.004	<0.002	<0.002
	N-org.	0.025/0.01*			0.27		0.16	0.14	0.16	0.31		0.16	0.31	0.3	0.15	0.31	0.35		0.246	0.159	0.271	0.147	0.265	0.47		0.390	0.494	0.369	0.511	0.427
	N-tot.sol.	0.025/0.01*			0.22		0.24	0.19	0.15	0.22		0.23	0.16	0.22	0.11	0.2	0.32		0.243	0.304	0.124	0.150	0.236	0.48		0.403	0.360	0.273	0.337	0.372
	N-total	0.05/0.01*	0.3	0.25	0.24	0.44	0.2	0.18	0.2	0.3	0.39	0.16	0.32	0.3	0.17	0.32	0.35	0.35	0.260	0.175	0.293	0.176	0.295	0.5	0.4	0.427	0.504	0.414	0.511	0.440
	P-tot.sol	0.005			<0.005		0.019	0.019	0.016	<0.005		0.011	0.011	0.012	0.009	0.01	<0.005		0.008	0.007	0.008	<0.005	0.011	<0.005		0.014	0.016	0.014	0.014	0.016
	P-total	0.005	0.01	0.02	0.01	0.04	0.02	0.022	0.022	<0.005	0.013	0.014	0.019	0.014	0.015	0.018	<0.01	0.01	0.013	0.008	0.016	0.009	0.012	<0.01	0.01	0.026	0.028	0.019	0.017	0.021
Herbicide	Atrazine (µg/L)	0.5					<0.5		<0.5			<0.5		<0.5		<0.5				<0.5		<0.5				<0.5			<0.5	
	Dibromo-DDE (%)*	0.5					67.8		79.2			67.3		75.6		74.3				70.8		67.4				65.4			62.4	
	DEF (%)*	0.5					100		113			95.5		107		105				101		99.4				91			87.1	

	Analyte	LOR	ANZG (2018)		Estuary						Reference sites									
					EST01		EST02		EST03		DR1		KR1		KR2		KE1		SR4	
			LR	E	SS-WQGV	1	SS-WQGV	1	SS-WQGV	1	SS-WQGV	1	SS-WQGV	1	SS-WQGV	1	SS-WQGV	1	SS-WQGV	1
Miscellaneous	TDS-calc	1			31600	36800	33200	41000	31600	41900	200	206	146	75	110	72		52		190
	TSS	5			66.8	41	704	50	582	20	0.9	<5	6.6	70	6.6	<5	1.5	<5	1.5	<5
	Temp (°C)				31.4	33.56	29.6	31.28	29.4	30.9	31.2	29.1	29.1	29.2	29.1	28.8	28.1	27.9	30.4	30.8
	Turbid (NTU)		15	20	34.8		624		444		5.3		6.2		6		19.1		1.8	
	pH (units)		6-8	6-8.5	8.2	8.4	8.2	8.37	8.1	8.35	8.2	8.8	7.6	7.6	8.2	7.2	7.5	7.1	7.9	6.9
	DO (%)		90	80	88	84.4	95	93.2	91	89.5	84	69.2	67	68.5	88	50.3	39	19.4	74	56.3
	Econd (mS/m)	1	250		5444	5660	5848	6000	5720	6450	42.5	31.7	27.6	11.6	35.4	11.1	41.4	8	30.9	29.2
Ionic composition	Alkalinity	1			187	184	171	166	147	183	207	173	106	55	135	49	135	41	150	157
	Acidity	1			15.4	5	13.8	10	14	3	4.8	<1	3.8	4	3.8	2	9.2	5	5	1
	Hardness	1			6400	7350	7100	8210	6920	8460	156	124	104	39	75	40	136	29	144	
	CO3	1			11	<1	9	<1	9	<1	3	13	<1	<1	<1	<1	<1	<1	<1	<1
	Cl	1			19960	20100	21860	22500	20200	23200	16	8	15	4	18	6	44	3	5	5
	F	0.1			0.8	0.8	0.92	0.9	0.93	0.9	0.29	0.2	0.1	<0.1	0.07	<0.1	0.16	<0.1	0.13	
	SO4-S	1			2740	2790		3010		3170	21	<1		3	2.5	3		<1	5.2	5
	HCO3	1			228	184	206	166	180	183	218	161	132	55	114	49	169	41	178	157
	Ca	1			439	519	465	551	453	568	28	20	21	9	26	8	24	5	27	25
	Mg	1			1294	1470	1448	1660	1404	1710	26	18	14	4	18	5	17	4	21	17
	Na	1			11400	10900		12500		12900	17	19		6	30	5		4	4	5
	K	1			397	554		683		700	12	3	8	4	8	3	8	2	3	4
Nutrients	DOC	1			4.3	4	2.3	3	1.6	2	3.1	5	4.5	5	4.2	4	11.5	7	2.3	3
	N-NH3	0.005			0.07	0.044	0.014	<0.005	<0.01	0.006	<0.01	<0.005	<0.01	0.018	<0.01	0.041	0.032	<0.005	<0.01	<0.005
	N-NOx	0.002	0.01	0.03	<0.01	0.009	<0.01	0.002	0.017	<0.002	<0.01	<0.002	<0.01	0.011	0.014	0.084	<0.01	<0.002	<0.01	<0.002
	N-org.	0.025/0.01*			0.57	0.513	0.24	0.560	0.2	0.332	0.31	0.44	0.39	0.74	0.38	0.32	0.95	0.62	0.15	0.13
	N-tot.sol.	0.025/0.01*			0.57	0.442	0.22	0.297	0.16	0.181	0.21	0.22	0.38	0.4	0.3	0.53	0.83	0.44	0.15	0.1
	N-total	0.05/0.01*	0.3	0.25	0.66	0.566	0.33	0.562	0.47	0.338	0.29	0.44	0.38	0.77	0.37	0.44	0.94	0.62	0.16	0.13
	P-tot.sol	0.005			<0.005	0.019	<0.005	0.024	<0.005	0.018	<0.005	0.025	<0.005	0.018	<0.005	0.017	0.01	0.014	<0.005	0.016
	P-total	0.005	0.01	0.02	0.03	0.07	<0.005	0.09	0.032	0.049	0.016	0.038	<0.005	0.067	<0.005	0.039	0.022	0.032	<0.005	0.02
Herbicide	Atrazine (µg/L)	0.5						<0.5												
	Dibromo-DDE (%)*	0.5						62												
	DEF (%)*	0.5						86.1												

Appendix 2. Sediment quality values (mg/kg unless indicated), obtained from potentially impacted lower Keep River and estuary sub-sites in 2022. Values highlighted purple = SS-SQGV exceedance. ANZG (2018) sediment default guideline values (DVG) and default guideline values-High (GV-H) are also displayed. N.B. values in red typeface indicate that the limit of reporting (LOR) was greater than the SS-SQGV.

			Major Ions							Nutrients					Total Metals																											Herbicide		
		Analyte	Si	Cl	SO4	Na	K	Ca	Mg	NO3-N	N-Total	P-Total	NH4-N	TOC%	Al	Sb	As	Ba	Be	Bi	B	Cd	Cr	Co	Cu	Ga	Fe	La	Pb	Li	Mn	Mo	Hg	Ni	Se	Ag	Sn	Ti	U	V	Zn	Atrazine	DDE%	DEF%
		LOR	1	10	10	50	50	50	50	0.1	20	2	0.2	0.02	50	0.5	1	10	1	0.1	50	0.1	1	1	1	0.1	50	0	1	0.1	10	2	0.01	1	0.1	0.1	0.1	10	0.1	2	1	0.05	0.05	0.05
Site		DGV														2	20					1.5	80		65				50				0.15	21		1					200			
		GV-High														25	70					10	370		270				220				1	52		4					410			
		SS-SQGV	**190**	**850.4**	**384**	**936**	**1300**	**4140**	**5900**	**<1**	**732**	**150**	**35**	**1**	**16620**	**0.13**	**2.1**	**170**	**0.73**	**0.16**	**2.5**	**<0.05**	**29**	**23**	**18**	**8.2**	**32000**	**20**	**11**	**6**	**748**	**0.22**	**0.286**	**18**	**0.11**	**<0.05**	**0.8**	**73.4**	**1**	**66**	**29**			
	1	L	38	40	10	180	1580	3420	4260	<0.1	550	148	29	0.89	16300	<0.50	2.21	160	<1	0.3	<50	<0.1	26.4	21.4	19.8	6.3	32300	22.2	13.3	4.8	414	<2	<0.01	16.5	0.3	<0.1	1.1	190	1	78.4	22.8	----	----	----
		M	11	20	10	90	920	7630	2760	<0.1	230	114	33.9	0.33	9430	<0.50	1.82	360	<1	0.2	<50	<0.1	15.4	28.8	12.4	3.8	20100	18.8	9.5	2.7	1280	<2	<0.01	13.5	0.2	<0.1	0.7	100	0.7	58	12.8	----	----	----
		R	34	80	10	250	2380	5120	6640	<0.1	730	222	46.2	0.71	24700	<0.50	2.97	220	1	0.4	<50	<0.1	38.5	28.8	28.5	9.2	47300	31.8	17.9	6.8	829	<2	<0.01	23.7	0.4	<0.1	1.7	250	1.4	108	32.9	<0.05	75.8	75.3
K4	2	L	73	20	20	140	2070	3240	5700	<0.1	770	205	36.2	0.72	21500	<0.50	2.57	240	<1	0.3	<50	<0.1	37.3	38.7	27.1	8.2	48800	27.5	15.4	6.4	696	<2	<0.01	23.4	0.3	<0.1	1.4	250	1.2	106	31.2	----	----	----
		M	14	30	<10	180	1700	5130	6510	<0.1	690	142	75.5	0.64	19200	<0.50	2.18	190	<1	0.3	<50	<0.1	35.6	24.8	24.9	7.5	38800	25.6	14.5	5.6	907	<2	<0.01	21.9	0.3	<0.1	1.3	230	1.2	98.1	28.1	----	----	----
		R	16	30	<10	120	1420	3510	4140	<0.1	460	117	72.7	0.76	15000	<0.50	1.79	160	<1	0.3	<50	<0.1	22.9	22.1	18.1	5.7	30000	19.8	11.9	4	544	<2	<0.01	15.2	0.2	<0.1	1	160	1	74.8	19.9	----	----	----
	3	L	13	20	<10	80	850	2050	2510	<0.1	240	84	51.7	0.26	8250	<0.50	1.14	100	<1	0.2	<50	<0.1	15.5	13.6	10.9	3.2	18100	11.9	7.9	2.3	371	<2	<0.01	9.6	0.1	<0.1	0.6	130	0.6	46.4	12.8	----	----	----
		M	22	10	<10	130	1370	3440	4360	<0.1	620	133	83.7	0.47	14600	<0.50	1.74	160	<1	0.2	<50	<0.1	25.3	20	18.1	5.5	29300	19.3	10.8	4.1	693	<2	<0.01	15.5	0.2	<0.1	1	180	0.9	69.9	20.1	----	----	----
		R	29	40	<10	180	1800	4180	5150	<0.1	730	162	71.4	1.19	18900	<0.50	2.14	190	<1	0.3	<50	<0.1	30.2	24.9	23.8	7	36600	27.4	15.6	5.1	810	<2	<0.01	19.5	0.3	<0.1	1.4	190	1.1	87.1	26.2	<0.05	79.3	81.4
		SS-SQGV	**182**	**694**	**308**	**920**	**1400**	**4020**	**5940**	**1**	**596**	**140**	**9**	**0.8**	**16340**	**0.12**	**2**	**160**	**0.67**	**0.15**	**2.5**	**<0.05**	**29**	**22**	**18**	**7.8**	**32000**	**19**	**10**	**6**	**740**	**0.22**	**0.31**	**18**	**0.1**	**<0.05**	**0.7**	**99.2**	**0.9**	**66**	**29.2**			
	1	L	8	2580	170	2450	1870	3160	5280	<0.1	490	137	33.6	0.58	15300	<0.50	1.69	130	<1	0.2	<50	<0.1	29	19.8	19.4	5.9	31100	19	11.2	5	492	<2	<0.01	17.9	0.2	<0.1	1	280	0.8	73.3	26	----	----	----
		M	9	2740	60	2650	2030	3970	6360	<0.1	320	103	52.4	0.43	18000	<0.50	1.65	140	<1	0.3	<50	<0.1	30.8	18.3	22.1	6.5	32400	21.5	12.2	5.3	445	<2	<0.01	19.2	0.2	<0.1	16	200	1.2	72.6	28.8	----	----	----
		R	9	7730	980	6500	2950	2630	6350	<0.1	540	164	10.3	0.62	19100	<0.50	2.49	170	1	0.3	<50	<0.1	35	20	23.3	7.3	38800	25.3	14	6.1	521	<2	<0.01	20.3	0.2	<0.1	1.5	240	1	88.1	31	<0.05	104	102
	2	L	12	1430	30	1790	3200	5060	8760	<0.1	510	150	45.5	0.54	25300	<0.50	2.46	190	1	0.4	<50	<0.1	47.2	24.3	31.6	9.7	47400	27.8	14.8	8.1	687	<2	<0.01	27.4	0.2	<0.1	1.7	320	1.2	106	41	----	----	----
		M	11	1770	40	1600	2820	5340	8050	<0.1	580	161	101	0.76	23200	<0.50	2.35	190	1	0.5	<50	<0.1	43.3	25.4	29.6	8.7	44400	27.6	14.7	7.6	623	<2	<0.01	26.5	0.3	<0.1	1.6	300	1.2	101	38.2	----	----	----
		R	12	5340	370	4980	3620	4320	8580	<0.1	540	169	29.2	0.66	28400	<0.50	2.7	240	1	0.4	<50	<0.1	46.2	25.4	31.1	10.3	49200	31	16.1	8.2	792	<2	<0.01	27	0.3	<0.1	1.9	280	1.2	105	40.5	----	----	----
	3	L	8	860	50	830	1010	2350	3180	<0.1	330	117	26	0.4	8090	<0.50	1.16	90	<1	0.2	<50	<0.1	18.9	13.1	11.4	3.3	19900	11.7	7.8	2.8	371	<2	<0.01	11.1	0.1	<0.1	0.6	200	0.6	50	15.4	----	----	----
K3		M	10	4290	370	3940	2740	3860	5730	<0.1	560	150	110	0.53	22000	<0.50	2.03	220	1	0.3	<50	<0.1	33.3	16.8	22.8	7.7	36900	24.5	12.8	5.8	505	<2	<0.01	18.7	0.3	<0.1	1.4	140	0.8	79	28.9	----	----	----
		R	12	750	50	930	1550	2970	4220	<0.1	580	150	49.8	0.55	14000	<0.50	1.74	130	<1	0.2	<50	<0.1	25.7	18.6	17.1	5.4	28700	18.1	10.9	4.3	462	<2	<0.01	15.8	0.2	<0.1	1	190	0.7	67.6	22.8	<0.05	86.1	87.6
	4	L	11	900	40	910	1650	3210	4680	<0.1	370	139	45.1	0.33	14600	<0.50	1.76	130	<1	0.2	<50	<0.1	28.6	17.8	17.9	5.6	29900	17.2	10.1	4.6	430	<2	<0.01	16.3	0.2	<0.1	1	240	0.8	69.9	23.1	----	----	----
		M	12	1380	10	1740	2700	5500	8380	<0.1	480	192	72.8	0.45	22100	<0.50	2.4	190	1	0.4	<50	<0.1	43.8	26	29	8.7	45800	26.6	15.3	7.5	686	<2	<0.01	27	0.2	<0.1	1.5	370	1.3	105	39.4	----	----	----
		R	11	840	30	730	1950	3530	5840	<0.1	430	139	37.8	0.37	14600	<0.50	1.57	160	<1	0.2	<50	<0.1	27.6	19	20.1	5.6	29600	20.8	12.2	4.8	391	<2	<0.01	18	0.2	<0.1	0.9	220	1	66.8	25.1	----	----	----
	5	L	12	440	10	1020	2900	5490	9510	<0.1	340	146	34.9	0.36	22100	<0.50	2.41	180	<1	0.4	<50	<0.1	47.4	25.7	31.2	9	47200	26.6	15	8.2	649	<2	<0.01	29.6	0.2	<0.1	1.6	490	1.4	107	43	----	----	----
		M	9	1410	160	1640	1500	2860	5170	<0.1	290	137	7.3	0.36	11400	<0.50	1.39	110	<1	0.2	<50	<0.1	26	16.2	17.4	4.8	26300	17.2	10	4.4	437	<2	<0.01	16.9	0.1	<0.1	0.9	250	0.8	65	23.4	----	----	----
		R	12	780	10	950	2560	4990	8200	<0.1	340	148	33.9	0.41	19400	<0.50	2.27	160	<1	0.4	<50	<0.1	42	21.9	27.5	7.8	41200	23.7	13.2	7.3	606	<2	<0.01	25.5	0.3	<0.1	1.4	420	1.2	92.5	38.2	<0.05	90.7	93.2
		SS-SQGV	**160**	**5840**	**812**	**5160**	**2200**	**4720**	**6720**	**1**	**522**	**160**	**7.2**	**0.7**	**17300**	**0.12**	**2.3**	**172**	**0.76**	**0.16**	**6.2**	**<0.05**	**29**	**23**	**19**	**8.3**	**33200**	**20**	**11**	**7**	**1100**	**0.28**	**0.49**	**19**	**0.11**	**<0.05**	**0.7**	**100**	**1**	**66**	**31**			
	1	L	8	5870	370	4000	1590	3320	4800	<0.1	520	117	36.9	2.26	11700	<0.50	1.86	110	<1	0.2	<50	<0.1	25.2	18.6	18.2	4.4	24500	17.8	10.4	4.5	363	<2	<0.01	17.7	0.2	<0.1	1.4	210	1	67.2	22.8	----	----	----
		M	13	19900	2300	14000	4500	4160	8740	<0.1	500	166	59.3	0.51	26400	<0.50	2.76	230	1	0.3	<50	<0.1	42.4	24.5	29.8	8.8	42400	29	15.3	8.7	526	<2	<0.01	26.1	0.3	<0.1	1.7	200	1.3	99.8	38.9	----	----	----
		R	15	6160	710	6510	3250	3360	6970	0.1	570	165	40.7	0.69	19200	<0.50	2.44	170	1	0.3	<50	<0.1	32.2	25.9	24.5	6.7	35300	25.5	14.1	7	553	<2	<0.01	21.9	0.2	<0.1	1.2	200	1.3	90.6	30.9	----	----	----
	2	L	6	8490	1160	6970	2200	2210	5050	<0.1	450	143	29.2	0.55	12500	<0.50	1.93	140	<1	0.2	<50	<0.1	24.8	22.4	18.2	4.8	26800	17.9	11	4.8	468	<2	<0.01	16.8	0.2	<0.1	0.9	160	0.9	74.8	22.3	----	----	----
		M	10	11600	690	9090	3740	3480	7970	<0.1	430	131	51.9	0.45	23900	<0.50	2.24	200	1	0.3	<50	<0.1	39.8	22.6	27.3	8.1	39700	25.7	13.4	8.1	552	<2	<0.01	25.1	0.3	<0.1	1.5	190	1.2	90.1	37.4	----	----	----
		R	8	11700	1870	9420	3320	2080	6080	<0.1	540	164	19.6	0.72	15600	<0.50	2.24	110	<1	0.2	<50	<0.1	27	24.7	20.7	5.6	29800	20	12.3	6.7	497	<2	<0.01	18.1	0.3	<0.1	1.1	160	1	79	25.8	<0.05	80.3	88.2
	3	L	6	9210	1120	6660	2570	2710	5940	<0.1	590	149	20	0.71	15700	<0.50	2.13	160	<1	0.3	<50	<0.1	30.2	22.9	21.9	5.8	31300	21.1	12.9	6	604	<2	<0.01	19.5	0.2	<0.1	1.1	210	1	83.4	27.2	----	----	----
K2		M	8	5080	240	4050	1980	3650	5590	<0.1	360	114	18	0.4	14700	<0.50	1.88	160	<1	0.2	<50	<0.1	30.4	20.8	20.8	5.4	28700	20.2	12.7	5.7	495	<2	<0.01	19.7	0.2	<0.1	1	180	0.9	76.2	26.4	----	----	----
		R	10	13600	1560	9820	3750	4440	8090	<0.1	440	123	72	0.63	22100	<0.50	2.48	220	1	0.3	<50	<0.1	38.4	22.7	27.6	7.6	38500	26.6	14.3	8.4	514	<2	<0.01	24.6	0.3	<0.1	1.6	200	1.2	92.1	35.7	----	----	----
	4	L	6	5080	430	4330	1760	3120	4720	<0.1	550	125	23	0.77	13600	<0.50	1.92	130	<1	0.3	<50	<0.1	25.8	18.2	17.8	5.2	27700	17.9	10.9	5.1	511	<2	<0.01	16	0.3	<0.1	1	220	0.9	67.8	22.9	----	----	----
		M	6	3460	200	3470	1370	2180	3890	<0.1	230	90	19.4	0.23	11000	<0.50	1.76	80	<1	0.2	<50	<0.1	21.9	14.7	13.9	4.1	21700	13.4	8.9	3.7	378	<2	<0.01	13.2	0.1	<0.1	0.8	200	0.6	53.2	17.7	----	----	----
		R	7	5520	660	5600	2430	3020	6080	<0.1	370	101	7.2	0.29	16800	<0.50	2.16	130	<1	0.3	<50	<0.1	29.4	16.9	20.3	6.1	29300	18.8	11	5.6	381	<2	<0.01	17.9	0.2	<0.1	1	230	1	66.9	25.5	<0.05	75.1	85.1
	5	L	6	4930	570	4270	1770	1430	3070	<0.1	290	101	9.7	0.12	10900	<0.50	1.36	100	<1	0.1	<50	<0.1	18.4	9.6	11.3	3.9	19100	12.7	7.2	3.4	218	<2	<0.01	9.8	0.1	<0.1	0.7	120	0.5	45.5	14.8	----	----	----
		M	6	4820	590	4450	1400	6070	2800	<0.1	300	89	6.5	0.31	8060	<0.50	1.39	110	<1	0.1	<50	<0.1	15.2	14.1	9.5	3.1	15800	15.3	7	2.5	436	<2	<0.01	9.4	0.1	<0.1	0.6	100	0.4	41.9	11.6	----	----	----
		R	5	5240	720	5100	1580	1620	2840	<0.1	260	84	7.7	0.27	9300	<0.50	1.33	120	<1	0.1	<50	<0.1	16.7	10.4	9.9	3.4	16600	11.9	6.9	2.7	332	<2	<0.01	9.2	0.2	<0.1	0.6	110	0.4	41.1	13	----	----	----

Site			Major Ions							Nutrients					Total Metals																											Herbicide		
		Analyte	Si	Cl	SO4	Na	K	Ca	Mg	NO3-N	N-Total	P-Total	NH4-N	TOC%	Al	Sb	As	Ba	Be	Bi	B	Cd	Cr	Co	Cu	Ga	Fe	La	Pb	Li	Mn	Mo	Hg	Ni	Se	Ag	Sn	Ti	U	V	Zn	Atrazine	DDE%	DEF%
		LOR	1	10	10	50	50	50	50	0.1	20	2	0.2	0.02	50	0.5	1	10	1	0.1	50	0.1	1	1	1	0.1	50	0	1	0.1	10	2	0.01	1	0.1	0.1	0.1	10	0.1	2	1	0.05	0.05	0.05
Site		DGV														2	20					1.5	80		65				50				0.15	21		1					200			
		GV-High														25	70					10	370		270				220				1	52		4					410			
K1		**SS-SQGV**	**190**	**10400**	**1820**	**8080**	**2640**	**11200**	**6520**	**1**	**460**	**150**	**4.2**	**0.7**	**17000**	**0.09**	**2.5**	**114**	**0.75**	**0.14**	**13.2**	**<0.05**	**27**	**21**	**15**	**7.7**	**29400**	**18**	**10**	**7**	**630**	**0.32**	**0.45**	**17**	**0.11**	**<0.05**	**0.6**	**112**	**0.8**	**56**	**25**			
	1	L	18	26700	3820	17800	5660	27100	14700	<0.1	430	228	13	0.35	17000	<0.50	6.06	30	1	0.3	<50	<0.1	34.9	15.6	16.5	5.9	29600	16.6	10.1	14.2	456	<2	<0.01	18	0.2	<0.1	1.1	340	0.7	53.6	29.8	----	----	----
		M	18	26900	4210	17100	5390	24400	14300	<0.1	510	258	15.3	0.43	15400	<0.50	6.24	20	1	0.4	<50	<0.1	32.5	14.5	15.5	5.3	27800	15	9.4	13.8	386	<2	<0.01	16.6	0.3	<0.1	1	330	0.6	49.9	28.3	----	----	----
		R	15	23600	3700	16000	4850	23200	12000	<0.1	530	256	8.6	0.36	14300	<0.50	4.95	40	1	0.2	<50	<0.1	28.2	12.8	14.2	4.9	24800	14.2	8.6	10.9	302	<2	<0.01	15	0.2	<0.1	0.9	280	0.6	46	24.5	<0.05	82.1	100
	2	L	10	16000	1460	13800	3230	3520	6710	<0.1	530	157	35.9	0.73	14600	<0.50	2.52	110	1	0.2	<50	<0.1	24.9	14.9	17	5.2	25600	16.4	9.6	5.7	322	<2	<0.01	14.8	0.2	<0.1	1	160	0.7	63	22.1	----	----	----
		M	23	34600	3730	22900	6280	7880	13100	<0.1	700	248	64.1	0.5	25900	<0.50	5.1	130	2	0.3	<50	<0.1	42	19	25.2	8.6	39800	24	13.4	11.8	454	<2	<0.01	23	0.3	<0.1	1.6	200	0.8	80.2	37	----	----	----
		R	21	32600	3920	21400	5960	14100	13700	<0.1	650	260	54.6	0.5	21500	<0.50	5.45	80	2	0.3	<50	<0.1	37.8	15.9	20.3	7.2	34500	17.7	10.8	12.9	435	<2	<0.01	19.7	0.2	<0.1	1.4	240	0.7	67.3	31.5	----	----	----
	3	L	12	11600	1550	12700	4340	2360	6610	<0.1	420	115	10.7	0.31	22000	<0.50	2.26	200	1	0.3	<50	<0.1	33.3	20.9	22.6	7.3	34300	23.8	14.7	6.4	439	<2	<0.01	19.9	0.3	<0.1	1.4	120	1.3	78.2	29.9	----	----	----
		M	10	23900	3800	18800	5230	2110	7620	<0.1	390	119	10.5	0.41	22500	<0.50	2.18	190	1	0.3	<50	<0.1	34.4	18	24.1	7.6	34500	26.3	13.7	7.5	277	<2	<0.01	20.7	0.2	<0.1	1.5	120	1.1	83.1	31.5	----	----	----
		R	7	12400	1970	9640	3370	1660	5460	<0.1	380	122	5.6	0.56	13800	<0.50	2.27	120	<1	0.2	<50	<0.1	25.6	17.6	18	5.2	27500	17.3	10.5	5.6	171	<2	<0.01	16	0.2	<0.1	1	190	0.8	70.6	24.4	----	----	----
	4	L	6	13100	1950	10200	2880	1920	5960	<0.1	360	107	23.4	0.46	14800	<0.50	2.04	150	<1	0.2	<50	<0.1	26.6	21.3	20.2	5.5	29600	19.4	11.7	5.1	332	<2	<0.01	17.3	0.2	<0.1	1	190	0.9	77.7	24.9	----	----	----
		M	6	11100	1480	8040	2320	2230	5040	<0.1	400	120	23.2	0.84	12100	<0.50	1.83	120	<1	0.2	<50	<0.1	25.2	18.5	16.8	4.6	25400	16.2	10.7	4.4	448	<2	<0.01	16.2	0.2	<0.1	0.9	200	0.8	67.3	21.2	----	----	----
		R	7	13200	1760	10200	3350	2100	6630	<0.1	540	144	27.7	0.57	17600	<0.50	2.3	150	<1	0.3	<50	<0.1	32.2	23.2	23.4	6.5	34000	22	13	6.3	357	<2	<0.01	20.4	0.3	<0.1	1.2	220	1	85.7	29.3	<0.05	88.3	83.2
	5	L	7	10900	1770	9000	2720	1410	4890	<0.1	280	85	11.2	0.43	12700	<0.50	2.09	90	<1	0.2	<50	<0.1	23.3	15	16.5	4.6	24200	16.3	10.3	5	156	<2	<0.01	14	0.2	<0.1	0.9	140	0.7	65	20.3	----	----	----
		M	7	8810	1300	7780	2020	1280	3890	<0.1	310	92	8.5	0.42	9280	<0.50	1.89	80	<1	0.2	<50	<0.1	17.8	13.3	13.2	3.4	18300	13.2	8.6	3.6	206	<2	<0.01	11.3	0.2	<0.1	0.7	120	0.6	51.9	15.7	----	----	----
		R	6	8250	1360	7220	2630	1460	5460	<0.1	200	91	13.4	0.32	12900	<0.50	1.96	140	<1	0.2	<50	<0.1	26.2	16.7	18.1	4.6	25500	17.2	10.8	5.3	306	<2	<0.01	16.6	0.1	<0.1	0.9	190	0.8	67	22.2	----	----	----
EST01		**SS-SQGV**	**154**	**8800**	**1580**	**6560**	**2900**	**48600**	**7980**	**1**	**344**	**210**	**2**	**0.71**	**10520**	**0.06**	**3.6**	**17**	**0.34**	**<0.05**	**23**	**<0.05**	**18**	**10**	**9**	**4.3**	**18000**	**12**	**6**	**8**	**290**	**0.23**	**0.21**	**10**	**0.06**	**<0.05**	**<0.5**	**220**	**0.5**	**29**	**18**			
		L	7	9610	1510	7000	1730	49500	6590	<0.1	160	202	7.2	0.17	5170	<0.50	3.17	10	<1	<0.1	<50	<0.1	12.4	6.5	5.3	2	10400	10.5	4	5.3	235	<2	<0.01	7.6	0.1	<0.1	0.4	320	0.4	21.2	12.8	----	----	----
		M	8	10100	1590	8690	2640	40400	8450	<0.1	240	200	11.1	0.12	7780	<0.50	3.96	10	<1	0.1	<50	<0.1	17.2	8.6	7.9	2.9	15200	11.1	5.5	7.5	262	<2	<0.01	9.8	0.2	<0.1	0.6	270	0.4	28.1	16.3	----	----	----
		R	8	9960	1620	8200	2280	47800	7840	<0.1	160	193	1	0.16	6800	<0.50	3.69	10	<1	0.1	<50	<0.1	15	7.6	6.8	2.5	13200	11.4	4.8	6.4	260	<2	<0.01	9	0.1	<0.1	0.5	340	0.5	25.6	15.3	----	----	----
EST02		**SS-SQGV**	**160**	**11000**	**2020**	**7020**	**1680**	**59800**	**7120**	**1**	**168**	**240**	**1**	**0.52**	**6098**	**<0.05**	**5.2**	**12**	**0.19**	**<0.05**	**22**	**<0.05**	**13**	**10**	**5.6**	**2.8**	**15000**	**12**	**4**	**6**	**388**	**0.21**	**0.662**	**7**	**<0.05**	**<0.05**	**<0.5**	**224**	**0.4**	**24**	**15**			
		L	8	13000	2110	10000	2700	43200	8030	<0.1	240	220	0.9	0.19	7500	<0.50	4.18	10	<1	0.1	<50	<0.1	16.2	8.3	7.1	2.7	15200	11.2	5.3	6.6	252	<2	<0.01	9.1	0.1	<0.1	0.5	270	0.5	28.5	14.5	----	----	----
		M	6	9390	1470	7000	1740	63000	7460	<0.1	90	220	1.9	0.09	4810	<0.50	7.22	20	<1	<0.1	<50	<0.1	12.5	8.1	4.7	2	14000	12.6	4.8	4.9	446	<2	<0.01	8	0.2	<0.1	0.4	250	0.5	27.6	12.5	----	----	----
		R	6	13500	2080	8750	1940	89200	8780	<0.1	180	285	<0.2	0.23	5090	<0.50	6.07	10	<1	<0.1	<50	<0.1	12.8	8.3	4.9	2.1	13500	14.9	4.7	5.6	438	<2	<0.01	8.4	0.1	<0.1	0.4	270	0.5	25	13.3	<0.05	89.4	94.7
EST03		**SS-SQGV**	**178**	**10900**	**2580**	**7420**	**2220**	**68200**	**7700**	**<1**	**176**	**264**	**2**	**0.5**	**7370**	**0.07**	**8.6**	**12**	**0.23**	**<0.05**	**24**	**<0.05**	**15**	**12**	**5.6**	**3.3**	**17000**	**12**	**5**	**7**	**546**	**0.3**	**0.896**	**8**	**0.05**	**<0.05**	**0.6**	**258**	**0.4**	**30**	**15**			
		L	7	9190	1360	7300	2040	52800	7680	<0.1	180	208	9.2	0.17	5880	<0.50	5.41	<10	<1	0.2	<50	<0.1	13.8	8	5.6	2.3	13700	11.2	4.9	6	340	<2	<0.01	8.4	0.2	<0.1	0.5	230	0.5	26.1	13.5	----	----	----
		M	5	10200	1590	7830	1710	90800	8760	<0.1	120	275	1.5	0.11	4400	<0.50	8.91	10	<1	<0.1	<50	<0.1	11.8	8.5	4.2	1.9	14500	15	5	4.9	554	<2	<0.01	8.5	0.1	<0.1	0.4	260	0.5	28	12.6	----	----	----
		R	6	10600	1620	8000	1860	99700	9240	<0.1	130	256	<0.2	0.12	4770	<0.50	7.62	10	<1	<0.1	<50	<0.1	12.2	8.5	4.5	2	14100	16	5	5.3	523	<2	<0.01	8.4	0.2	<0.1	0.4	260	0.5	26.4	12.7	----	----	----

Appendix 3. Catch per unit effort (CPUE) calculations for *Pristis pristis and Pristis clavata* by site and year expressed as individuals per net metre per hour ($m^{-1}.h^{-1}$).

Site Information		*Pristis pristis*											
		2011		2012		2013		2020		2021		2022	
Code	Type	n	CPUE	n	CPUE	n	CPUE	n	CPUE	n	CPUE	n	CPUE
EST01	PE	0	0	0	0	0	0	0	0	0	0	-	-
EST02	PE	0	0	0	0	0	0	0	0	-	-	0	0
EST03	PE	0	0	0	0	0	0	0	0	-	-	0	0
K1	PE	0	0	1	0.000813	0	0	2	0.001626	0	0	0	0
K2	PE	5	0.004065	2	0.001626	1	0.000813	0	0	0	0	0	0
K3	PE	0	0	0	0	0	0	1	0.000813	-	-	1	0.000813
K4	PE	0	0	0	0	0	0	1	0.001075	1	0.001075	0	0
KE1	Ref	0	0	0	0	0	0	0	0	-	-	0	0
SR4	Ref	0	0	0	0	0	0	0	0	-	-	0	0
DR1	Ref	0	0	0	0	0	0	0	0	0	0	0	0

Site Information		*Pristis clavata*											
		2011		2012		2013		2020		2021		2022	
Code	Type	n	CPUE	n	CPUE	n	CPUE	n	CPUE	n	CPUE	n	CPUE
EST01	PE	7	0.014583	11	0.022917	0	0	4	0.008333	4	0.008333	-	-
EST02	PE	0	0	0	0	2	0.004167	3	0.00625	-	-	0	0
EST03	PE	0	0	7	0.014583	3	0.00625	2	0.004167	-	-	0	0
K1	PE	0	0	0	0	0	0	0	0	0	0	6	0.006061
K2	PE	0	0	0	0	0	0	0	0	0	0	0	0
K3	PE	0	0	0	0	0	0	0	0	-	-	0	0
K4	PE	0	0	0	0	0	0	0	0	0	0	0	0
KE1	Ref	0	0	0	0	0	0	0	0	-	-	0	0
SR4	Ref	0	0	0	0	0	0	0	0	-	-	0	0
DR1	Ref	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 4. Historic fish species and numbers recorded from each potentially impacted and reference (KE1, DR1 and SR4) site sampled in 2022.

	K1						K2						K3					K4						Reference (KE1, SR4, DR1)					
Species	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Acanthopagrus palmaris		1																											
Ambassis interrupta							1						1																
Ambassis sp.											1			1															
Amniataba percoides				1						1						1					1			28		2	2	1	
Anodontiglanis dahli																								4		2	2		
Arrhamphus sclerolepis	5	10		5	2		1		10		1																		
Carcharhinus leucas	13		2	1	6	6					9		2	1	2		2												
Eleutheronema tetradactylum			14	2	16	6					7	4			1														
Ellochelon vaigiensis	7	6	3	9	7	3			6	14	18	2	6	3		3	14						23						
Elops hawaiensis	3				1		1						1																
Gerres filamentosus																										1			
Glossamia aprion	1										1											1		1					
Glossogobius spp.											1											1							1
Hephaestus jenkinsi								1														1		4				1	2
Hypseleotris compressa													1																
Kurtus gulliveri	1							2																					
Lates calcarifer	4	3	11	2	10	4	2		4	4	11	10	7	7		7	7	1	12		1	5	4	3	3	1			1
Leiognathus equulus	14	2		1	2		8	7					3	2	1														
Leiopotherapon unicolor																					1				1			1	
Lutjanus argentimaculatus	1				1																								2
Marilyna meraukensis				1	3			1		1	2	3			2	1	1												
Megalops cyprinoides			2		1			1		4	1			1				2	1		2	3	2	3		3	2	4	10
Melanotaenia australis																						1						1	3
Mogurnda mogurnda																		1											
Moolgarda buchanani		6		8	33	1																							
Nematalosa erebi	72	146	155	149	242	22	68	116	108	84	76	67	61	40	62	59	117	19	8	42	48	11	21	47	68	27	11	7	9
Nematalosa vlaminghi		4																											
Neoarius graeffei	9	7	8	7	4	6	13	18	4	22	16	5	36	23	17	25	21	21	8	7	14	10	9	21	8	2	13	1	5
Neoarius midgleyorum			1		2						3				1							1		16	2	2	3	1	21
Neosilurus ater										1								8	6	2	1			2		1	1	1	1
Nibea squamosa								2						1		1													
Parambassis gulliveri									1							1		1		1				7			6		
Planiliza ordensis	46	27	14	13	9	19	22	19	11	38	15	27	34	17	3	20	25	24	5	4	2	15		13	15	37	5		10
Plicofollis argyropleuron		1																											
Plicofollis nella				2																									
Polydactylus macrochir	1	1			2		1																						
Pomadasys kaakan					1												2												
Pristis clavata						6																							
Pristis pristis		1		2			5	2	1							1	2				1	1							
Scatophagus argus											4																		
Scomberoides commersonnianus		1																											
Strongylura krefftii			1	1	1		2	2				2	1	1		3	2		1			1		1		1		2	1
Syncomistes bonapartensis							1																	4			3		
Syncomistes trigonicus																								1					
Thryssa kammalensis							14		1				4		2														
Thryssa sp.		11			7	4		1								4													
Toxotes chatareus	4	4	1		10	2	4	3	5	1	5	4	7		1	1	2	1	2	2	2	1		1	1		5	1	4
Zenarchopterus sp.											1																		

Appendix 5. Historic edge macroinvertebrate species data (adjusted taxa level of identification) from each site sampled in 2022. X = taxa recorded.

				Keep River																								Reference					
				K1						K2						K3						K4											
CLASS	Order	Family	Lowest Taxon	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Oligochaeta			Oligochaeta spp.					x	x	x	x		x		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Polychaeta			Polychaeta spp.	x	x	x	x	x	x			x		x	x			x															x
Arachnida	Sarcoptiformes		Oribatida spp.					x																					x				
	Trombidiformes	Trombidioidea	Trombidioidea spp.					x									x															x	
			Hydracarina spp.															x					x	x		x		x	x	x		x	
			Acarina spp.																x						x		x				x		x
Branchiopoda	Diplostraca	Cyzicidae	Eocyzicus spp. (juv)																														x
Entognatha	Entomobryomorpha	Entomobryoidea	Entomobryoidea spp.										x				x					x								x			
	Poduromorpha	Poduroidea	Poduroidea spp.																									x					
Insecta	Coleoptera	Carabidae	Carabidae spp.												x									x			x		x				
		Chrysomelidae	Chrysomelidae spp.																		x												
		Curculionidae	Curculionidae spp.											x		x																	
		Dytiscidae	*Allodessus bistrigatus*		x						x																						
			Batrachomatus spp.																											x			
			Bidessini spp.									x																	x	x			
			Bidessus spp.																								x						x
			Clypeodytes feryi													x			x			x	x		x	x	x		x	x	x	x	
			Clypeodytes larsoni																								x					x	x
			Clypeodytes migrator																			x											
			Clypeodytes weiri																								x					x	
			Cooelatus clarki	x																													
			Copelatus nigrolineatus													x		x							x	x			x	x	x	x	x
			Cybister godeffroyi																											x			
			Cybister tripunctatus				x																										
			Hydaticus consanguineus													x						x										x	
			Hydaticus vittatus	x																					x			x					
			Hydroglyphus basalis	x						x	x		x			x	x		x			x	x	x	x	x		x	x	x		x	
			Hydroglyphus daemeli							x	x					x						x						x	x				
			Hydroglyphus fuscolineatus																											x			
			Hydroglyphus godeffroyi							x						x						x					x						
			Hydroglyphus grammopterus										x						x							x	x				x		x
			Hydroglyphus leai	x	x					x	x	x				x	x						x	x		x	x	x	x	x			x
			Hydroglyphus mastersii																								x						
			Hydroglyphus orthogrammus																						x						x		
			Hydroglyphus trifasciatus	x						x						x						x						x	x				
			Hydroglyphus trilineatus														x												x				
			Hydrovatus opacus														x																
			Hydrovatus ovalis				x			x				x		x			x		x	x			x	x	x	x			x	x	x
			Hydrovatus parallelus								x						x	x					x	x			x			x			
			Hyphydrus contiguus																									x					

				Keep River																								Reference					
				K1						K2						K3						K4											
CLASS	Order	Family	Lowest Taxon	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Insecta	Coleoptera	Dytiscidae	*Hyphydrus decemmaculatus*																						x								
			Hyphydrus elegans																								x		x				x
			Hyphydrus lyratus	x						x	x		x			x	x						x	x	x			x	x		x		x
			Hyphydrus spp.																										x			x	
			Laccophilus cingulatus							x	x					x		x				x		x	x			x	x	x			x
			Laccophilus clarki	x						x	x		x		x	x	x		x			x	x	x	x	x	x	x	x	x	x		x
			Laccophilus religatus								x																x						
			Laccophilus seminiger																x						x								
			Laccophilus sharpi				x			x	x		x			x	x				x	x	x	x	x		x	x	x	x	x		x
			Laccophilus spp.																					x		x			x	x	x		
			Laccophilus spp. (L)																								x						
			Laccophilus transversalis																								x						
			Laccophilus unifasciatus													x						x						x		x		x	
			Laccophilus walkeri										x			x		x	x			x	x					x		x	x	x	
			Limbodessus compactus	x	x												x		x			x		x		x		x	x	x			x
			Megaporus ruficeps				x			x	x	x	x			x	x	x			x	x	x		x	x	x	x	x		x		x
			Megaporus spp.																		x												x
			Neobidessodes flavosignatus	x						x																						x	
			Neobidessodes mjobergi							x						x												x				x	
			Neobidessodes spp.							x														x									
			Onychohydrus spp.																										x				
			Rhantaticus congestus																						x						x		
			Sternopriscus aquilonaris																											x			
			Tiporus demmaculatus																														x
			Tiporus josepheni																							x						x	x
			Tiporus undecimmaculatus																		x										x		
		Elmidae	*Austrolimnius* spp.								x							x										x	x	x	x		
			Notriolus spp.													x																	
			Elmidae (L)																														x
		Georissidae	*Georissus* spp.										x								x									x			x
		Gyrinidae	*Dineutus australis*																														
			Macrogyrus darlingtoni																					x						x			
			Macrogyrus paradoxus																														
			Macrogyrus spp.																										x				
		Hetericeridae	*Heterocerus* spp.						x																								x
		Heteroceridae	Heteroceridae spp.																													x	
		Hydraenidae	*Hydraena* spp.	x					x	x	x		x		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
			Limnebius spp.																		x			x								x	
			Ochthebius spp.	x	x					x	x	x	x				x	x	x				x	x		x	x			x	x		
		Hydrochidae	*Hydrochus* spp.	x	x		x			x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
		Hydrophilidae	*Amphiops australicus*							x	x	x	x		x			x	x		x							x		x	x		x
			Amphiops duplopunctulatus																											x			

				Keep River																								Reference					
				K1						K2						K3						K4											
CLASS	Order	Family	Lowest Taxon	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Insecta	Coleoptera	Dytiscidae	*Amphiops micropunctatus*																														x
			Amphiops spp.																									x	x	x	x		
			Anacaena spp.																x		x												
			Berosus dallasae																													x	
			Berosus josephenae														x																
			Berosus munitipennis																			x											
			Berosus pulchellus														x							x	x	x							
			Chaetarthria nigerrima																														
			Coelostoma fabricii																		x							x					
			Enochrus deserticola				x				x	x	x				x	x	x					x	x				x	x	x		x
			Enochrus esuriens	x																													
			Enochrus eyrensis	x						x						x						x						x					x
			Helochares clypeatus													x					x						x						
			Helochares marreensis												x			x			x					x	x	x					x
			Helochares spp.										x					x	x					x		x		x		x			
			Helochares tatei	x			x			x			x					x	x									x					x
			Helochares tristis										x																				
			Hydrobiomorpha bovilli																														x
			Laccobius billi										x																				x
			Paracymus pygmaeus	x	x					x	x		x	x		x	x	x	x			x	x	x	x	x		x	x	x	x	x	
			Paracymus spenceri																								x			x			x
			Paracymus spp.										x																		x		
			Regimbartia attenuata	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x
			Regimbartia spp.																											x			
			Sternnolophus marginatus													x						x											
			Sternolophus spp.																									x					
			Hydrophilidae (L)																								x						
		Limnichidae	Limnichidae spp.								x		x				x	x	x		x			x	x	x		x	x	x	x	x	
		Noteridae	*Hydrocanthus micans*				x			x						x	x	x						x	x	x		x			x		
			Hydrocanthus waterhousei																		x						x						x
			Neohydrocoptus subfasciatus	x	x					x					x	x	x	x			x	x			x	x	x	x		x	x		
			Notomicrus tenellus																x		x					x	x			x	x	x	x
		Scirtidae	Scirtidae spp.													x								x			x	x	x	x	x	x	x
		Spercheidae	*Spercheus* spp.										x																				
		Staphylinidae	Pselaphinae spp.																								x						
			Staphylinidae spp.					x					x	x					x		x				x	x				x	x		
	Diptera	Cecidomyiidae	Cecidomyiidae spp.															x														x	
		Ceratopogonidae	*Austroconops* spp.																								x						
			Ceratopogoninae spp.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
			Dasyheleinae spp.	x		x				x	x	x	x			x	x	x	x			x	x	x		x		x	x	x			
			Dasyheleinae spp.																								x						x
			Forcipomyiinae spp.										x				x	x				x				x		x	x	x	x		

				Keep River																									Reference					
				K1						K2						K3						K4											
CLASS	Order	Family	Lowest Taxon	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Insecta	Diptera	Chironomidae	Chironomidae spp.	x			x			x	x	x	x	x		x	x	x	x			x	x	x	x	x		x	x	x	x	x	
			Chironominae spp.	x	x		x			x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
			Orthocladiinae spp.			x					x						x	x	x			x	x	x	x	x	x	x	x	x	x		x
			Tanypodinae spp.	x		x	x			x	x		x			x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
		Culicidae	*Aedes* spp.										x				x	x				x							x		x		
			Anopheles spp.						x	x	x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
			Culex spp.								x		x						x					x	x				x	x			
			Culicidae spp.								x	x	x					x	x				x		x						x	x	
		Dolichopodidae	Dolichopodidae spp.								x																						
		Empididae	Empididae spp.													x																	
		Ephydridae	Ephydridae spp.																					x									
		Muscidae	Muscidae spp.																					x							x	x	
		Psychodidae	Psychodidae spp.																											x			
		Sciomyzidae	Sciomyzidae spp.																						x						x		
		Simuliidae	Simuliidae spp.			x				x	x						x	x			x			x					x	x			
		Stratiomyidae	Stratiomyidae spp.								x		x			x	x	x	x			x	x	x	x	x		x	x	x	x		
		Tabanidae	Tabanidae spp.										x					x	x			x		x	x	x	x	x	x	x	x		x
		Tanyderidae	Tanyderidae spp.															x					x	x				x	x	x			
		Tipulidae	Tipulidae spp.														x																
	Ephemeroptera	Baetidae	*Cloeon fluviatile*	x			x			x	x	x	x				x	x	x		x		x	x	x	x		x	x	x	x	x	
			Cloeon sp. NT2							x											x							x					x
			Cloeon sp. Red Stripe				x			x	x	x				x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x
			Cloeon spp.						x		x					x		x			x	x	x				x	x	x				x
			Platybaetis spp.														x																
			Pseudocloeon hypodelum																									x					
			Pseudocloeon plectile								x														x								
			Pseudocloeon spp.															x															
			Baetidae spp.	x			x			x	x	x	x			x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	
		Caenidae	*Tasmanocoenis* sp. E							x											x								x			x	x
			Tasmanocoenis sp. M										x					x	x					x		x				x		x	x
			Tasmanocoenis sp. P/*arcuata*							x						x	x	x					x	x	x	x	x	x	x	x	x	x	x
			Tasmanocoenis spp.														x						x						x				
			Wundacaenis dostini																				x	x		x		x	x	x	x	x	
			Caenidae spp.				x			x	x		x			x	x	x	x			x	x	x	x	x		x	x	x	x	x	
			Tasmancoensis spp.																		x												x
		Leptophlebiidae	*Atalophlebia* spp.																										x				
			Manggabora wapitja																											x			
			Thraulus spp.																									x			x		
			Leptophlebiidae spp.																									x		x			
	Hemiptera	Belostomatidae	*Diplonychus eques*													x						x						x					x
			Diplonychus spp.				x				x		x			x			x			x			x			x	x	x	x	x	
			Belostomatidae spp.								x		x				x	x	x				x	x	x				x	x	x		

				Keep River																								Reference					
				K1						K2						K3						K4											
CLASS	Order	Family	Lowest Taxon	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Insecta	Hemiptera	Gelastocoridae	*Nerthra* spp.													x	x										x	x					
		Gerridae	*Limnogonus fossarum gilguy*	x						x	x	x			x	x	x				x	x		x			x	x					
			Limnogonus hungerfordi														x											x					
			Limnogonus luctuosus																			x		x				x					
			Limnogonus spp.								x						x																x
			Rhagadotarsus anomalus							x						x	x						x				x	x	x	x			x
			Tenagogerris pallidus												x																		
			Gerridae spp.	x	x					x	x	x				x	x				x		x					x					
		Hebridae	*Hebrus axillaris*																									x					
			Hebrus nourlangiei																									x					
			Laccotrephes tristis																x						x						x		
			Merragata hackeri							x														x				x		x			
			Hebridae spp.														x	x												x			
		Hydrometridae	*Hydrometra* spp.								x																						x
		Meenoplidae	Meenoplidae spp.												x																		
		Mesoveliidae	*Mesovelia ebbenielseni*		x					x																		x					
			Mesovelia horvathi	x								x									x	x		x			x	x		x			x
			Mesovelia spp.								x	x			x						x	x	x	x		x	x	x	x	x			x
			Mesovelia vittigera								x							x			x					x							x
			Mesoveliidae spp.															x															
		Micronectidae	*Austronecta bartzarum*																x				x		x				x		x		
			Austronecta micra										x				x		x				x	x	x	x			x	x	x	x	
			Micronecta adelaidae				x																				x			x	x	x	x
			Micronecta annae																		x			x			x		x	x	x		
			Micronecta gracilis				x																										
			Micronecta lansburyi																														
			Micronecta ludibunda																				x		x				x				
			Micronecta paragoga															x	x					x	x	x				x			
			Micronecta robusta		x						x										x		x					x					
			Micronecta spp.				x						x								x			x	x	x					x		x
			Micronecta virgata																							x							x
			Micronectidae spp.	x		x	x			x			x			x	x	x	x			x	x	x	x	x		x	x	x	x	x	
		Microvelidae	*Microvelia* spp.																		x						x						x
		Naucoridae	*Naucoris subopacus*								x																				x		
		Nepidae	*Austronepa angusta*																		x									x			
			Laccotrephes tristis																														x
			Ranatra diminuta			x	x						x	x	x			x	x		x			x	x		x				x		
			Ranatra occidentalis		x					x	x	x				x	x	x				x	x	x				x	x	x			
			Ranatra spp.								x						x							x			x		x	x			
			Nepidae spp.										x					x	x												x		
		Notonectidae	*Anisops* spp.																		x								x				x
			Enithares atra																												x		x

				Keep River																										Reference					
				K1						K2						K3						K4											
CLASS	Order	Family	Lowest Taxon	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Insecta	Hemiptera	Notonectidae	Enithares loria							x	x		x			x						x	x				x	x	x	x			x
			Nychia sappho							x			x			x			x		x	x	x	x	x	x	x	x	x	x	x	x	x
			Nychia spp.										x																				
			Notonectidae spp.							x	x		x			x	x	x	x			x		x	x	x		x	x	x	x	x	x
		Ochteridae	Ochterus spp. (Juv)																								x						
		Pleidae	Paraplea spp.	x	x		x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
		Veliidae	Microvelia herberti							x						x		x									x	x		x			
			Microvelia katherinae													x													x	x			
			Microvelia malipatili																					x					x				
			Microvelia odontogaster															x												x			
			Microvelia peramoena													x								x				x	x	x			
			Microvelia spp.							x	x	x				x	x					x	x	x				x	x	x			
			Microvelia torresiana													x												x					
			Nesidovelia herberti										x																				
			Nesidovelia peramoena										x						x												x		
			Petrovelia katherinae										x																				
			Veliidae spp.							x			x			x		x	x			x		x	x	x		x		x	x		x
	Lepidoptera	Crambidae	Acentropinae spp.																												x		
			Eoophyla repetitalis																											x			
			Eoophyla spp.																														
			Margarosticha spp.															x												x			
			Parapoynx spp.																											x			
			Tetrernia spp.																											x			
			Lepidoptera spp.															x						x						x			x
	Neuroptera	Sisyridae	Sisyridae spp.																											x	x		
	Odonata	Aeshnidae	Anax spp.																										x				
		Austrocorduliidae	Austrocordulia territoria																											x			
		Coenagrionidae	Argiocnemis spp.								x						x						x										
			Argiocnemis pygmaea																								x						
			Argiocnemis rubescens											x	x								x				x						
			Austroagrion spp.																		x								x				
			Ischnura aurora	x			x			x	x		x						x		x						x	x	x		x		x
			Ischnura heterosticta									x																					
			Ischnura spp.									x	x					x						x			x			x			x
			Pseudagrion aureofrons	x	x		x			x	x		x	x		x	x				x	x	x		x	x		x	x		x	x	
			Pseudagrion lucifer												x													x					
			Pseudagrion microcephalum	x	x		x			x	x		x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x			
			Pseudagrion spp.									x						x						x					x				
			Coenagrionidae spp.							x		x									x			x					x				
		Gomphidae	Antipodogomphus neophytus																						x	x		x				x	x
			Austrogomphus arbustorum																											x			
			Austrogomphus gordoni																										x		x		

CLASS	Order	Family	Lowest Taxon	Keep River																								Reference					
				K1						K2						K3						K4											
				2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Insecta	Odonata	Gomphidae	*Ictinogomphus australis*																										x				
		Hemicorduliidae	*Hemicordulia intermedia*																				x						x	x			
			Hemicordulia spp.																										x	x			
		Isostictidae	*Eurysticta kununurra*																									x		x			
		Libellulidae	*Austroepigomphus turner*																									x					
			Crocothemis nigrifrons															x											x				
			Crocothemis nigrifrons																														x
			Diplacodes bipunctata																						x						x		
			Diplacodes haematodes				x				x		x				x	x	x				x	x	x	x		x	x	x			
			Diplacodes spp.															x						x									
			Hydrobasileus brevistylus																											x	x		x
			Macrodiplax cora									x						x											x				
			Nannophlebia mudginberri																										x				
			Nannophlebia spp.																											x			
			Neurothemis stigmatizans																		x								x				x
			Orthetrum caledonicum																					x				x			x		
			Pantala flavescens																										x				
			Potamarcha congener																														x
			Rhodothemis lieftincki																														x
			Tramea spp.																												x		
			Zyxomma elgneri																														x
			Libellulidae spp.														x	x					x						x				
			Libelulidae spp.																		x												
			Tramea spp.																														x
		Lindeniidae	*Ictinogomphus australis*																														x
		Platycnemididae	*Nososticta* spp.							x							x	x	x			x		x			x				x		
			Anisoptera spp.	x			x			x	x	x	x			x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x
			Zygoptera spp.	x	x		x			x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x	x
	Thysanoptera		Thysanoptera spp.													x	x					x											
	Trichoptera	Calamoceratidae	*Anisocentropus* spp.															x					x	x	x				x	x	x		
		Ecnomidae	*Ecnomina* spp.																												x		
			Ecnomus spp.							x						x	x	x	x			x	x	x	x	x		x	x	x	x	x	
		Helicopsychidae	Helicopsychidae spp.																											x			
		Hydropsychidae	*Cheumatopsyche* spp.																														
			Cheumatopsyche wellsae							x	x						x	x				x		x	x					x			
			Hydropsychidae spp.																									x					
		Hydroptilidae	*Hellyethira* spp.			x																	x						x	x			
			Orthotrichia spp.				x									x		x	x									x	x	x	x		
			Hydroptilidae spp.																				x										
		Leptoceridae	*Leptocerus atsou*																												x		
			Leptocerus spp.																									x	x				

				Keep River																								Reference					
				K1						K2						K3						K4											
CLASS	Order	Family	Lowest Taxon	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Insecta	Trichoptera	Leptoceridae	*Oecetis* spp.	x			x			x	x		x			x		x	x		x		x	x	x	x	x	x	x	x	x		x
			Triaenodes spp.			x	x									x	x	x	x		x		x	x	x			x	x	x	x		
			Triplectides australicus																									x			x		
			Triplectides australis							x	x												x						x				
			Triplectides ciuskus seductus	x			x			x	x		x			x	x	x	x			x	x	x	x	x		x	x	x	x		
			Triplectides helvolus																				x	x									
			Triplectides parvus							x																							
			Triplectides spp.							x	x										x		x		x		x	x	x			x	
			Triplectides australicus																								x						x
			Triplectides australis																		x						x						
			Triplectides ciskus seductus																														x
			Triplectides parvus																								x						
			Trolectides helvolus	x																								x					
			Leptoceridae spp.							x			x			x	x	x	x			x	x		x	x		x	x	x	x		
		Philopotamidae	*Chimarra* spp.								x						x													x			
			Chimarra uranka								x																						
			Philopotamidae spp.																											x			
		Polycentropodidae	*Paranyctiophylax* spp.																										x		x		
			Trichoptera spp.																										x				
Malacostraca	Amphipoda	Aoridae	*Grandidierella* spp.		x					x	x						x						x										
		Corophiidae	Corophiidae spp.			x	x	x	x			x		x	x			x			x												
		Melitidae	Melitidae spp.					x													x												
			Amphipoda spp. (stygofauna)		x																												
	Decapoda	Atyidae	*Caridina nilotica*	x	x	x	x			x	x	x	x			x	x	x	x			x	x	x	x	x		x	x	x	x		
			Caridina serratirostris		x					x	x	x				x	x	x	x			x	x	x	x	x		x	x	x	x		
			Caridina spp.	x	x	x		x	x	x	x			x	x	x		x			x					x	x			x		x	x
			Caridina thermophila																									x					
			Atyidae spp.	x			x			x			x						x						x						x		
		Brachyura	Brachyura spp.																										x				
		Hymenosomatidae	*Amarinus lacustris*	x	x	x		x						x																			
			Amarinus spp.						x																								
		Palaemonidae	*Macrobrachium australe*																			x											
			Macrobrachium bullatum	x	x	x	x	x		x	x	x	x			x	x	x	x			x	x	x	x	x		x	x	x	x		
			Macrobrachium lar																										x				
			Macrobrachium rosenbergii	x	x	x	x	x	x	x	x			x	x	x	x		x			x	x	x			x	x	x			x	x
			Macrobrachium spp.	x	x	x		x		x		x		x		x		x			x	x	x	x		x		x	x	x		x	x
			Palaemonidae spp.				x						x						x						x						x		
		Penaeidae	*Penaeus* spp.		x																												
Hydrozoa	Anthoathecata	Hydridae	*Hydra* spp.										x					x					x	x				x	x	x			
Bivalvia	Cardiida	Cyrenidae	*Corbicula* spp.	x						x								x			x			x	x	x	x			x			x
	Sphaeriida	Sphaeriidae	*Pisidium* spp.		x																												
			Sphaeriidae spp.																				x										

				Keep River																										Reference					
				K1						K2						K3						K4													
CLASS	**Order**	**Family**	**Lowest Taxon**	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022	2011	2012	2013	2020	2021	2022
Bivalvia	Unionida	Hyriidae	Hyriidae spp.	x	x		x				x	x	x	x				x											x		x		
			Lortiella spp.						x						x						x						x						x
Gastropoda	Cerithimorpha	Thiaridae	Melanoides spp.																												x		
			Thiara spp.																									x	x	x			
	Hygrophila	Lymnaeidae	Bullastra vinosa																											x	x		
		Planorbidae	Amerianna spp.																										x	x	x		
			Ferrissia petterdi										x						x					x	x			x	x	x	x		x
			Gyraulus spp.				x		x	x	x		x		x		x	x	x		x	x	x	x	x		x	x	x	x	x	x	x
			Leichhardtia spp.																									x					
			Hygrophila spp.																														x
	Hypsogastropoda	Bithuniidae	Bithuniidae spp.																												x		
		Bithyniidae	Gabbia spp.						x		x				x						x								x				
			Bithyniidae spp.		x			x						x																			x
		Clenchiellidae	Coleglabra spp.					x						x																			
		Tateidae	Tateidae spp.		x			x			x	x						x												x			
		Thiaridae	Thiara spp.																														x
		Viviparidae	Notopala spp.																														x
	Neotaenioglossa	Hydrobiidae	Hydrobiidae spp.	x						x																							
		Viviparidae	Notopala spp.				x																					x			x	x	
			Gastropoda spp.	x	x	x											x																
Nematoda			Nematoda spp.				x			x									x						x	x				x		x	x
Nemertea			Nemertea spp.															x						x				x		x			
Turbellaria			Turbellaria spp.															x					x	x									
			Total Taxa Richness	**50**	**34**	**19**	**45**	**16**	**16**	**80**	**79**	**39**	**75**	**25**	**28**	**78**	**80**	**93**	**74**	**0**	**68**	**70**	**78**	**97**	**80**	**71**	**77**	**119**	**123**	**133**	**106**	**60**	**100**

End Document