River Runs Through It. Evaluation of Groundwater and Surface Water Connectivity and its Implication on Riparian Biogeochemistry and Ecology

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1 Introduction

- As flow enters riverine floodplains it carries with it sediment, organic matter and nutrients from upstream water bodies stimulating microbial communities and biogeochemical cycling.
- Landscape scale factors can also influence riverine water balance through changes in rainfall-runoff relationships and groundwater interaction.
- Land clearing and intensive irrigation can affect the groundwater elevation (i.e. subsurface saline aquifer) allowing high salinity groundwater to seep into the river affecting the ecosystems integrity.

Objectives

1. Evaluate rainfall and discharge relationships along the lower reaches of the Wimmera River.
2. Evaluate river salinity (specific conductance) and determine how faunal composition changes due to high salinity conditions.
3. Investigate nutrient trends in the Wimmera River.

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2 Material and Methods

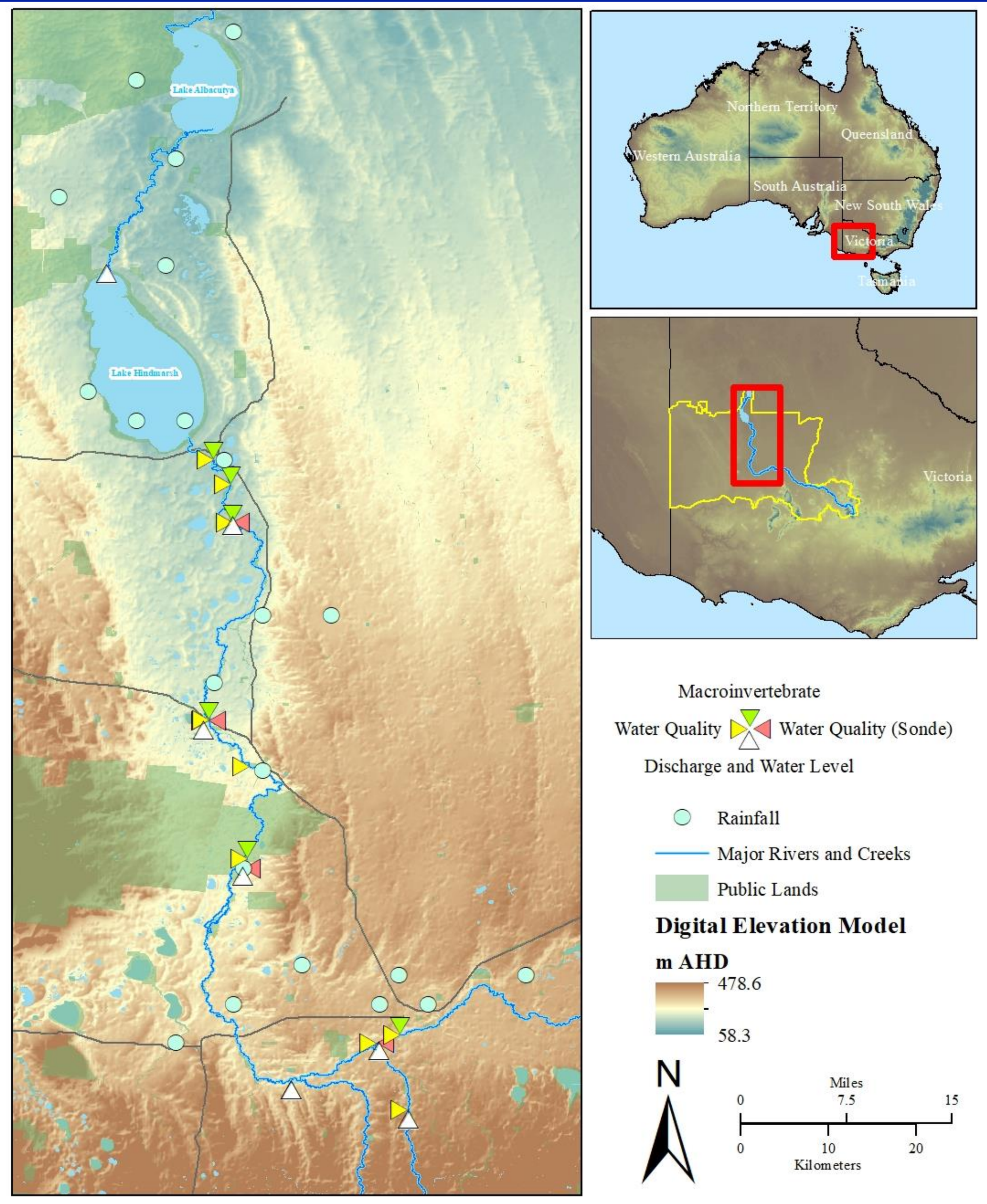

Figure 1. Monitoring locations along the lower Wimmera River between the town of Horsham and Lake Albacutya

Data sources

- Hydrologic data were queried from the Victoria State Government Department of Environment, Land, Water and Planning (DELWP) water measurement information system (WMIS; http://data.water.vic.gov.au).
- Rainfall data were queried from the Australian Government Bureau of Meteorology (BoM) environmental information explorer (http://www.bom.gov.au/jsp/eiexplorer/).
- Grab and *in-situ* water quality data were retrieved from the DELWP WMIS
- Additional water quality data and macroinvertebrate data were provided by the Environmental Protection Authority Victoria.

Data Analysis

- Annual discharge volumes were calculated for each discharge monitoring locations based on the EPA Victoria water year (June 1st – May 30th).
- Annual rainfall totals were also computed by water year.
  - Drought severity was assessed between WY1920 and 2016 using the standardized rainfall anomaly (SRA; Asfaw et al. 2018) index where total annual rainfall (P_t) are related to the mean and standard deviation (P_m and σ, respectively) observed across the entire.

$$SRA = \frac{P_t - P_m}{\sigma}$$

- Daily average specific conductivity was calculated from sonde data collected at Horsham, Dimboola, Lochiel and Tarranyurk (Fig 1).
- Annual (WY) geometric mean total phosphorus (TP) and total nitrogen (TN) were computed and analyzed using Kendall's tau trend analysis for sites (Fig 1).
- Macroinvertebrate Salinity Sensitivity Index (SSI; Horrigan et al. 2005) and Diversity Indices (Shannon H' and Simpson 1-D) were evaluated from sites with greater than two years of data and concurrent salinity monitoring.
  - SSI and grab sample specific conductance was compared using spearman's correlation.
  - SSI was compared to diversity indices using spearman's correlation.

Horrigan et al. (2005) Marine and Freshwater Research 56:825–833.
Asfaw et al. (2018) Weather and Climate Extremes 19:29–41.

3 Results

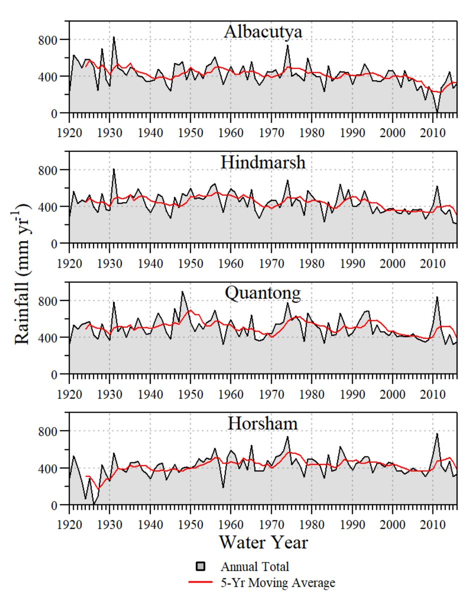

Figure 2. Annual and five-year moving average regional rainfall for regions along the Wimmera River between Horsham and Lake Albacutya spanning water year 1920 and 2016 (June 1st 1919 and May 30th 2017).

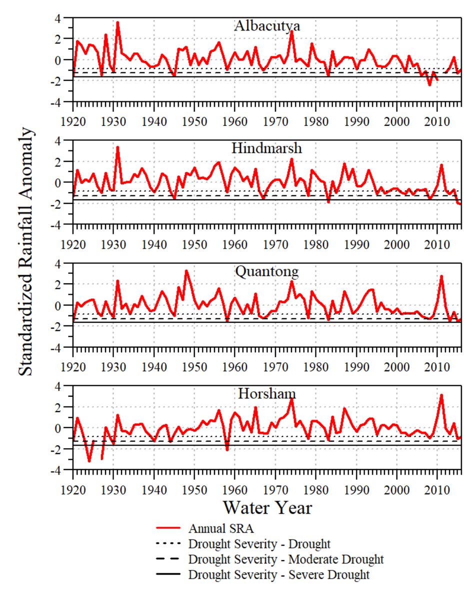

Figure 3. Annual standardized rainfall anomaly values for the period spanning water 1920 and 2016 (June 1st 1919 and May 30th 2017) along the Wimmera River between Horsham and Lake Albacutya. Drought severity categories are also identified by a series of dashed lines.

Table 1. Long term (WY 1920 – 2016) and medium term (WY1990 – 2016) trend analysis of annual rainfall totals for regions across the study area. Mann-Kendall trend analysis and Thiel-Sen's were used to assess long and medium-term trends. Lochiel and Dimboola regions were excluded from long-term trend analysis due to extensive missing data.

Period	Region	Thiel-Sen's Slope	τ-value	ρ-value
Long Term (1920 - 2016)	Albacutya	-1.6	-0.27	*<0.01*
	Hindmarsh	-1.5	-0.25	*<0.01*
	Quantong	-0.9	-0.15	*<0.05*
	Horsham	0.5	0.09	0.23
Medium (1990 - 2016)	Albacutya	-5.1	-0.36	*<0.05*
	Hindmarsh	-4.1	-0.37	*<0.01*
	Lochiel	-3.7	-0.9	*<0.05*
	Dimboola	-4.5	-0.26	0.06
	Quantong	-6.6	-0.42	*<0.01*
	Horsham	-3.3	-0.25	0.06

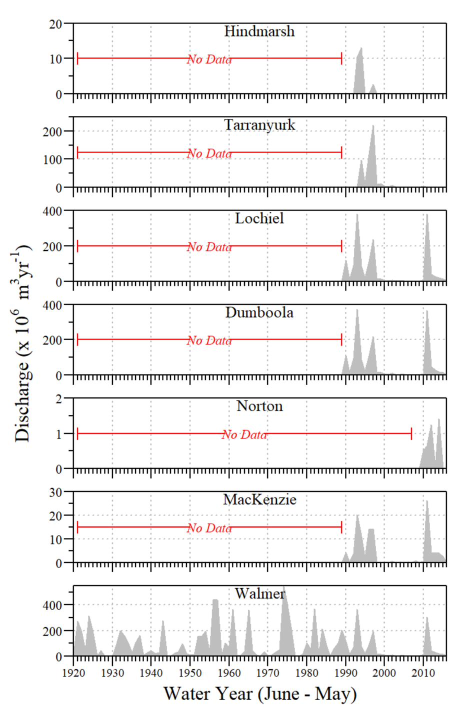

Figure 3. Annual discharge volume along the Wimmera River including major tributaries Norton and MacKenzie Creek within our study area. Period of record varies for each location with Walmer (i.e. Horsham) having the longest and Norton the shortest.

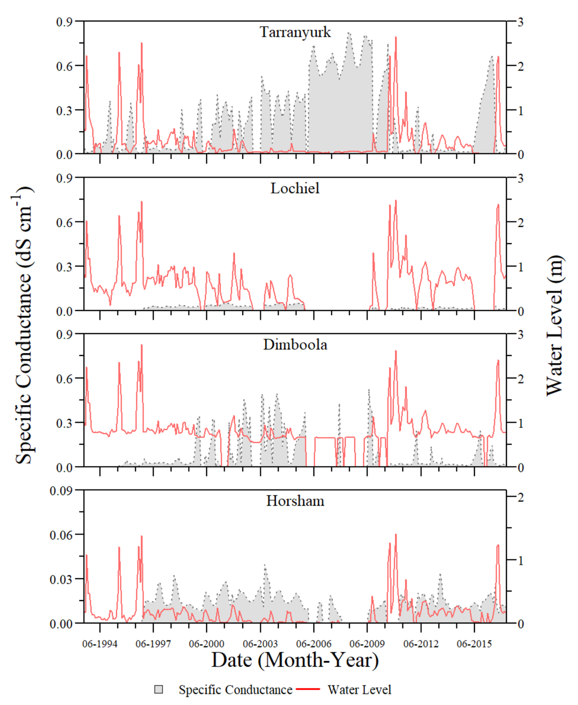

Figure 5. Monthly mean specific conductance (from high-frequency sonde data) and water level data for locations along the Wimmera River.

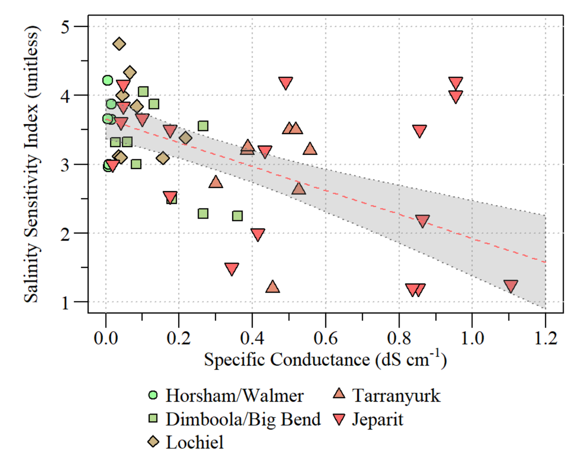

Figure 6. Macroinvertebrates salinity sensitivity index (SSI) by grab sample specific conductance at monitoring locations along the Wimmera River. SSI =1 indicates high salinity tolerance tax; SSI = 10 indicates salinity sensitive taxa. Relationship correlation indicated by median-based linear model (red-dashed line) and 95% confidence interval (grey shaded region).

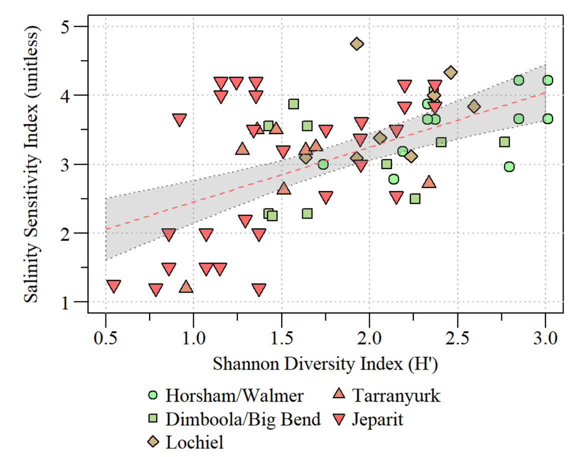

Figure 7. Macroinvertebrates salinity sensitivity index (SSI) by Shannon's diversity index at monitoring locations along the Wimmera River. SSI =1 indicates high salinity tolerance tax; SSI = 10 indicates salinity sensitive taxa. Relationship correlation indicated by median-based linear model (red-dashed line) and 95% confidence interval (grey shaded region).

- Macroinvertebrate SSI was negatively correlated with surface water specific conductance (N=68, r-value=-0.33, ρ-value<0.05)
- Macroinvertebrate SSI was positively correlated with Shannon's diversity index (N=68, r-value=0.45, ρ-value<0.01)

Table 2. Summary statistics of selected water quality parameters at monitoring stations along the Wimmera River. Data represented as mean ± standard error (minimum – maximum; Sample Size). TP= Total Phosphorus; SRP = Soluble Reactive Phosphorus (also known as Filterable Reactive Phosphorous); TN = Total Nitrogen; NO_X = Nitrate-Nitrite; SPC= Specific Conductance; TSS= Total Suspended Solids.

Area[1]	TP (μg L⁻¹)	SRP (μg L⁻¹)	TN (mg L⁻¹)	NO_X (μg L⁻¹)	SPC (μS cm⁻¹)	TSS (mg L⁻¹)
Jeparit	157 ± 41 (16 - 820; 25)	---	3.6 ± 1.18 (0.8 - 16; 14)	38 ± 0.015 (3 - 370; 25)	50171 ± 9797 (1790 - 110374; 15)	14.5 ± 3.8 (7 - 40; 8)
Tarranyurk	31 ± 8 (5 - 74; 8)	---	1.2 ± 0.10 (0.9 - 1.4; 4)	24 ± 0.021 (3 - 170; 8)	45313 ± 3126 (29930 - 55601; 8)	---
Lochiel	45 ± 3 (7 - 300; 319)	6.9 ± 0.8 (1 - 150; 311)	1.2 ± 0.03 (0.5 - 3.8; 315)	31 ± 0.004 (2 - 510; 319)	3020 ± 138 (359 - 21740; 316)	17.3 ± 0.8 (2 - 120; 311)
Dimboola/ BigBend	36 ± 7 (16 - 74; 9)	---	1.4 ± 0.20 (0.8 - 1.7; 3)	8 ± 0.004 (3 - 41; 9)	14070 ± 3655 (2671 - 35900; 9)	---
Dimboola	51 ± 8 (8 - 1000; 176)	17.4 ± 12.5 (3 - 1000; 80)	1.1 ± 0.03 (0.5 - 2.9; 174)	46 ± 0.008 (3 - 1000; 176)	42750 ± 22550 (20200 - 65300; 2)	14.2 ± 1.4 (1 - 140; 171)
MacKenzie	79 ± 6 (12 - 490; 192)	9.0 ± 1.7 (3 - 250; 192)	1.3 ± 0.05 (0.5 - 4.2; 192)	32 ± 0.007 (2 - 760; 192)	244 ± 21 (95 - 2238; 135)	16.5 ± 1.3 (1 - 150; 192)
Horsham	54 ± 2 (5 - 210; 339)	6.0 ± 0.4 (3 - 60; 339)	1.1 ± 0.02 (0.01 - 3; 339)	55 ± 0.005 (2 - 800; 339)	1490 ± 36 (216 - 4127; 337)	20.5 ± 1.2 (1 - 180; 339)
Horsham/ Walmer	35 ± 5 (22 – 45; 4)	---	0.8 ± 0.07 (0.75 – 0.88; 2)	11 ± 0.005 (3 – 22; 4)	987 ± 174 (607 – 1528; 5)	---

[1] Sites used to characterize regions along the river.

Area	Site ID	Source
Jeparit	141490	EPA Victoria
Jeparit	154300	EPA Victoria
Tarranyurk	415247	EPA Victoria
Lochiel	142100	EPA Victoria
Dimboola/Big Bend	141540	EPA Victoria

Area	Site ID	Source
Dimboola	154500	EPA Victoria
Lochiel	415246	DELWP
MacKenzie	415251	DELWP
Horsham	415200	DELWP
Horsham/Walmer	154600	EPA Victoria

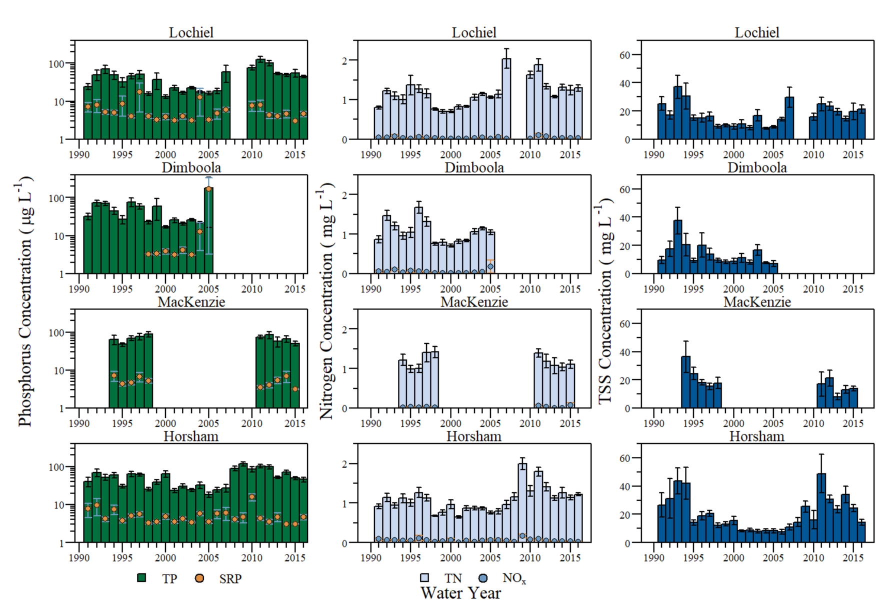

Figure 8. Annual mean (± SE) total phosphorus (TP), soluable reactive phosphorus (SRP), total nitrogen (TN), nitrate-nitrite (NO_X) and total suspended solid concentrations for locations with sufficient data. Only years with greater than four samples were included. Water year spans June 1st to May 31th. Statistically significant trends were only apparent for select parameters at Lochiel (TN: τ=0.28, ρ<0.01), Dimboola (TSS: τ= -0.52, ρ<0.01) and MacKenzie (TSS : τ= -0.60, ρ<0.05).

4 Conclusions

- Rainfall patterns have significantly declined in several regions of the Wimmera river across the long (96 year) and medium (26 year) term period potentially indicating a shift in regional climate (Fig 2).
- Using the SRA index flood and drought periods can be identified, several drought periods were identified including the World War II (1939 – 1946) and Millennial (2001 – 2009) drought and flood years (i.e. 1942, 2011, etc.) to name a few (Fig 3 and 4).
- Specific conductance values vary dramatically along the lower reaches of the Wimmera River (Fig 5 and Table 2).
- River water level generally corresponds with high salinity (specific conditions) especially in the lower reaches (i.e. Tarranyurk; Fig 5).
- Periods of high salinity within the river influences macroinvertebrate diversity. As expected, opportunistic taxa (less salinity sensitive species) were present at both impacted and unimpacted sites while high salinity sites corresponded with lower diversity (Fig 6 and 7).
- Generally, total nutrients concentrations have remained constant with low inorganic nutrient concentrations. Suspended solids were variable across the network with some sites experiencing significant declines in concentrations (Fig 8).

5 Acknowledgements

We would like to thank the Victoria State Government and the Environmental Protection Authority Victoria for allowing access to the extensive and extremely valuable data collected along the Wimmera River. More specifically I would like to thank Anne-Maree Westbury and her team in providing supplemental water quality and macroinvertebrate data.

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