



Government of **Western Australia**
Department of **Water**

Ecological study of the lower Canning River environmental water releases

(below Canning Dam to Kent Street Weir)



Looking after all our water needs

Water Science
technical series

Report no. WST 35
November 2010



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A technical report by the Water Science Branch

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Summary

A drying climate coupled with often unsustainable human use has led to a significant change in river flows; a situation evident in many systems across south-west Western Australia. In the Canning River, a reported 98 per cent loss of summer flow (Storey et al 1998) has occurred in below the Canning Dam, including flow reduction as a result of surface water and groundwater extraction of in the catchment.

Maintenance of flow dynamics is vital to ecosystem function and the associated benefits of a healthy environment (e.g. nutrient recycling and carbon flux to the atmosphere). Specific flow conditions, including frequency, duration, inundation area, altered timing and low-flow period, are often intrinsically linked with system-specific variables. For instance, there is a direct relationship between flow and the lifecycle of many riverine fish, including their pre-spawning condition and maturation, spawning cues and behaviour, survival of larvae and juveniles and associated recruitment.

Environmental water releases have been used to combat reductions in flow in the lower Canning River since the 1950s. The water releases are designed to supplement low-rainfall periods during the dry summer months – scheme water supplied through Water Corporation infrastructure is used to maintain water for both human use (licensed abstraction) and restoration of basic environmental needs. While it is considered the water releases have generally achieved the objective of maintaining minimum requirements for human use, their success in terms of supporting environmental requirements is largely unknown. It is well accepted that regime restoration is one of the overriding requirements enabling systems to naturally recover and in turn maintain critical ecosystem services and processes (McIntyre et al. 2007).

This study was designed to assess the effectiveness of environmental water releases in maintaining ecological function and thus promoting associated ecosystem processes/services in the lower Canning River. Specifically, the investigation targeted two key questions:

- 1 Is supplemented river flow sufficient to maintain stream connectivity for fish migration?
- 2 Does the general ecological health of the reaches of the Canning River, near the environmental release points (ERPs), display any impacts as a result of low flows?

Whether or not unnatural (unseasonal) flows negatively affect aquatic ecology was also considered (e.g. species typically driven to spawn based on winter flow-cues may be urged to spawn outside of natural cycles).

The study was based on the assumption that in the absence of supplemental flows, summer stream connectivity would be significantly reduced. This would in turn affect fish species migrating for spawning and feeding, as well as general distribution or colonisation in the case of juveniles. In the lower Canning River, this has significant implications for freshwater cobbler (*Tandanus bostocki*), which migrate upstream in

summer to spawn. Impacts on environmental condition, such as deterioration of water quality through stagnation (reduced dissolved oxygen), were also assessed.

To this end, four sites downstream from four of the six ERPs were monitored monthly for fish abundance, species diversity and water quality from November 2009 to April 2010. A single macroinvertebrate and vegetation survey was also undertaken in November 2009.

No significant evidence was found to suggest negative impacts on either connectivity or environmental health related to flow. Migration of freshwater cobbler was evident through most of the system and included confirmation of reproductive condition. There was no obvious loss of flow-sensitive taxa (fish and macroinvertebrates), general diversity, or degradation of water quality or environmental health beyond that expected for an urban system.

This study also showed that viable populations of fish were supported throughout the lower Canning River. Six species of native fish were observed: freshwater cobbler (*Tandanus bostocki*); western minnow (*Galaxias occidentalis*), western pygmy perch (*Edelia vittata*), Swan River goby (*Pseudogobius olorum*), nightfish (*Bostockia porosa*) and western hardyhead (*Leptatherina wallacei*) and two species of native freshwater crayfish: smooth marron (*Cherax cainii*) and gilgie (*Cherax quinquecarinatus*). A number of exotic species were also observed, including the spangled perch (*Leiopotherapon unicolor*), reported for the first time in a south-west Western Australian river.

From these results, the ongoing use of environmental water releases is supported, without which a loss of ecosystem health is likely and the critical processes and services provided would likely be at risk.

1 Introduction

Stream flow in the Canning River has reduced due to hydrological disturbance in its catchment; a 98 per cent loss of streamflow below the Canning Dam has been estimated (Storey et al. 2002). Demand has increased due to landholders and other water users being licensed to abstract water from the river.

In the 1950s six environmental release points (ERPs) were established along the lower Canning River (below the Araluen pumpback) to supplement flows during summer low-flow periods. The idea was to provide water to licensed water users and landholders where no infrastructure for scheme water was available. More recently, the ERPs have been recognised as critical to protecting the river's environmental values through maintaining natural connectivity (sufficient depth to allow fish passage) preserving aquatic and fringing vegetation by maintaining pool depth, and preventing deterioration of water quality such as anoxic conditions that can form in stagnant areas.

It is recognised that fish require river connectivity to migrate and breed (King et al, 2009; Mallen-Cooper 1993; Harris 1998). The timing of these migrations depends on the biology of the different fish species. The freshwater cobbler is considered an iconic freshwater fish endemic to south-west Western Australia, and is this study's target species. This species migrates upstream during the summer to breed and would consequently be affected by low summer flows. Other native fish such as the western pygmy perch and western minnow migrate during spring when the river is flowing from winter inputs. These species benefit from the ERPs because suitable habitat, food resources and environmental conditions can be maintained during the summer to sustain juveniles and promote recruitment.

This study's main aims are to investigate:

- whether river flow in the lower Canning River – supplemented by environmental water flows – is sufficient to maintain stream connectivity (by assessing freshwater cobbler population dynamics within river)
- the ecological health of the reaches of the Canning River near the ERPs (by using ecological indicators such as fish and crayfish community dynamics, aquatic macroinvertebrates, habitat features and water quality)
- whether any adverse effects are apparent due to potentially unnatural summer flow conditions.

1.1 Environmental water releases and release points

Six modified scour valves have been installed in the Canning River's main channel: these take scheme water from the suburban network. The valves are situated along a 25 km stretch of the river from Araluen to Gosnells (Figure 1). Flow from the ERPs is regulated by the Department of Water's Water Allocation Planning Branch in conjunction with the Water Corporation. The scheme water's release is regulated based on flow triggers at Seaforth gauging station (AWRC ref. 616027) in Gosnells (see Appendix E). Once switched on, the flow is continuous 'summer flow'. In

addition, up to three five-day pulses ('fish pulses') of increased flow are currently allocated in summer as part of the *lower Canning River water allocation plan*. These strategic pulses in flow, used when low-flow triggers are reached due to insufficient summer rainfall, are designed to prevent migrating native fish such as the freshwater cobbler being trapped below low-flow points in the river (e.g. riffles).

2 Methods

2.1 Site selection

In the lower Canning River there are six environmental release points (ERPs) where scheme water is discharged, namely Gosnells Bridge, Manning Avenue, Orlando Street, Bernard Street, Hill 60 and Araluen.

Four primary study sites – GOS, BROOK, STOK, CONF – were selected on the Canning River's main channel, downstream of four of the ERPs (see Figure 1 and Table 1). Note: the GOS and STOK sites were previously studied by Storey (1998) and ARL (1988).

One additional site was included – TRIB – which was situated off the Canning River's main channel in a tributary fed by the Araluen release water. This site was included to determine whether the release water was producing a flow-related swimming response; that is. leading fish away from the main channel. As such, only fish populations were studied at this site. The TRIB site was selected because flow rate from the release point at this site was higher than the main channel flow, thus having the potential to override cues from the main channel.

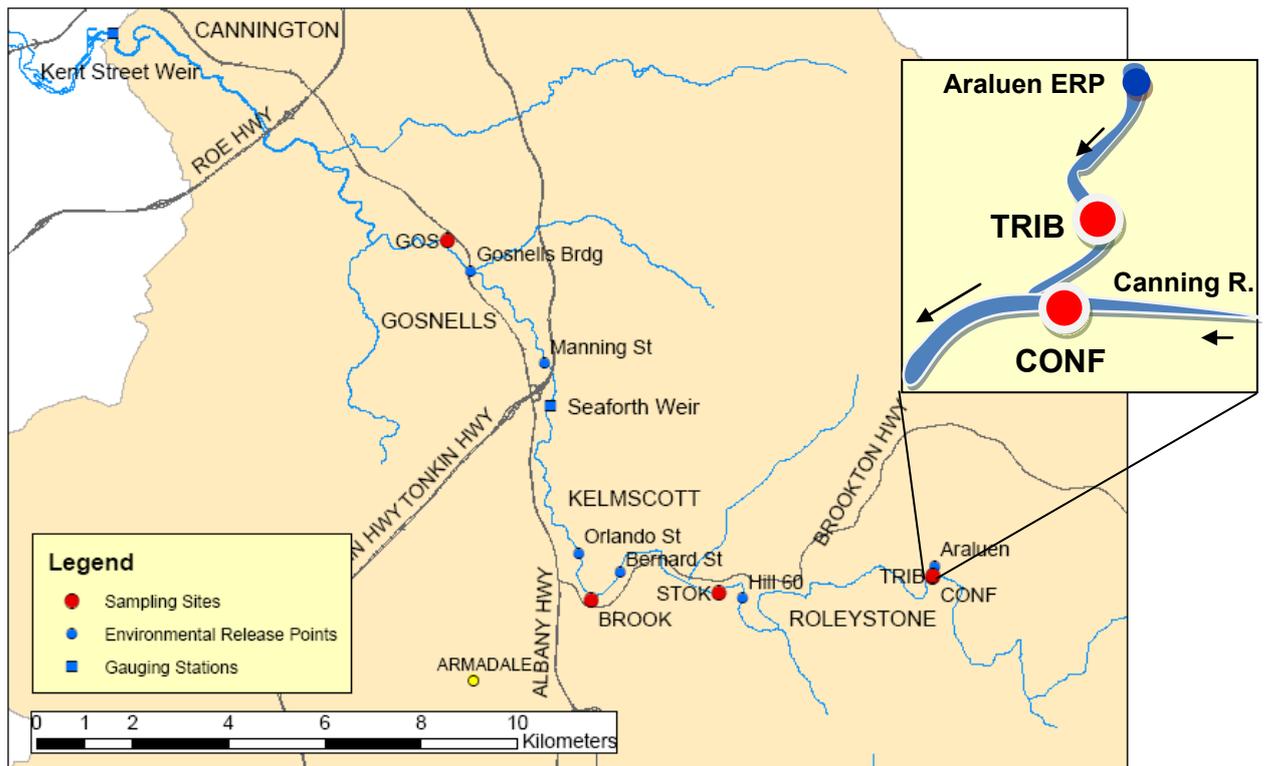


Figure 1 Location of environmental release points and study sites on the lower Canning River

The ERPs use chlorinated drinking water. Chlorine concentrations were measured 500 m downstream of the ERPs in 2005 (Chandler & Reid 2005) and were found to be at or below concentrations protecting 90 per cent of species (ANZECC & ARMCANZ 2000). To avoid any potential localised impacts of chlorine on the aquatic ecology, site selection avoided areas immediately downstream of the ERPs (this was not applicable for the TRIB and CONF sites given the available area), see Table 1.

Table 1 Sampling sites, locations and coordinates

Site	Nearest upstream ERP	Distance to ERP (m)	Easting	Northing
GOS	Gosnells Bridge	800	405081	6452357
BROOK	Bernard Street	1000	408074	6444831
STOK	Hill 60	800	410711	6444977
CONF	Araluen	252	415167	6445331
TRIB	Araluen	200	415182	6445352

2.2 Sampling regime

Sampling was undertaken monthly over a four-day period between November 2009 and April 2010 capturing the 'summer flow' period. This incorporated a single sampling point before the first environmental water release on 1 December 2009, and five further sampling points during the release period, including capturing responses to two 'fish pulses' (see Section 1.1).

Sampling involved fish trapping, water quality monitoring, macroinvertebrate collection and assessment of aquatic habitat and fringing vegetation. Specific methods are described below.

2.3 Fish sampling

Fish sampling was carried out using large fyke nets (rectangle-mouth, opening 75 cm high and 105 cm wide) and small fyke nets (D-shaped-mouth, opening 55 cm high and 70 cm wide). Both fyke types had the same wing dimensions (55 cm high and 400 cm long) and mesh size (0.2 cm). Rectangle-mouth fykes are taller and hence deployed in deeper sections as required; no effect on catchability has been documented or is expected.

Two fyke nets were deployed at each site with one opening upstream and one opening downstream, to catch fish migrating downstream and upstream respectively.

Sampling was conducted over 72 hours (assessment over multiple days improves the ability to capture migration pulses), with the contents of fykes assessed and emptied at 24-hour intervals (three sampling points).

The following information was recorded for both fish and crayfish:

- species
- abundance
- general health: noting presence of parasites, lesions and disease
- reproductive condition: noting courtship colours, milt expression and gravid females
- size: total length (TL) for fish and carapace length (CL) for freshwater crayfish. (The size of animals was assigned to size-class categories (Table 2), generally highlighting juvenile, mature adult and older individuals. Shell length was recorded for tortoises).

Table 2 Fauna size class

Size-class		
Small fish TL	Large fauna TL	Crayfish CL
WM, WPP, N, SRG, WHH, M, OSL, GF	FC, SP, LNT	M, G, Y
0–20	0–100	0–20
20–50	100–200	20–50
50–100	200–400	50–76
+100	+400	76–100
		+100

TL = total length (mm), CL = carapace length (mm), WM = western minnow, WPP = western pygmy perch, N = nightfish, SRG = Swan River goby, WHH = western hardyhead, M = mosquitofish, OSL = one-spot livebearer, GF = goldfish, FC = freshwater cobbler, SP = spangled perch, LNT = long neck tortoise, M = marron, G = gilgie, Y = yabby.

Native species were returned to the water in the direction they were travelling so as to reduce the likelihood of recapture. Feral species were euthanased by submerging the fish in a 3 mL/L solution of clove oil to first anaesthetise and then kill them.

Data analysis

The freshwater cobbler's population dynamics were used as the primary indicator for this trial, due to the associated influence of summer flows on migration requirements. General community composition was assessed as an indication of river health, as per the methods detailed below. However, as composition is a function of a range of factors (pollution, riparian condition/fringing vegetation, habitat complexity, water quality, flow dynamics, physical form and catchment conditions), the results are only indicative, because the direct effect of the environmental water releases cannot be definitively assessed.

Fish and crayfish were assessed using observed/expected scoring protocols developed for the South-West Index of River Condition (SWIRC). This assesses the number of species collected with expected species distribution for each site. Scores

consider catchability of individual species based on different expectations for rare, seasonal and common species (see Table 3).

The degree of invasion from exotic species was also assessed as an indication of general health, based on Nativeness Index scoring protocols from the SWIRC.

Table 3 *Components of the Fish and crayfish sub-index (Storer et al. 2010). Adapted from the sustainable river fish index of the sustainable river audit (Davies et al. 2008)*

Component	Metric	Definition	Weighting
Expectedness: Information on species richness relative to reference condition	Observed to expected ratio (O/E)	Compares the native species expected to occur in a site based on reference condition and the actual species collected. The total number of native species predicted to occur in the subcatchment is corrected downwards for species believed to be either rare or seasonal and unlikely to be caught in sampling.	0.25
	Observed to predicted ratio (O/Pr)	Compares the native species predicted to have occurred (pre-European) in a subcatchment against the native species actually caught at the site. This metric includes the rare species	0.17
	Observed to predicted ratio (O/Ps)	A comparison of the native species predicted to have occurred (pre-European) in a subcatchment against the native species actually caught at the site. This metric includes the seasonal species	0.08
Nativeness: Information on proportions of abundance and species richness that are native rather than alien	Proportion native abundance	Proportion of individuals that are native species.	0.25
	Proportion native species	Proportion of species that are native species.	0.25
Expert rule: Exotic species	Presence of exotics in absence of natives	The lowest score assigned to a site with fish present (exotic or native) = 0.05 No fish = zero.	

$$\begin{aligned} \text{FCSI} &= \text{Expectedness (OE + OP)} + \text{Nativeness} \\ &= \text{OE} + [(2 \cdot \text{OP}_r) + \text{OP}_s] + \text{P}_{Ab} + \text{P}_{Sp} \end{aligned}$$

Where FSCI = Fish and crayfish sub-index, OE = observed to expected ratio, OP_r = observed to predicted ratio (includes rare species), OP_s = observed to predicted ratio (includes seasonal species), P_{Ab} = proportion native abundance, P_{Sp} = proportion native species

2.4 Water quality monitoring

Surface water quality (0.2 m depth) was monitored in-situ at each site for temperature, electrical conductivity (mS/cm), dissolved oxygen (mg/L and per cent saturation) and pH.

Single spot readings were taken at all sites in November and December using a handheld multi-sensor probe, the YSI 6600.

From January to April 2010 a multi-sensor data logger (Eureka Manta) was used to collect information every 10 minutes over the three-day sampling period from all sites excluding TRIB. This equipment was unavailable during November and December 2009.

Turbidity was assessed using the Eureka Mantas for one sampling event (three days).

Spot flow-readings were also recorded at all sites using a Global flow meter or, when flows were less than 0.2 m/s, a measuring tape and float.

Water quality data provides general information relating to ecological health: as with biotic community data, these data are primarily indicative.

2.5 Macroinvertebrate sampling

A single macroinvertebrate sample was collected at the four primary study sites (excluding TRIB) during the November 2009 sampling event. TRIB was not assessed because this site was only included in the study to monitor fish movement.

The Australian River Assessment System (AusRivAS) sampling methods (Halse et al. 2001) were adopted for comparability with data previously collected from the Canning River catchment (Storey et al. 1998; Galvin et al. 2009). From the AusRivAS method, a 250 µm mesh triangular sweep-net was used to collect invertebrates from the water column, the fine upper layer of benthic sediment and woody debris over a 10 m length of river channel habitat. Macrophyte habitat is not sampled to ensure comparability between study sites (as it is not expected at all sites), however this was not possible at the CONF site given the dominance of macrophytes. A detailed sampling method is provided in the Western Australian AusRivAS manuals available on the Department of Water website.

Samples were processed (picked) in the field, with a total of 200 individuals from each sample (or the entire sample if fewer than 200 invertebrates were present) preserved in a solution of 70 per cent ethanol in water until identification in the laboratory. Note: live-picks were conducted by trained personnel, which is a critical requirement in using this method so that the ability to return a representative sample is optimised, given the presence of cryptic species.

Identification was carried out by the Australian Water Quality Centre in South Australia. Macroinvertebrates were identified to family level, with the exception of Oligochaeta (worms) and Acarinida (mites) – identified to Order; Chironomidae (midges) – identified to Sub-family; and *Ephemeroptera* (mayfly), *Odonata* (dragonfly and damselfly), *Plecoptera* (stonefly) and *Trichoptera* (caddisfly) – identified to Genera. Microcrustacea (Ostracods, Copepods and Cladocerans) were not collected as part of the sample because naturally fluctuating populations make it difficult to draw conclusions.

Assessment of macroinvertebrate data considered functional feeding groups listed on the Murray-Darling Freshwater Research Centre website (2006) and comparisons of

species composition against data collected in previous studies throughout the Canning River catchment (Storey et al. 1998; Galvin et al. 2009).

2.6 General site and habitat assessment

Aquatic habitat features, fringing vegetation extent and condition and land-use characteristics were recorded at each site – following protocols outlined in the SWIRC (Storer et al. 2010). This was done to provide a general assessment of ecological health to elucidate between conditions that are influenced by streamflow versus the various other impact factors in the Canning River system.

The assessment was done once at each site (100 m of riverbank assessed, left and right banks) during the first sampling event. Site conditions were monitored at each sampling point thereafter to ensure conditions were stable.

Factors investigated included baseflow and bankfull widths, adjacent vegetation widths and main vegetation types, bank shape; stream habitat diversity, presence of macrophytes, and woody debris; flow characteristics; stream shading; substrate type; bank condition; pollution sources; localised land use; riparian vegetation health (prevalence of exotic species); and any fish barriers.

3 Results

3.1 Hydrological conditions

Sampling was first conducted before the environmental water releases commenced, and continued monthly during the releases. This included direct assessment of two 'fish pulses' (additional flow released over five days following the breach of low-flow triggers – see Section 1.1) occurring in December and January. On both occasions, flow increase was apparent on the second day of sampling and reached maximum flow by the third and final day of fish sampling.

Timing of the sampling relative to the environmental water releases, streamflow and rainfall is shown in Figure 2.

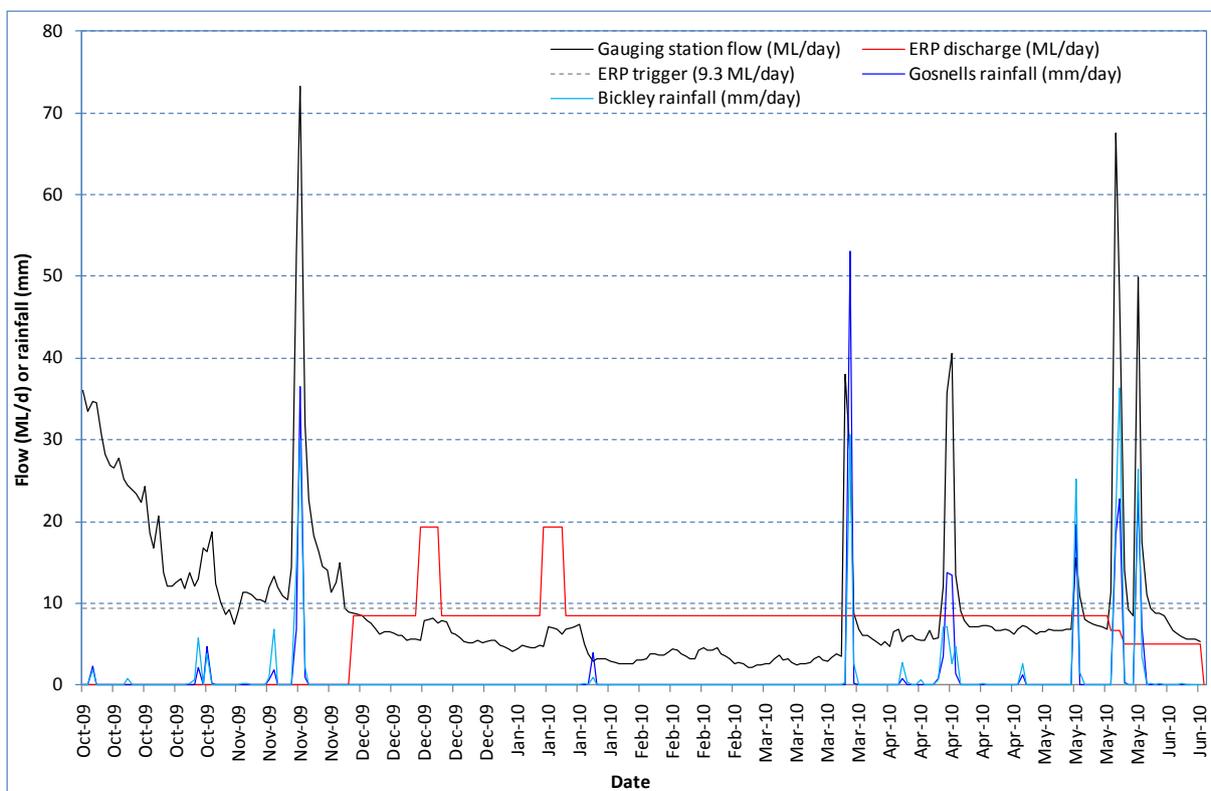


Figure 2 Rainfall (Bickley Brook and Gosnells), streamflow (Cannington Seaforth station), ERP total daily flow, ERP trigger and sampling periods

3.2 River connectivity

River connectivity was primarily assessed by analysing freshwater cobbler (*Tandanus bostocki*), given that this species migrates upstream to spawn in summer.

Approximately 95 per cent of the freshwater cobbler captured during the study were observed migrating upstream (collected in fykes with their openings facing downstream). No trend was apparent in animals travelling downstream, with only a few individuals captured at the most downstream site (GOS) in November and

December. As such, only data from cobbler migrating upstream are discussed further.

Cobbler travelling upstream were generally recorded at the lower three sites (GOS, BROK and STOK) from November 2009 to January 2010 (Figure 3). Only two cobbler were recorded at the CONF site (February and March), and none at the TRIB site.

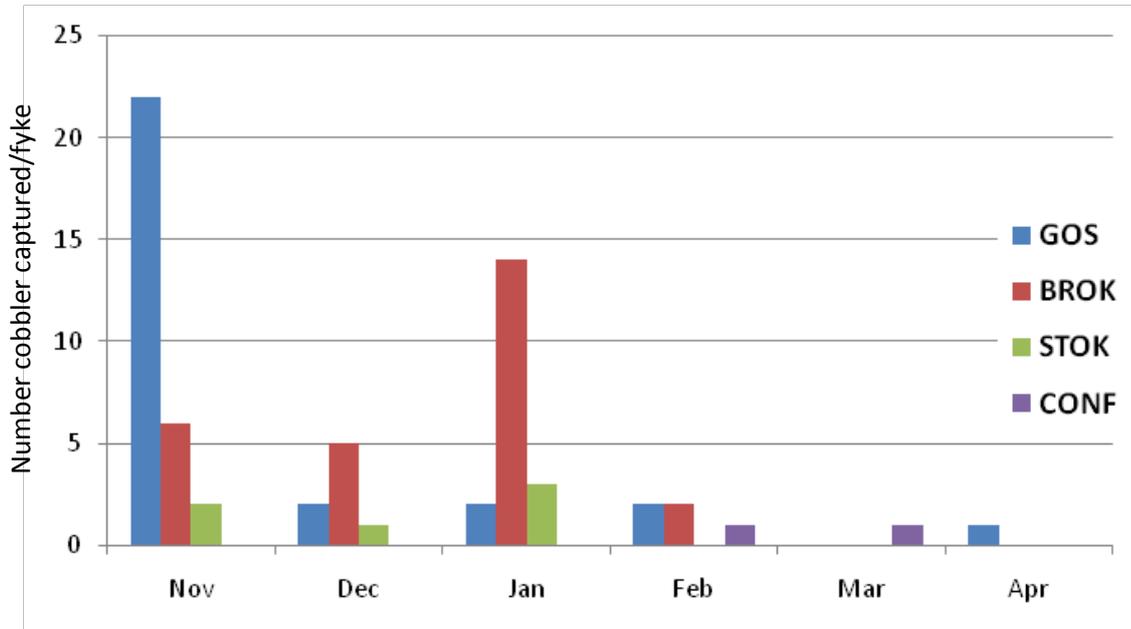


Figure 3 Freshwater cobbler in downstream-facing fyke nets in the lower Canning River

The size of freshwater cobbler ranged from large adults (>400 mm) to juveniles (<100 mm TL), however the large individuals (over 200 mm) dominated catches, and cobbler over 400 mm were only captured in November (the exception was one individual caught in January) (Figure 4).

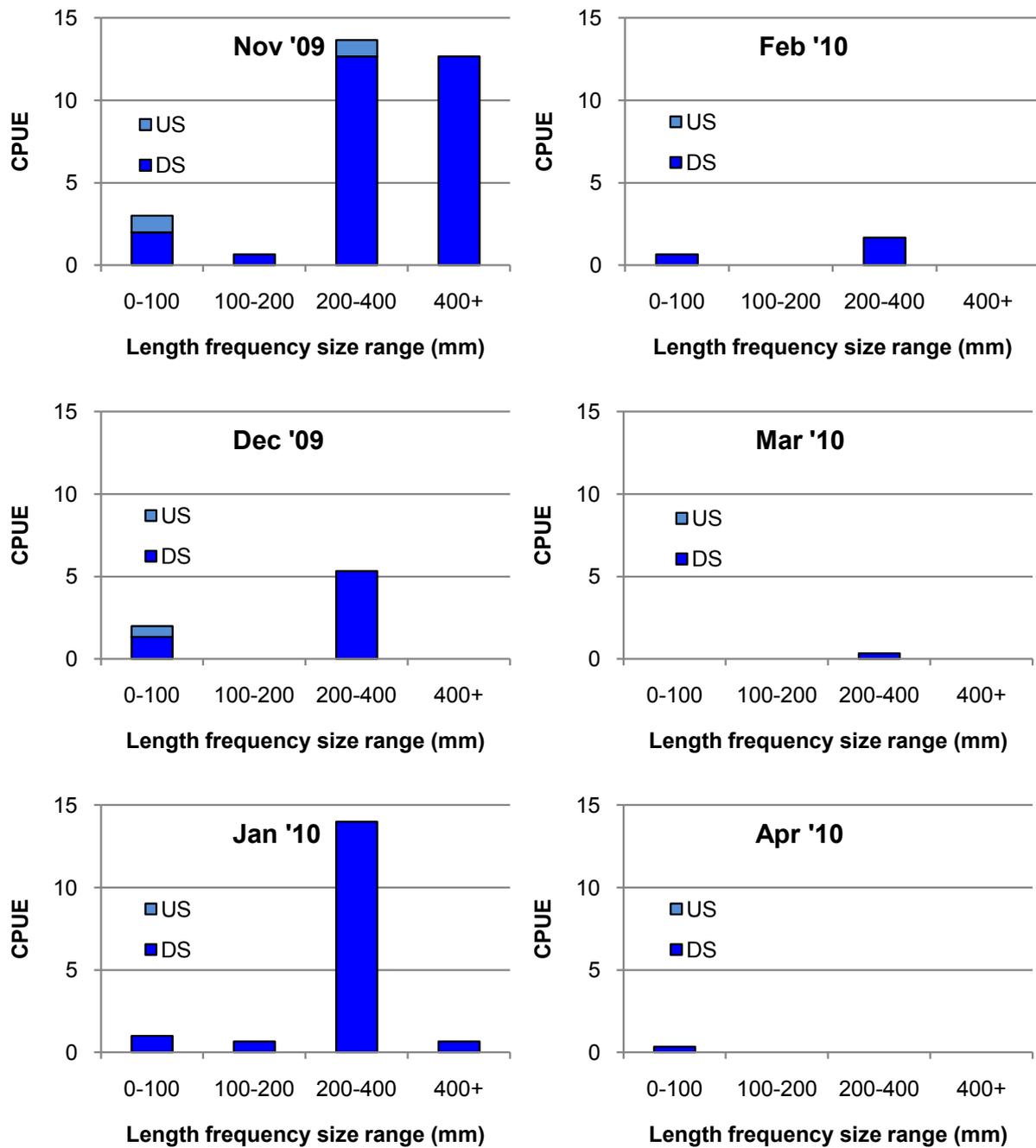


Figure 4 Length frequency distribution of freshwater cobbler caught in the lower Canning River. Fish caught in the downstream (DS) nets were considered to be migrating upstream while those in the upstream (US) nets were migrating downstream

Almost all fish over 200 mm in November and December 2009 were in breeding condition, with milt and eggs being released upon gentle pressure.

3.3 General system health

The river's environmental health was assessed using various indicators including fish species richness and abundance of natives and exotics, water quality, habitat quality and aquatic macroinvertebrates. These data are provided below.

Fish and crayfish species richness

Nine fish species and four species of crustaceans and were caught in the lower Canning River from Gosnells Bridge to Araluen during the study period. As summarised in Table 4, these species included:

- four species of freshwater fish endemic to south-west Western Australia: western pygmy perch (*Edelia vittata*), western minnow (*Galaxias occidentalis*), nightfish (*Bostockia porosa*) and freshwater cobbler (*Tandanus bostocki*)
- two species of native estuarine fish (inhabiting freshwater): Swan River goby (*Pseudogobius olorum*) and western hardyhead (*Leptatherina wallacei*)
- three species of freshwater crustaceans endemic to south-west Western Australia: smooth marron (*Cherax cainii*), gilgie (*Cherax quinquecarinatus*), and freshwater shrimp (*Palaemonetes australis*)
- three species of exotic fish and a single species of exotic crayfish: one-spot livebearer (*Phalloceros caudimaculatus*), mosquitofish (*Gambusia holbrooki*), spangled perch (*Leiopotherapon unicolor*) and yabby (*Cherax* spp.).

Photographs of each are shown in Appendix B (figures B1 to B13).

Table 4 Species presence/absence and species richness by site

Main fish groups/species	GOS	BROOK	STOK	CONF	TRIB
Freshwater native fish					
Western pygmy perch (<i>Edelia vittata</i>)	✓	✓	✓	✓	✓
Western minnow (<i>Galaxias occidentalis</i>)	✓	✓	✓	✓	✓
Nightfish (<i>Bostockia porosa</i>)	✓	✓	✓	✓	✓
Freshwater cobbler (<i>Tandanus bostocki</i>)	✓	✓	✓	✓	-
Estuarine native fish					
Swan River goby (<i>Pseudogobius olorum</i>)	✓	✓	-	-	✓
Western hardyhead (<i>Leptatherina wallacei</i>)	✓	-	-	-	-
Freshwater native crustaceans					
Marron (<i>Cherax cainii</i>)	✓	✓	✓	✓	✓
Gilgie (<i>Cherax quinquecarinatus</i>)	✓	✓	✓	✓	✓
Freshwater shrimp (<i>Palaemonetes australis</i>)	✓	✓	✓	✓	✓
Freshwater exotic fish					
One-spot livebearer (<i>Phalloceros caudimaculatus</i>)	✓	✓	✓	✓	✓
Mosquitofish (<i>Gambusia holbrooki</i>)	✓	✓	✓	-	-
Spangled perch (<i>Leiopotherapon unicolor</i>)	✓	-	-	-	-
Freshwater exotic crayfish					

Main fish groups/species	GOS	BROOK	STOK	CONF	TRIB
Yabby (<i>Cherax</i> spp.)	✓	-	-	✓	✓
Total native species	9	8	7	7	7
Total exotic species	4	2	2	2	2
Total species	13	10	9	9	9

The four freshwater native fish species and three native freshwater crustacean species were caught at all sites with the exception of TRIB, where freshwater cobbler was absent (Table 4 and Table 5).

The greatest species richness was found at the GOS site; that is, two native estuarine species (site closest to estuary), the exotic yabby and two individual spangled perch. Other sites had similar species richness for both native and exotic species (Table 5).

Observed/expected scores were calculated for all sites, based on the methods outlined in Storer et al. 2010. All sites scored 1 for expected common species, and equal to or greater than 0.94 for expected rare or seasonal species. These scores reflect that observed species matched those expected for the system. The minor reduction in score for expected rare/seasonal species was due to the absence of lamprey. However, this species has a small window for capture and its distribution is based on limited evidence; as such no concerns were raised from this finding.

The Nativeness Index, as per Storer et al 2010, was also calculated. Results were between 0.72 and 0.85, with the GOS site being the lowest at 0.72. The reduced score from the maximum of 1 reflects the exotic species captured, however scores still exist within the 'slightly modified' category, which highlights that exotic species do not dominate the Canning River.

Abundance of fish and crayfish

The total abundances of fish and crayfish at each of the five sites are shown in Table 5.

Table 5 Total catch of various fish and crayfish species captured at five sites in the lower Canning River. The abundances are the total number of specimens from six monthly sampling events from November 2009 to April 2010

Main fish groups/species	GOS	BROOK	STOK	CONF	TRIB
Freshwater native fish					
Western pygmy perch (<i>Edelia vittata</i>)	808	80	183	990	58
Western minnow (<i>Galaxias occidentalis</i>)	423	188	44	86	107
Nightfish (<i>Bostockia porosa</i>)	50	31	16	288	32
Freshwater cobbler (<i>Tandanus bostocki</i>)	80	75	11	2	0
<i>Sub-total</i>	1361	374	254	1366	197
Estuarine native fish					
Swan River goby (<i>Pseudogobius olorum</i>)	262	3	0	0	1
Western hardyhead (<i>Leptatherina wallacei</i>)	2	0	0	0	0
<i>Sub-total</i>	264	3	0	0	1
Freshwater native crustaceans					
Marron (<i>Cherax cainii</i>)	275	984	717	360	79
Gilgie (<i>Cherax quinquecarinatus</i>)	1102	154	25	102	30
Freshwater shrimp (<i>Palaemonetes australis</i>)	547	4	4	260	4
<i>Sub-total</i>	1924	1142	746	722	113
Freshwater exotic fish					
One-spot livebearer (<i>Phalloceros caudimaculatus</i>)	407	359	1	0	0
Mosquitofish (<i>Gambusia holbrooki</i>)	339	19	54	95	37
Spangled perch (<i>Leiopotherapon unicolor</i>)	2	0	0	0	0
<i>Sub-total</i>	748	378	55	95	37
Freshwater exotic crayfish					
Yabby (<i>Cherax</i> spp.)	3	0	0	13	4

From data reported in Table 5 a number of general findings are apparent.

- Estuarine species are predominantly found at the GOS site (closest to the estuary).
- Freshwater fish abundance is highest at the GOS and CONF sites, largely due to the large numbers of western pygmy perch; and also western minnow and nightfish at the GOS and CONF sites respectively.
- Freshwater crustacean abundance shows a decreasing trend up the catchment (GOS through to TRIB), with gilgies and shrimp largely responsible for numbers at the GOS site. Marron dominate the middle reaches (BROOK and STOK), with abundances becoming more evenly distributed at CONF.
- Exotic species are more prevalent in the lower sites (GOS and BROOK), although they are present throughout.
- The TRIB site (small tributary, likely ephemeral without flow from the ERP) has consistently lower abundances for most fish/crayfish species.

Throughout the study, the abundance of western pygmy perch, western minnows, marron and estuarine species declined at all sites, while nightfish numbers reduced in the lower catchments, being found only at the CONF site towards the end of the study period.

Water quality data

With the exception of dissolved oxygen, data for parameters measured was within acceptable ranges for biota (see literature review in Storer et al. 2010). Throughout the study at all sites, the average electrical conductivity was 0.36 mS.cm⁻¹ (standard deviation 0.06 mS.cm⁻¹, range from 0.30 to 0.68 mS.cm⁻¹); temperature ranged from 18.5 to 22.5°C and followed a diurnal cycle; and pH ranged from 6.9 to 7.7, with an average of 7.2 (standard deviation 0.20). Turbidity was lowest at sites GOS and STOK (average 5.7 and 4.4 NTU respectively) and relatively high at BROOK (average 16.0 NTU), based on one data point.

Dissolved oxygen levels were typically within acceptable levels at all sites (≥ 6 mg/L). However, low oxygen readings were recorded at both the BROOK and CONF sites, where oxygen levels remained between 4 and 4.5 mg/L for approximately 10 hrs (~midnight to 10am) on one sampling occasion. The lowest readings were recorded in February at the BROOK site and in December at the CONF site. No obvious effects of low dissolved oxygen were recorded when sites were observed during the day (e.g. algae, faunal behaviour).

Water quality data has not been provided in this report, but is available from the Department of Water.

Macroinvertebrate data

Abundance and richness

In total, 27 macroinvertebrate taxa were recorded in the lower Canning River from the GOS to CONF sites (TRIB site was not sampled) in November 2009 (Appendix C). The macroinvertebrate fauna comprised Nemertea (ribbon worms), Nematoda (round worms) and Oligochaeta (earthworms); seven Dipteran families (true fly larvae); four Gastropod families (snails, freshwater limpets); one each of the Bivalve (mussels); Hydracarina (water mites) and Decapod (freshwater shrimp) families; and two Coleopteran families (water beetles); as well as one Ephemeroptera family (mayfly), five Odonata families (dragonflies) and five Trichopteran families (caddisflies).

The total abundance of macroinvertebrates present at all sites was generally low, in particular at the BROOK site, which recorded only 33 organisms. Taxa richness ranged from 10 to 16 families/genera. The highest taxa richness was recorded at the CONF and STOK sites, both of which were characterised by relatively intact riparian vegetation.

Table 6 Summary of macroinvertebrate abundance and richness at four sites in the lower Canning River in November 2009

Site	Habitat	Total abundance	Number of taxa
GOS	Channel	120	12
BROOK	Channel	33	10
STOK	Channel	188	15
CONF	Macrophyte	89	16

Functional feeding groups

The functional complexity and condition of a river is demonstrated in the diversity of the functional feeding groups. Functional feeding groups were assigned to all taxa based on information obtained from the literature. Sources included Merrit and Cummins 1996; Gooderham and Tsyrlin 2002; Hawking and Smith 1997; and Davis and Christidis 1997.

The proportions of each functional feeding group for each site are shown in Figure 5. The five functional feeding groups were present at all sites except CONF, which was missing filtering collectors. Gathering collectors followed by predators dominated invertebrate assemblage at all sites.

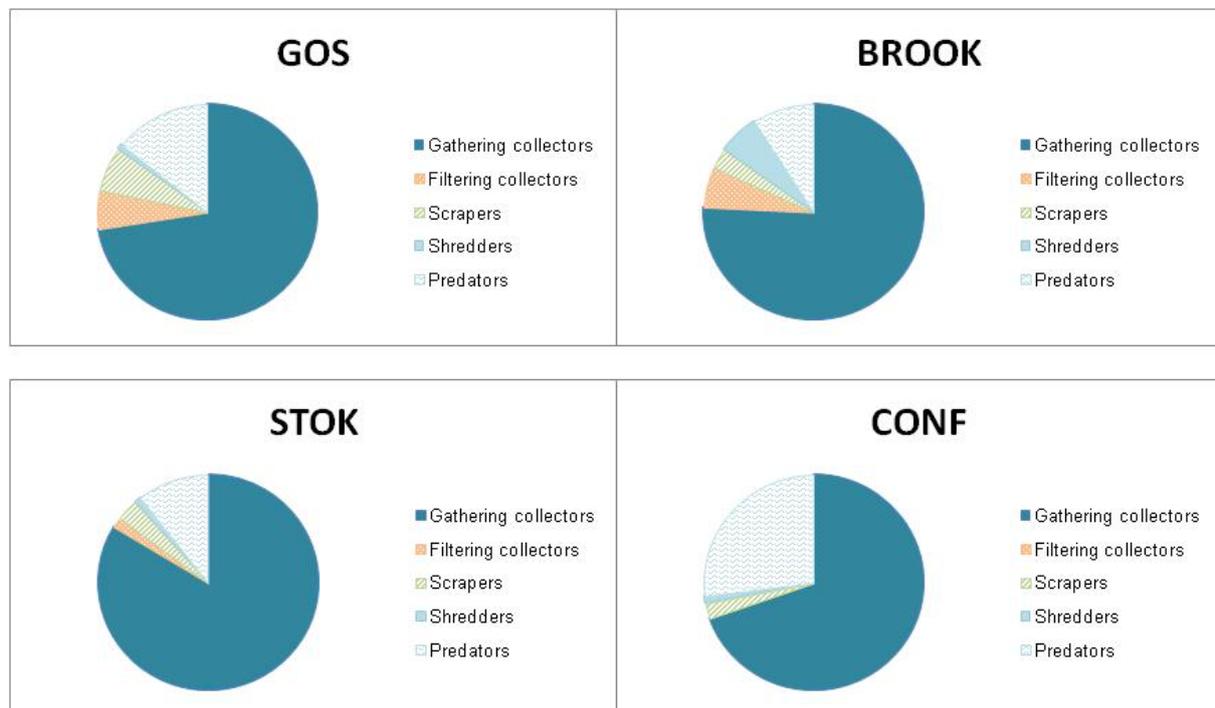


Figure 5 Proportional abundance of functional feeding groups of macroinvertebrates collected at the four sites in the lower Canning River in November 2009

General site and habitat assessment

Each site was assessed based on aquatic habitat, physical form, fringing vegetation and land use (see summary in Table 7).

In general all sites contained multiple types of aquatic habitats, had diverse biological substrates, and were each degraded to some degree. The upper sites CONF and TRIB contained more remnant vegetation and were less affected by urban areas. Evidence of some siltation was present at all sites (except TRIB) with the greatest levels found in the pool site CONF. An extended analysis of each site is provided in Appendix D.

Field sheets used to assess site and habitat features are from Storer et al. 2010.

Table 7 Summary of main habitat characteristics of each site

Main features	GOS	BROOK	STOK	CONF	TRIB
Main aquatic environment	Channel	Channel	Channel	Macrophytes	Channel
Habitat features	Draping vegetation/root overhang and woody debris	Submerged macrophytes, draping vegetation/root overhang and woody debris	Emergent macrophytes, draping vegetation and woody debris	Emergent and submerged aquatic plants, draping vegetation and woody debris	Emergent macrophytes, draping vegetation/root overhang and woody debris
Shading	Moderately shaded	Majority shaded	Moderately shaded	Majority shaded	Well shaded
Physical substrate	Fine sand and silt	Fine sand and silt	Sand and some boulders	Fine silt	Pebbles and boulders
Biological substrate	Leaves, twigs and branches	Twigs and branches	Leaves, twigs, branches and detritus	Detritus, few leaves, twigs, branches	Leaves, twigs and branches
Bank erosion	Highly eroded – human access and clearing; bare, devoid of vegetation	Highly eroded – human access and clearing	Moderately eroded – human access, clearing and irrigation drawdown	Little erosion – well-vegetated banks	Highly eroded – combination of narrow channel and fast flow
Riparian vegetation	Mostly cleared except large native trees	Mostly cleared understorey dominated by exotic plant species; extending to water's edge	Partly cleared except large native trees; some remaining native understorey	Intact riparian vegetation, some invasion by exotic weeds and shrubs	Intact riparian vegetation, some invasion by exotic weeds and shrubs
Native tree and shrub recruitment	Limited evidence	No evidence	Limited evidence	Considerable evidence for both trees and shrubs	Considerable evidence of natural recruitment of both trees and shrubs

Main features	GOS	BROOK	STOK	CONF	TRIB
Surrounding land uses	Remnant vegetation, crown land, agriculture and urban housing	Remnant vegetation, vacant crown land and urban housing	Hobby farms (mainly horse paddocks), remnant vegetation, vacant crown land and urban housing	Forest, urban roads and buildings	Forest and urban roads
Point source pollution	None evident	None evident	None evident	None evident	None evident
Non-point source pollution	Orchards, urban housing and roads	Urban housing	Hobby farms and urban housing and roads	Botanical gardens – possible nutrient and pesticide inputs; urban housing and roads	Botanical gardens – possible nutrient and pesticide inputs; urban housing and roads

4 Discussion

Any discussion around ecology is inherently complex – given countless contributing factors and the dynamic synergistic and antagonistic interactions in play. An assessment of ecological health and its relationship with environmental water releases is thus confounded by any number of factors. In the Canning River, health is a function of flow, contaminants from various land-use activities, removal of aquatic habitat, clearing of fringing vegetation, invasion of exotic species and construction of potential barriers.

To determine the role of environmental water releases, perhaps the simplest measure is an assessment against likely conditions with supplemented flow. This can be divided into two areas: the first relating directly to stream connectivity (and the ability for fish to migrate unimpeded throughout their natural range), and the second relating to general stream health – targeting elements likely to be specifically affected by loss of flow (e.g. loss of flow-sensitive biota, or localised decline in water quality due to reduced flushing).

These two areas are explained below.

4.1 Stream connectivity

Stream connectivity was primarily assessed in the study by examining freshwater cobbler population structure and reproductive condition. Although a number of species migrate for various reasons through summer (when loss of connectivity would be most likely), the cobbler is the only species requiring access to upstream habitats to spawn. Further, cobbler is the largest-bodied freshwater species in south-west Western Australia and therefore the most likely to be affected by reduced flow.

In the absence of supplemented flows it is reasonable to assume that the cobbler's range would be significantly restricted within the Canning River, and this – coupled with declining water and habitat quality due to increased stagnation of systems – would be reflected in abundance and population dynamics. This was not seen in the Canning River study.

Freshwater cobbler in the Canning River was present in a range of sizes, from juvenile to large adult, suggesting a viable population. This is further supported by evidence of reproductive condition in almost all individuals collected over 200 mm in length (gravid females and milt expressed from males upon gentle pressure).

Migration was also evident, given that over 90 per cent of individuals were caught in the downstream-facing fyke nets (suggesting upstream migration). For the Canning River, it appears that migration through the lower section (as represented by the GOS site) is around November as well as beforehand (i.e. prior to the first sampling event). Migrations were recorded through to February in the more upstream sites (BROOK and STOK). Note: the largest fish (400 mm plus) were almost exclusively recorded in November, suggesting the migration peak for larger fish is earlier than

the rest of the population (likely before November), in line with the time that flows are naturally higher.

Only a few individual cobbler were caught at the uppermost Canning River site (CONF), which is consistent with earlier reports on the river (WRM 2006). No fish were recorded at the TRIB site, however this was not unexpected given the site is a narrow, shallow, relatively steep, naturally ephemeral tributary with a pebbly bottom. The conditions occurring at the TRIB site are not consistent with an expectation of optimal spawning/nursery habitat for freshwater cobbler (Tim Storer pers. comm.), rather the species prefers areas of lower flow that are dominated by sandy substrate in which to nest and lay eggs.

Considering the small proportion (5 per cent) of freshwater cobbler captured in the upstream-facing fyke nets, it is unlikely that any downstream migration occurred during the study period. Extending the sampling program through the remainder of 2010 to capture the downstream migration in the autumn and winter, and continuing analysis through to the start of the upstream migration, would complete lifecycle data.

In summary, this study has demonstrated migration of freshwater cobbler in the lower Canning River over the summer months, indicating adequate stream connectivity. Although cobbler didn't appear to reach the uppermost sites, it is highly likely that spawning grounds – given the current available range (Canning Dam blocks movement further upstream from CONF) – would exist downstream of the CONF site.

4.2 Environmental health

In terms of overall system health, without supplemented flow in the Canning River general reductions or changes in species diversity would be likely – by direct loss of flow-sensitive species and potential losses due to water quality deterioration in localised areas (potential stagnation).

As reduced flow has an indirect relationship with available habitat, abundance would be expected to decline; according to the basic understanding of holding capacity (predominantly for fish and crayfish species). Abundance would further suffer if water quality and habitat were affected by flows, given reproductive success is linked with the health of these factors. It is also likely that in more extreme conditions, the prevalence of diseases, lesions and parasites would increase – because these are often associated with overcrowding and/or reduced water quality.

These likely symptoms are not prevalent in the Canning River: the diversity and abundance of fish and macroinvertebrates follow expected species compositions (Storer et al. 2010, Galvin et al. 2009, WRM 2006, Storey 1998) with no signs of impaired condition.

Fish and crayfish

Nine native fish and crayfish species were recorded, including four endemic freshwater fish, three endemic freshwater crustaceans and two estuarine fish (freshwater component of lifecycle). Data was comparable with other systems in the area without the same hydrological pressures (Galvin et al. 2009). In addition, no sign of poor condition was noted (lesions, disease or parasites) in fish or crayfish.

Exotic fish species (mosquitofish and one-spot livebearer) were consistently found throughout the five study sites, while the exotic crayfish species yabby was only infrequently found. These species are commonly found in most river systems and are very robust and fecund. One-spot livebearers appear to be a recent addition to the river system (WRM 2006; Storey 1998) and if their populations have not yet stabilised may represent an increasing risk to native species through competition and predation.

Exotic species offer little evidence regarding the role of environmental water releases, because there are numerous reasons for these populations. However, given that exotics do not dominate any of the sites (as shown by Nativeness Index), the conditions are likely not departed to the point where native species have lost competitive advantage. Note: spangled perch were not previously recorded in the rivers of south-west Western Australia – this is being investigated by the Department of Water, Department of Fisheries and the Swan River Trust.

The western minnow offered the only potentially concerning feature, with evidence of gravid females discovered. Previous studies of the western minnow (Storey 1998; Storer et al. 2010) have shown that this species spawns in winter and spring, moving upstream to lay eggs. This data may indicate that minnows are receiving spawning cues from summer flows, which if true may interfere with recruitment success. However, it is more likely the gravid females discovered were late or early individuals within the natural variability of spawning migration. Large migrating populations were not observed. This finding should be assessed in any further analysis of the system.

Note: there was a decline in catches of some species through the sampling period – specifically western minnow, western pygmy perch and nightfish (from lower sites) – but this is more likely related to reduced activity as water temperatures decline.

Macroinvertebrates

The taxa richness of the sites in this study were comparable to other sites within the Swan-Canning catchments collected as part of the River Health Assessment Scheme (RHAS; Galvin et al 2009). Taxa richness reported in the RHAS range from three taxa found in drain sites to 21 taxa found in minimally disturbed systems (e.g. Helena River). Higher taxa richness at CONF and STOK can be attributed to the intactness of the riparian vegetation, which plays an important role in providing stream shading, allochthonous inputs (leaves, twigs, various sizes of woody debris) and habitat (overhanging and draping vegetation). The riparian vegetation at the other two sites, BROOK and GOS, was less intact (increased clearing) and hence the diversity of

habitat available to the invertebrates was reduced. Reduced diversity was also apparent in the functional feeding groups where filtering collectors were completely absent at the CONF site. The diversity of macroinvertebrates depends on the amount and diversity (complexity) of the available habitat. Hence it is important to maintain sufficient flows to ensure that woody debris, submerged macrophytes and overhanging vegetation remains flooded. This ensures that both habitat and invertebrate diversity is maintained.

the life histories of aquatic macroinvertebrates are fundamentally linked with the flow regime (Bunn et al. 1986). In south-west rivers, both seasonality and the predictability of flow from year to year are the main features of the flow regime influencing aquatic invertebrate community structure and composition. Stream permanence is the main driver in determining the invertebrate fauna. Ephemeral streams or streams with intermittent flows are characterised by distinctive faunal communities compared with permanent-flowing streams. Some macroinvertebrates are only found in these systems because they have life histories specifically adapted to suit the dry season. Other invertebrates can be found in both permanent and ephemeral systems but differ in abundance. In this study macroinvertebrates were only collected in late spring (November) so no seasonal comparison can be made. However, the Canning River is known to be a permanent river system and with the additional flow provided by the environmental water releases during the summer months, it is likely the flows remain stable throughout the year. Most macroinvertebrates collected in this study are found in permanent river systems, with some occurring in both permanent and ephemeral systems. Hence the discharge of the environmental water releases is important to maintain this suite of organisms which are adapted to permanency of flow.

Water quality

Water quality data supports the role of environmental water releases, in that no obvious sign of deterioration due to stagnation was evident. The only exception was dissolved oxygen levels, which at two sites (CONF and BROOK) were reduced to levels at the lower end of tolerance for a number of freshwater species (see review in Storer et al. 2010). However, this is not uncharacteristic of urban systems and showed no correlation with biotic data. It is likely that sufficient refuge from any potential dissolved oxygen issues is available within the system. Outside of dissolved oxygen, none of the monitored physical water quality variables exceeded ANZECC and ARMCANZ (2000) guidelines for maintenance of ecological health in aquatic ecosystems.

The role of the environmental water releases in maintaining water quality is particularly important at the CONF site. This site had the highest population of nightfish and appeared to be a refuge site throughout the summer months. The CONF site is a macrophyte-dominated stream pool that contains high levels of submerged organic material. Without supplemental flow, this pool may either dry or stagnate, with potential for a significant reduction in oxygen levels – thus, putting nightfish populations at risk.

5 Conclusions

The key questions addressed by this study relate to the effectiveness of environmental water releases in maintaining river connectivity and environmental health.

This study supports that river flow in the lower Canning River appears to be sufficient to maintain connectivity. This was established by observations suggesting ongoing viability in freshwater cobbler populations within the system. Abundance data, population structure and the reproductive condition of freshwater cobbler indicate successful upstream migration of the species – in spawning condition in large numbers – through November 2009 and into February 2010. Without the volumes of water being discharged at the environmental release points (ERPs), river connectivity would likely be a major issue for migration and spawning habitat would be limited for reaches in urbanised, highly impacted and regularly disturbed areas (lower catchment).

This study also found that the areas near the ERPs in the lower Canning River were in good environmental health, indicated by the suite of ecological indicators employed (including fish and crayfish composition, aquatic macroinvertebrates and water quality). As mentioned in Section 4.2, the role of environmental water releases in maintaining river health is particularly important for the CONF site, given its likely role as a summer refuge for nightfish and as a nursery for other species.

From the information gathered, it is likely the environmental water releases are having a marked positive effect on river health and that the loss of supplemental flows from this system would result in significant impacts.

6 Recommendations

- Complete seasonal surveillance, targeting downstream migration of freshwater cobbler (to complete knowledge of the migration cycle in the lower Canning River).
- Use of fish tags to track migration of adult fish to spawning habitats. This will confirm connectivity, demonstrating whether individuals could transverse the system's length. It would also enable identification of specific spawning and nursery habitats (understanding spawning and nursery habitats will improve our ability to manage systems).
- Future chlorination studies should identify the taxa found and examine possible pollution impacts on sensitive aquatic macroinvertebrate indicator species.

Appendices

Appendix A – Temporal fish catch data

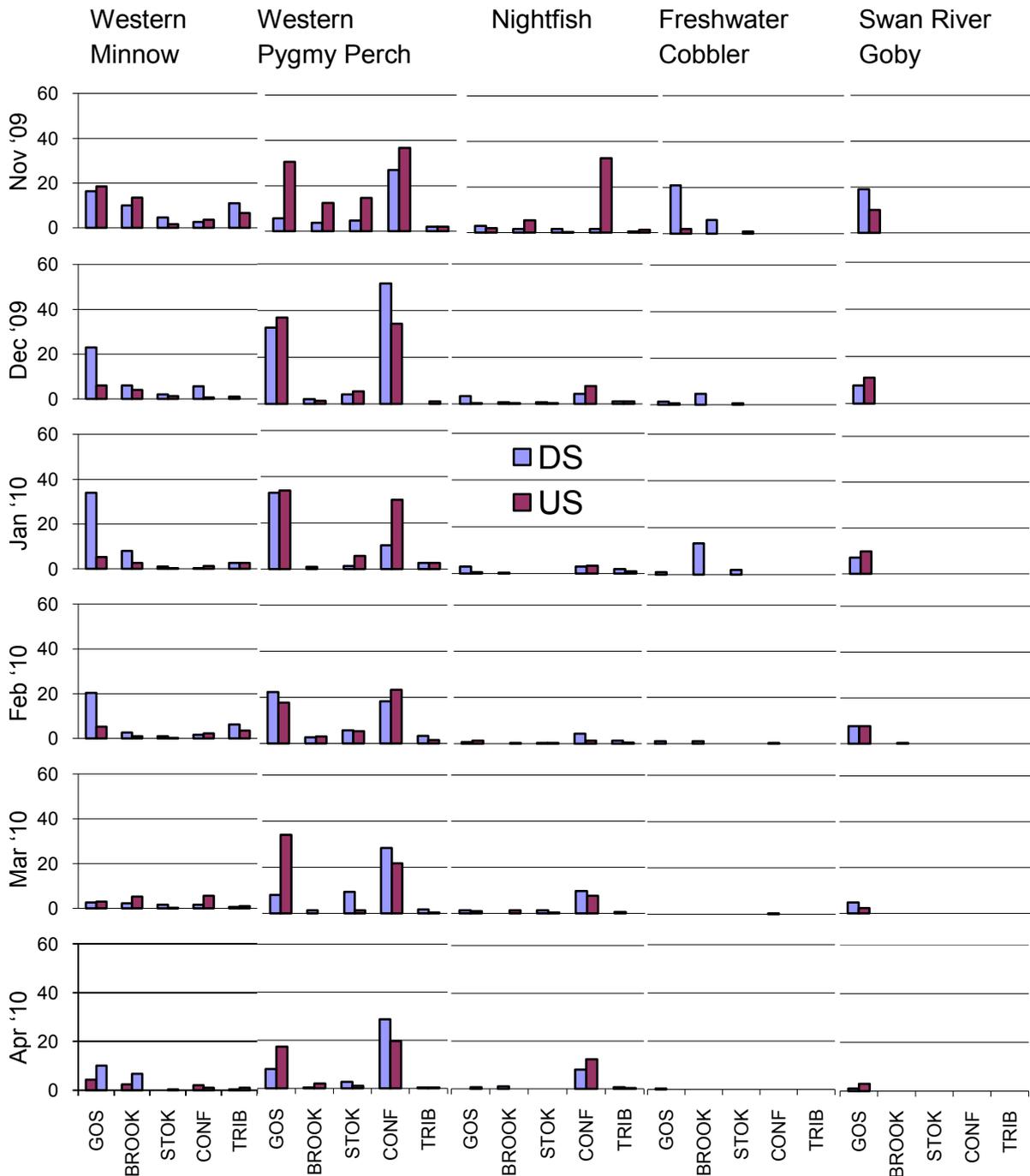


Figure A1 Native fish temporal catch data from five study sites in the upper Canning River (GOS, BROOK, STOK, CONF, TRIB) between Gosnells and Araluen

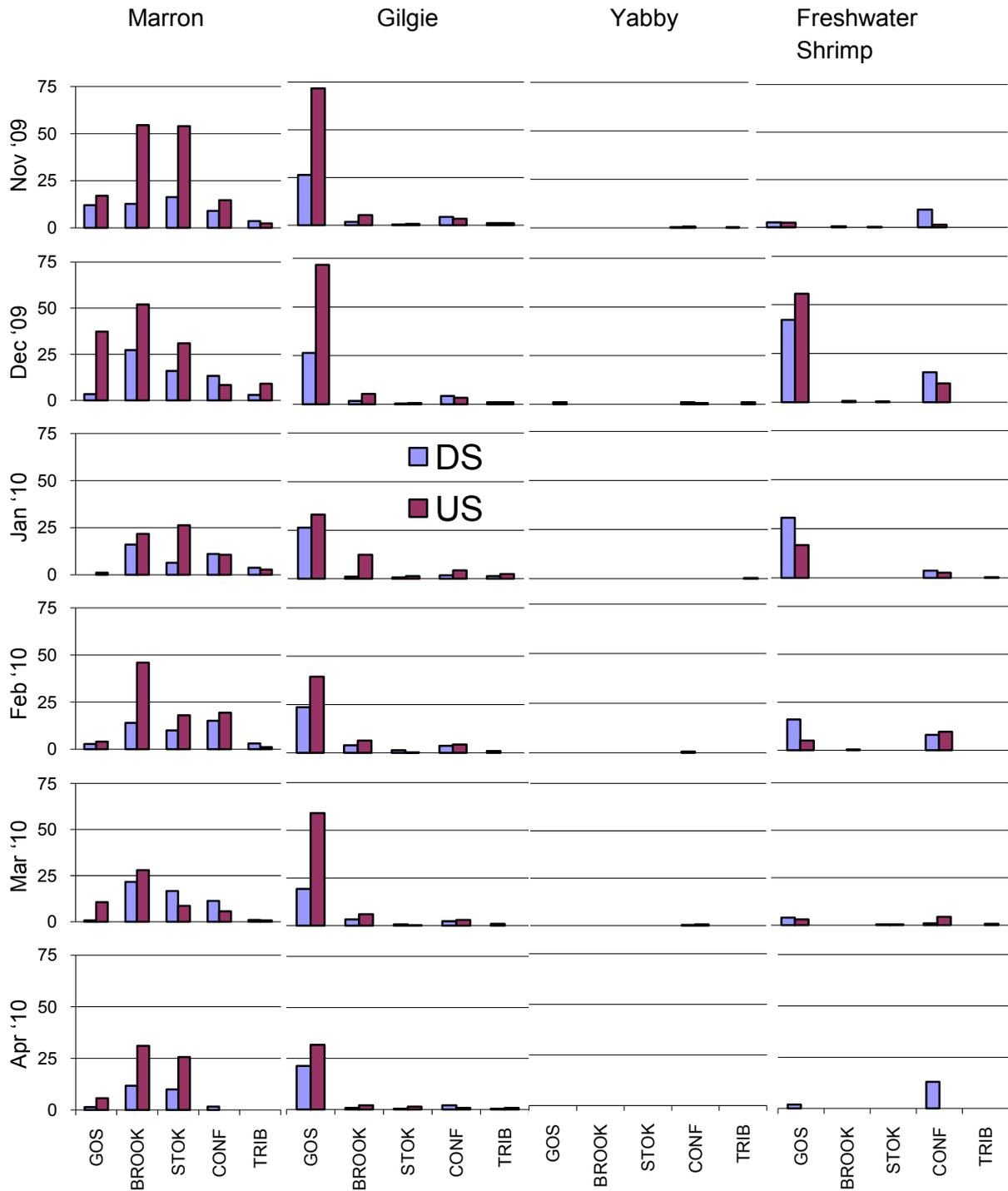


Figure A2 Crustacean temporal catch data from five study sites in the lower Canning River (GOS, BROOK, STOK, CONF, TRIB) between Gosnells and Araluen

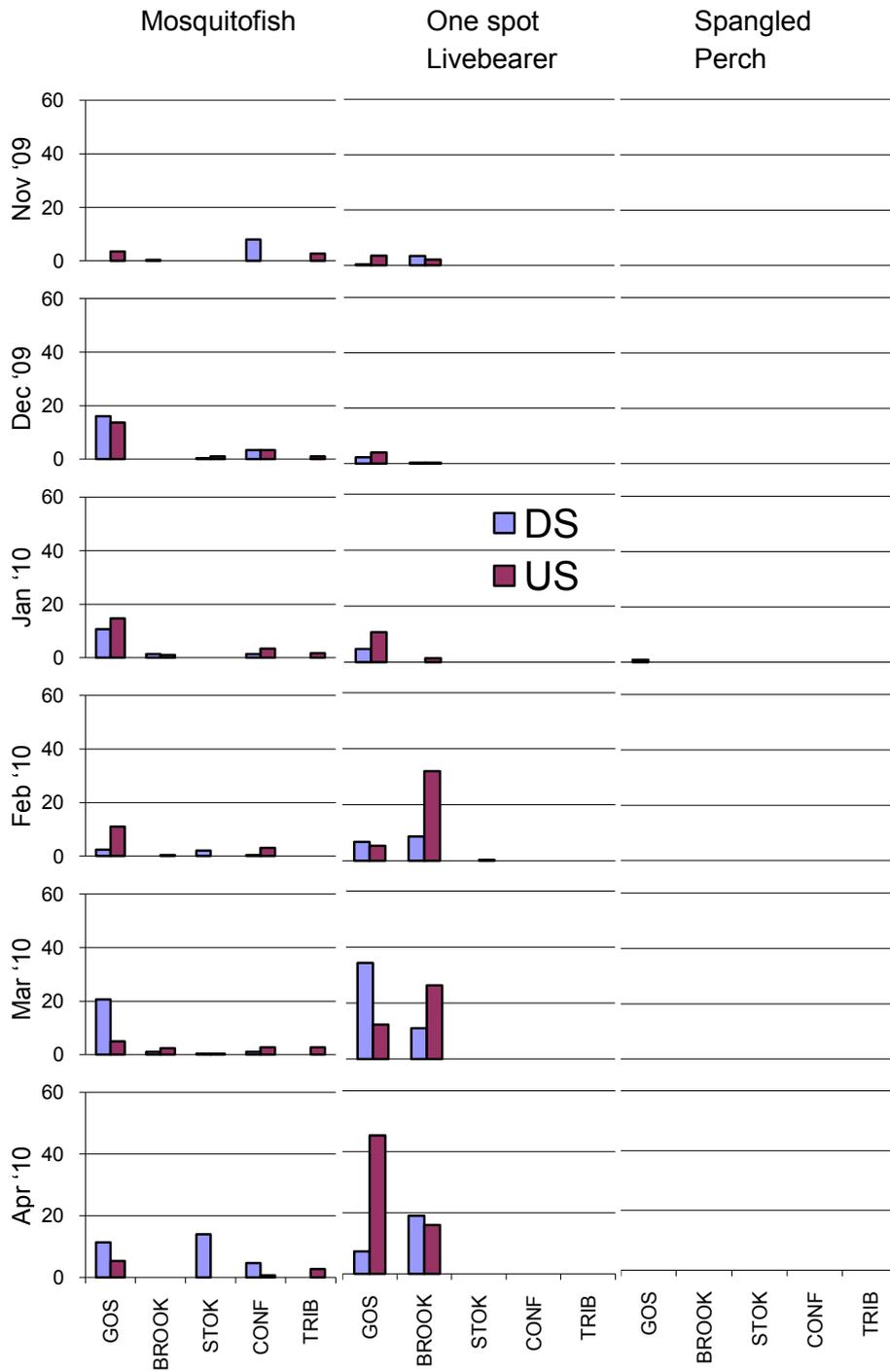


Figure A3 Exotic fish temporal catch data from five study sites in the lower Canning River (GOS, BROOK, STOK, CONF, TRIB) between Gosnells and Araluen

Appendix B – Fish and crayfish photographs



Figure B1 Western pygmy perch
(*Edelia vittata*)



Figure B2 Freshwater cobbler
(*Tandanus bostocki*)



Figure B3 Western minnow
(*Galaxias occidentalis*)



Figure B4 Freshwater cobbler
(*Tandanus bostocki*)
(juvenile)



Figure B5 Nightfish (*Bostockia porosa*)



Figure B6 Swan River goby
(*Pseudogobius olorum*)



Figure B7 Western hardyhead
(*Leptatherina wallacei*)



Figure B8 Freshwater shrimp
(*Palaemonetes australis*)



Figure B9 Marron (*Cherax cainii*)



Figure B.10 One-spot livebearer
(*Phalloceros caudimaculatus*)



Figure B11 Gilgie (*Cherax quinquecarinatus*)



Figure B12 Mosquitofish (*Gambusia holbrooki*)



Figure B13 Spangled perch
(*Leiopotherapon unicolor*)

Appendix C – Macroinvertebrate abundance

Table C1 Macroinvertebrate abundance at four sites in the lower Canning River in November 2009

Common name	Taxon Name	GOS	BROOK	STOK	CONF
		Channel	Channel	Channel	Macrophyte
Worm					
Ribbon worm	Nemertea spp.				1
Round worm	Nematoda spp.			2	
Earthworm	Oligochaeta spp.	47		11	3
Snail					
Tropical freshwater snail	Thiaridae spp.			2	
Ramshorn snails	Planorbidae spp.	1			
Freshwater limpet	Ancylidae spp.	6	1	3	
Mussel					
Freshwater mussel	<i>Westralunio carteri</i>			2	
Mite					
Water mite	Hydracarina spp.			1	5
Shrimp					
Freshwater shrimp	Palaemonidae spp.				36
Beetle					
Water beetles diving	Dytiscidae spp.		1	8	12
Water beetles surface	Gyrinidae spp.		1	2	1
Midge					
Crane fly	Tipulidae spp.		1		2
Dixid midge	Dixidae spp.				1
Biting midge	Ceratopogonidae spp.	11			
Black fly	Simuliidae spp.	7	1	1	
Midge non biting	Chironominae spp.	32	21	137	14
Midge non biting	Tanypodinae sp.			7	3
Midge non biting	Orthoclaadiinae spp.	8	3	6	5
Mayfly					
Mayfly small square gill	Tasmanocoenis sp.			5	1
Dragonfly					
Dragonfly	Austrogomphus sp.		1		
Dragonfly	Orthetrum sp	1			
Dragonfly alpine darner	Austroaeschna sp.				2
Dragonfly	Hemicordulia sp.	1			
Dragonfly	Hemicorduliidae spp.	4			
Caddisfly					
Caddisfly	Hellyethira sp.				1

Common name	Taxon Name	GOS	BROOK	STOK	CONF
		Channel	Channel	Channel	Macrophyte
Caddisfly	Hellyethira/Acritoptila spp.	1		1	
Caddisfly	Hydroptilidae juveniles				1
Caddisfly net-spinning	Hydropsychidae spp.		1		
Caddisfly long-horned	Triplectides sp.	1	2		
Caddisfly long-horned	Leptocerid juveniles			2	1

Appendix D – Habitat data

Described below are the habitat characteristics of each of the sites assessed.

GOS

The GOS site is a highly modified site that has retained a good proportion of woody debris. The site was characterised predominantly by channel habitat (no aquatic macrophytes), moderate amounts of woody debris of varying size, some draping vegetation/root overhang and stream shading that promoted good habitats. The physical substrate mostly consisted of fine sand and silt, producing a moderate plume when disturbed. The biological substrate comprised a variety of organic material such as leaves, twigs and branches that promoted good habitats. A large amount of erosion was present at the site due to human access and clearing. The riparian vegetation was largely cleared except for a few scattered large native trees and exotic weed understorey. There was limited evidence of recruitment of native trees. The surrounding land uses included remnant vegetation, crown land, agriculture and urban housing. No point-source pollution was evident but there was upstream and downstream non-point -source pollution from orchards, urban housing and roads.

BROOK

The BROOK site is a highly modified site with many exotic weeds and an incised channel from fast flows. The narrow channel showed evidence of high flows such as bank undercutting, although a log weir at the site provided some baffling of flow and protected areas. The site consisted predominantly of channel habitat with some submerged macrophytes (*Vallisneria* sp.) and woody debris present. The river was also mostly shaded with overhanging roots and vegetation draping into the water. The physical substrate was characterised by fine sand and silt, producing a moderate plume when disturbed. The biological substrate comprised twigs and branches. Bank erosion was high due to human access and clearing. The riparian vegetation had been cleared except for the large native trees. The riparian vegetation had been replaced by extensive stands of exotic grasses and vines. There was no evidence of recruitment of native trees or shrubs. Surrounding land uses included remnant vegetation, vacant crown land and urban housing. No point-source pollution was evident but there was non-point-source pollution from urban housing.

STOK

The STOK site is a highly modified upland site located next to a road bridge with remnant vegetation, woody debris and emergent sedge habitat. The site was mostly channel habitat with some emergent macrophytes, woody debris and draping vegetation present and moderate shading of the river. The physical substrate consisted predominantly of sand and some boulders, producing a moderate plume when disturbed. The biological substrate comprised leaves, twigs, branches and detritus. Bank erosion was moderate and a result of human access, clearing and

irrigation drawdown. In part the riparian vegetation had been cleared except for the large native trees, with some remaining native understorey. There was some limited evidence of native recruitment of trees and shrubs. Surrounding land uses included; hobby farms (mainly horse paddocks), remnant vegetation, vacant crown land and urban housing. No point-source pollution was evident but there was upstream and downstream non-point source pollution from hobby farms, urban housing and roads.

CONF

The CONF site is a relatively pristine upland pool site surrounded by dense native vegetation, dense aquatic macrophyte beds and stagnant, flocky sediment. The pool site was predominantly a macrophyte habitat with both emergent and submerged aquatic plants, woody debris, draping vegetation and stream shading. The physical substrate was mostly fine silt, producing a large persistent plume when disturbed. The biological substrate was dominated by detritus, with few leaves, twigs and branches – producing a strong anaerobic smell when disturbed. Bank erosion was minor due to well-vegetated banks. The riparian vegetation was intact, although some invasion by exotic weeds and shrubs had occurred. Natural recruitment of native trees and shrubs was evident. Surrounding land uses included forest, urban roads and buildings. No point-source pollution was evident but upstream there was non-point-source pollution from the botanical gardens (possible nutrient and pesticide inputs) and urban roads, and downstream from urban housing and roads.

TRIB

The TRIB site is a pristine upland narrow tributary surrounded by dense native vegetation. The site was predominantly channel habitat with the presence of some emergent macrophytes, woody debris, draping vegetation and root overhang. The river was well shaded. The physical substrate was characterised by pebbles and boulders; no plume was produced when disturbed. The biological substrate comprised leaves, twigs and branches. Bank erosion was high due to a combination of the narrow channel and fast flow. The riparian vegetation was intact, although some invasion by exotic weeds and shrubs was evident. Natural recruitment of native trees and shrubs was evident. Surrounding land uses included forest and urban roads. No point-source pollution was evident but there was upstream non-point-source pollution from the botanical gardens (possible nutrient and pesticide inputs) and urban roads.

Appendix E – Environmental water release management

Environmental water release flow rates

The environmental water releases are regulated in two ways: as a ‘summer flow’ (continuous 8.5 ML/day, total for Canning River – all sites) and additional ‘fish pulses’ which are short bursts of increased flow of (21.6 ML/d for five days). The environmental water release flow volumes vary between sites and are described in Table E1.

Table E1 Environmental water release flow rates

ERP site	Summer flow (ML/day)	Fish pulse (ML/day)
Gosnells Bridge	1.6	2.5
Manning Avenue	0.2	5.4
Orlando Street	1.6	4.7
Bernard Street	0.1	2.4
Hill 60	2.2	3.1
Araluen	2.8	2.8

Environmental water release triggers

The Department of Water’s Water Allocation Planning Branch has set the triggers for initiating ‘summer flows’ and any additional ‘fish pulses’ required (Table E2).

Table E2 Environmental water release trigger values

Environmental water release type	Start trigger	End trigger
Summer flow	Gauging station flow < 9.3 ML/day in spring or summer	> 40 mm cumulative rainfall after 1 April
Fish pulse	Flow < 9.3 ML/day for 15 consecutive days	No trigger (fixed five-day duration)

Environmental release point open and close dates

The six environmental release points were opened at the same time; and after the rainfall trigger value for shutting down was met, the sites were successively shut down two sites per week from the downstream areas first (Table E3).

Table E3 Environmental water release schedule

Environmental release point	Open date	Close date
Gosnells Bridge and Manning Avenue	1/12/2009	15/05/2010
Orlando Street and Bernard Street	1/12/2009	25/05/2010
Hill 60 and Araluen	1/12/2009	11/6/2010

Rainfall and stream flow data

Rainfall data was taken from the rain gauge at Gosnells City weather station (009106) and Bickley weather station (009021). Streamflow data was taken from Seaforth gauging station (616027) <<http://www.water.wa.gov.au/idelve/rms/>>

Glossary

Abstraction	The permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Allocation	Permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Allocation limit	Annual volume of water set aside for use from a water resource.
Analyte	A substance, chemical constituent or environmental condition that is determined in an analytical procedure.
Anoxic	An absence of oxygen, an extreme form of hypoxia or 'low oxygen' (anoxic 0 per cent and hypoxia < 40 per cent dissolved oxygen saturation in solution).
Aquatic ecology	Freshwater or marine communities of organisms dependent on each other and on their environment through food web interactions.
Aquatic habitat	Environments in which aquatic species live, influence or utilise. Common habitat types include protected low-flow areas, in-stream woody debris, leaf litter and sandy substrates, macrophyte areas and surfaces.
Aquatic macro-invertebrates	A general term for the community of aquatic invertebrates larger than 0.25 mm including larger fast swimming nekton inhabiting the upper water column and benthos which live within or on the bed. Generally excludes the smaller zooplankton (copepods and cladocerans).
Aquatic macrophytes	Emergent, submergent, or floating aquatic plants that grow in or near water and provide cover for fish and substrate for aquatic invertebrates, produce oxygen, and act as food for some fish and wildlife.
Barrier assessment	The measurement and classification barriers in rivers that prevent fish migration. Barriers can be physical such as dams and weirs, or chemical such as pollutants entering a waterway.
Baseflow	The component of streamflow supplied by groundwater discharge.
Baseline data	Data or measurements collected as a starting point, generally before a program or activity begins.
Biological substrate	The biological component of the streambed and other substrates which are made up of organic matter such as woody debris, sticks, leaves and decomposing matter.
Catch per unit effort	A measurement of abundance that accounts for effort or number of nets used or days fished.
Confluence	Running together, flowing together, e.g. where a tributary joins a river.
Critical habitat	Habitats that function to provide essential functions for aquatic fauna such as spawning events, nursery areas, or other important factors in aquatic biota lifecycles.
Discharge	The water that moves from the groundwater to the ground surface or above, such as a spring. This includes water that seeps onto the ground surface, evaporation from unsaturated soil, and water extracted from groundwater by plants (evapotranspiration) or engineering works (groundwater pumping)
Discharge rate	Volumetric outflow rate of water, typically measured in cubic metres per second (m ³ /sec).

Dissolved oxygen	A relative measure of the amount of oxygen that is dissolved or carried in water. It can be measured with a dissolved oxygen probe such as an oxygen sensor submerged in water. The units of concentration are generally mg/L or per cent sat: mg/L refers to the amount available and is more relevant to fish health; per cent sat refers to the concentration relative to the maximum amount possible given the ambient environmental conditions of temperature, salinity and pressure and is more widely used to assess environmental health.
Diurnal cycle	A pattern that recurs every 24 hours. In the case of water quality it refers to temperature and inversely related dissolved oxygen variations.
Ecological health	Symptoms of an ecosystem's ability to perform nature's functions, affected by anthropogenic disturbance such as pollution and development of habitat and food sources.
Ecological indicators	Ways of assessing ecological health using surrogates such as fish, macroinvertebrates and water quality.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirement	The water regime needed to maintain the ecological values (including assets, functions and processes) of water-dependent ecosystems at a low level of risk.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact, e.g. a lake, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Electrical conductivity	Used to measure salinity or impurities in water and uses variations electrical potential based on the solution's conductivity. 55mS/cm is equivalent to seawater concentration of 33 ppt or psu.
Endemic species	Unique to a particular geographic location.
Environmental release point (ERP)	The site at which supplementary scheme water is piped into a river to provide water users and the environment with summer water when natural flow ceases.
Environmental water releases	A program of piping supplementary water into rivers to provide water users and the environment with summer water when natural flow declines or ceases.
Environmental water provision	The water regimes that are provided as a result of the water allocation decision-making process, taking into account ecological, social, cultural and economic impacts. They may meet in part or in full the ecological water requirements.
Exotic species	An introduced or non-native species, outside its native distributional range, introduced either deliberately or accidentally by human activity.
Fecund	Fertile.
Fish kill	The sudden and mass death of aquatic animals due to the introduction of pollutants, the reduction of dissolved oxygen concentration in a waterbody, lifecycle related or unexplained.

Fish migration	Fish movement generally for diet or reproductive needs. Potamodromous fish migrate within fresh water; diadromous fish travel between salt and fresh water; anadromous fish live in the ocean mostly, and breed in fresh water; catadromous fish live in fresh water, and breed in the ocean; amphidromous fish move between fresh and salt water during their life cycle, but not to breed.
Fish pulses	Additional periods of increased flow in the management of environmental water releases within a river.
Flow	Streamflow – may be measured as m ³ /yr, m ³ /d or ML/yr. May also be referred to as discharge.
Flow triggers	Flow rate to initiate a management response such as the initiation of environmental water release flows or additional ‘fish pulses’.
Food web	The interrelated producer-predator-prey relationships that exist between species within an ecosystem. The food web is divided into two broad categories: the grazing web – materials typically pass from plants (producers) to plant eaters (herbivores) to flesh eaters (carnivores) (plants) and the detrital web (organic debris); and the detrital web – materials pass from plant and animal matter to bacteria and fungi (decomposers), then to detrital feeders (detritivores), and then to their predators (carnivores).
Functional feeding groups	Macroinvertebrate groupings based on feeding habits that relate to the trophic food levels on which they operate.
Fyke nets	A funnel-like net design including side-wings, baffles within the net tube, and a ‘cod end’ opening in which to catch fish. Fyke nets do not use bait and are usually placed within moderate-flowing rivers to catch up or downstream migrating fish.
Gauging station	A location used to monitor and test terrestrial bodies of water. Various hydrometry readings are made at gauging stations such as volumetric flow rate, water quality and observations of biota.
Gravid	The condition of a fish when carrying eggs internally.
Guidelines	Values or ranges of acceptable or unacceptable levels of a chemical, beyond which a management response is usually triggered.
Indicator species	A biological species that defines a trait or characteristic of the environment. A species may indicate an environmental condition such as pollution, species competition, a disease outbreak or climate change. Indicator species can be among the most sensitive species in a region and are used as an early warning for monitoring programs.
Inflows	Surface water runoff; deep drainage to groundwater (groundwater recharge); and transfers into the water system (both surface and groundwater), for a defined area
Licence	A formal authorisation which entitles the licence holder to ‘take’ water from a watercourse, wetland or underground source for a specified quantity and period of time.
Licensed abstracters	Water users issued a licence to draw water from a waterbody. These licences make up a portion of the water allocation for a particular resource.

Multi-sensor data logger	Often refers to a water quality meter placed and left in the field that measures and stores data on variables in the field (in situ). Variables can include: pH, temperature, dissolved oxygen, electrolytic conductivity and turbidity. Water quality data is collected by submersing the sensor in the water to indicate environmental conditions.
Multi-sensor probe	Often refers to a handheld water quality meter that measures variables in the field (in situ). Variables can include: pH, temperature, dissolved oxygen, electrolytic conductivity and turbidity. Water quality data is collected by submersing the sensor in the water to indicate environmental conditions.
Native species	A species given to a region or ecosystem as a result of natural processes only.
Nursery area	An aquatic habitat that is suitable for the rearing of juvenile aquatic fauna.
pH	A log scale for indicating the acidity of a solution in terms of hydrogen ion concentration.
Physical substrate	The silt, sand and stone components of the streambed.
Remnant vegetation	The remaining intact native vegetation after development of a naturally vegetated area.
Riffles	A stretch of stream producing choppy or broken water due to a shallow underlying rocky or sandy substrate.
Riparian right	Right of a riparian landowner to take water from a watercourse, which flows through or is contiguous to their property, unlicensed and free of charge for the purpose of non-intensive stock and ordinary domestic use, without sensibly diminishing the flow of water downstream.
Riparian vegetation	Plant habitats and communities along the river margins and banks.
Scheme water	Water diverted from a source (or sources) by a water services authority or private company and supplied via a distribution network to customers for urban, industrial or irrigation use.
Scheme water	Treated and piped drinking water supplied by a local water authority.
Scour valves	A pipe opening at a low point in a valley to clean the pipeline.
Species diversity	The number of species. A measure used to indicate health or change in a population.
Spot readings	A single reading taken at a point in time.
Stream connectivity	The degree of continuity or uninterrupted stretches of a river system. Relevant to migrating biota. Connectivity can be seasonally affected due to variations in flow, or interrupted from barrier structures such as weirs and dams.
Streamflow	The movement of water in rivers and other channels. Streamflow consists of surface runoff flows through channels in adjacent hillslopes, groundwater flow out of the ground, and water discharged from pipes.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Surface water allocation area	An area defined by the Department of Water, used for water allocation planning and management, that is generally a hydrologic basin or part of a basin.

Surface water allocation subarea	An area within a surface water management area defined by the Department of Water, used for water allocation planning and management, that is generally a hydrologic catchment.
Surface water resource	Defined area for allocation and licensing decisions for a particular plan area. For this plan, surface water resource boundaries are the same as surface water allocation subareas.
Sweep net	A lightweight (often 250 µm) mesh to collect aquatic insects by scooping the nets through the water column and across the streambed.
Trophic levels	A set of interconnected food relationships by which energy and materials circulate within an ecosystem relating to different levels of the food web.
Turbidity	The cloudiness of a fluid caused by suspended solids. The measurement of turbidity is a key test of water quality and the units of measurement are NTU (nephelometric turbidity units).
Watercourse	<p>A watercourse means:</p> <ol style="list-style-type: none"> any river, creek, stream or brook in which water flows any collection of water (including a reservoir) into, through or out of which any thing coming within paragraph (a) flows any place where water flows that is prescribed by local by-laws to be a watercourse <p>and includes the bed and banks of any thing referred to in paragraph a, b or c.</p> <p>(Definition from the <i>Rights in Water and Irrigation Act 1914</i>)</p>
Water-dependent ecosystems	Those parts of the environment which are sustained by the permanent or temporary presence of water.
Water entitlement	The quantity of water that a person is entitled to take on an annual basis in accordance with the <i>Rights in Water and Irrigation Act 1914</i> and a licence.
Water quality	The physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose.
Water regime	A description of the variation of flow rate or water level over time. It may also include a description of water quality.
Waterways	All streams, creeks, stormwater drains, rivers, estuaries, coastal lagoons, inlets and harbours.

Volumes of water

One litre	1 litre	1 litre	(L)
One thousand litres	1000 litres	1 kilolitre	(kL)
One million litres	1 000 000 litres	1 Megalitre	(ML)
One thousand million litres	1 000 000 000 litres	1 Gigalitre	(GL)

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