Overall and site-specific response of the macroinvertebrate community of Swan Coastal Plain Wetlands (Western Australia) to water quality gradients revealed by GF and HEA

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Study Sites:

35 Wetlands of the Swan Coastal Plain in Western Australia monitored in November 1989	
Climate Mediterranean	
Threats to the Wetlands' Biodiversity Water Salinization and Eutrophication	
Habitat and Water Quality Conditions	
	MIN/MEAN/MAX
Wetlands Depth m	0.2/2.03/15
Wetlands Open Water ha	0.5/51.7/449
Electrical Conductivity EC µS cm^{-1}	318.6/2563.1/19350.6
Dissolved Inorganic Nitrogen DIN µg L^{-1}	7.6/481.8/5030.4
Dissolved Inorganic Phosphorus DIP µg L^{-1}	3.8/114.1/629.4
Total Nitrogen TN µg L^{-1}	17.9 / 2868.1/13026
Total Phosphorus TP µg L^{-1}	6.4/160.7/5030.4
pH	3.47/7.58/9.39
Turbidity NTU	0.6/14.8/250
Biological Data 253 Macroinvertebrate Taxa have been identified and counted across the 35 wetlands	

Research Questions:

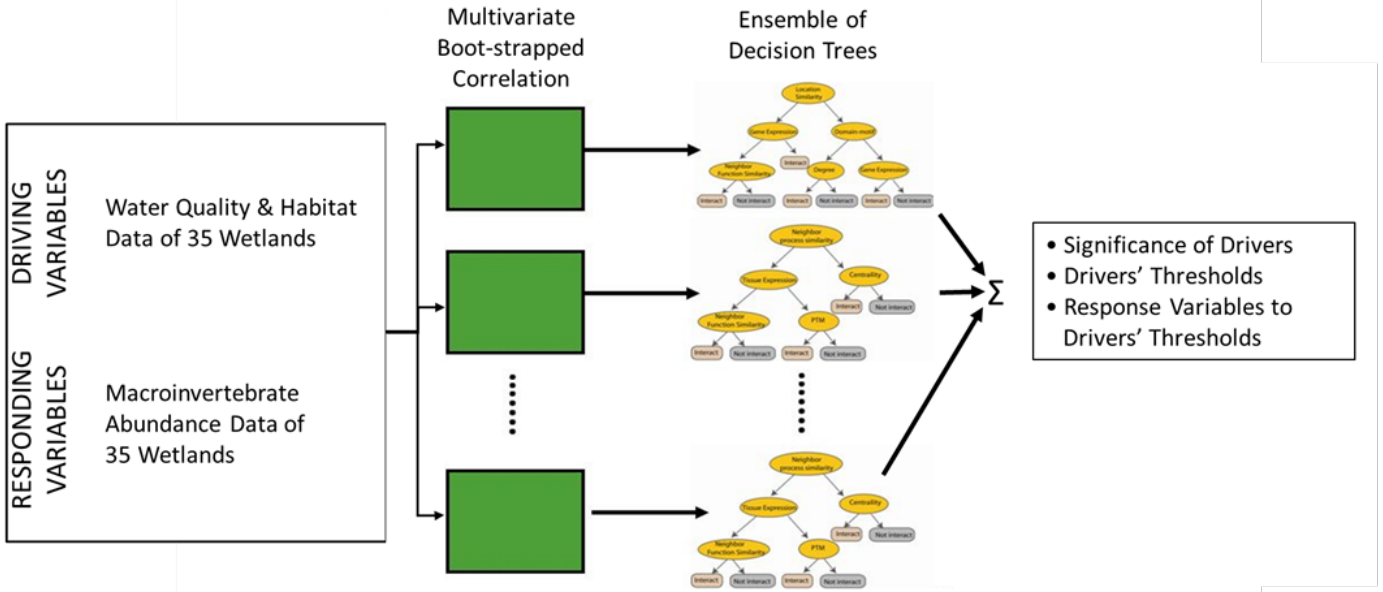
(1) Do driver thresholds revealed by GF for strongest responding macroinvertebrate species correspond with driver thresholds identified by HEA?

(2) Do driver thresholds revealed by GF and HEA identify indicator species for different salinity and eutrophication levels in the wetlands?

(3) Would indicator species allow to identify restoration “hotspots” across the 35 wetlands?

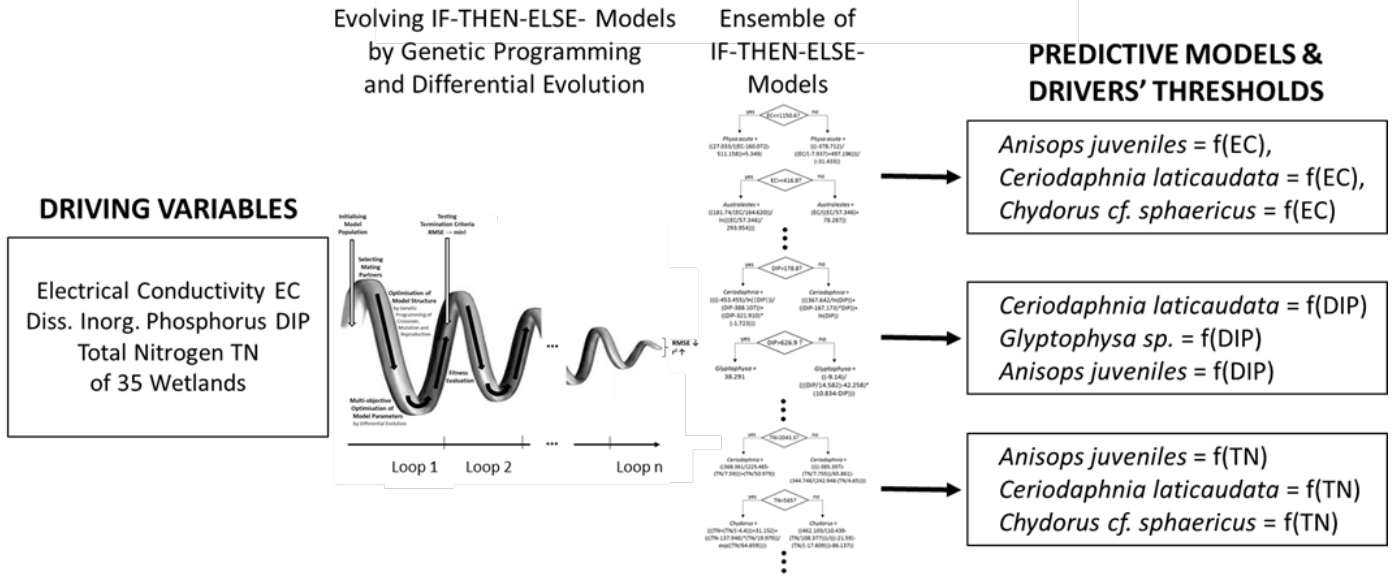
Methods:

INFERENTIAL MODELLING BY GRADIENT FORESTS GF:



'Gradient Forests' is an adaptation of **Random Forests** established by **Leo Breiman** implemented in R by
Pitcher, CR, Lawton,P, et al.:
Journal of Applied Ecology 2012, 49, 670-679.

INFERENTIAL MODELLING BY HYBRID EVOLUTIONARY ALGORITHM HEA:

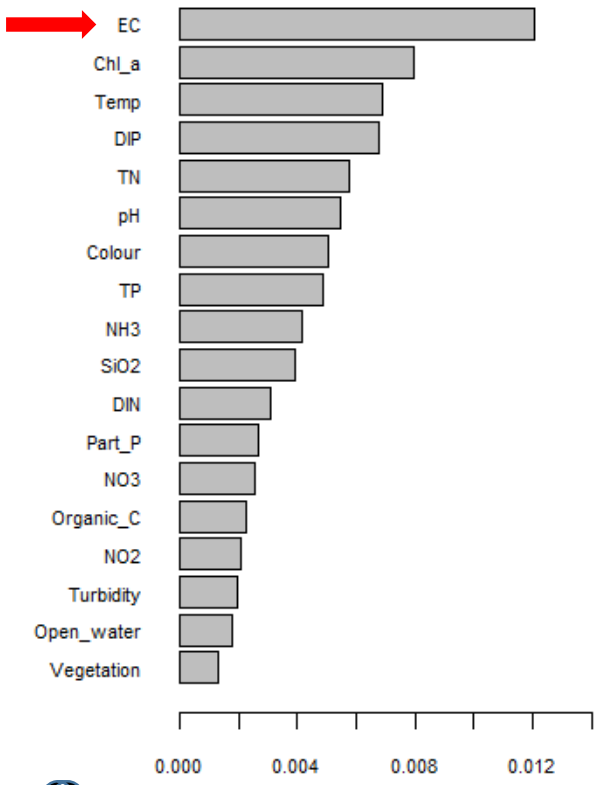


'Hybrid Evolutionary Algorithm' is an adaptation of **Evolutionary Computation** established by **John Holland** implemented in C⁺ by
Cao, H, Recknagel, F, Orr, P:
IEEE Trans Evol Comput 2014, 18, 793-806.

Both, Random Forests and Evolutionary Computation follow the cognitive principle of **'choices over open-ended possibilities'**

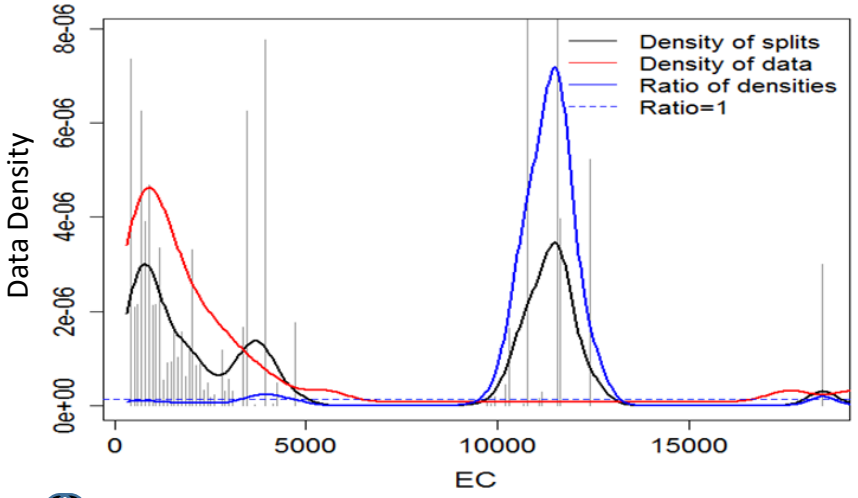
Results: GF based Analysis of EC Thresholds across the 35 Wetlands

r^2-weighted Driver Significance



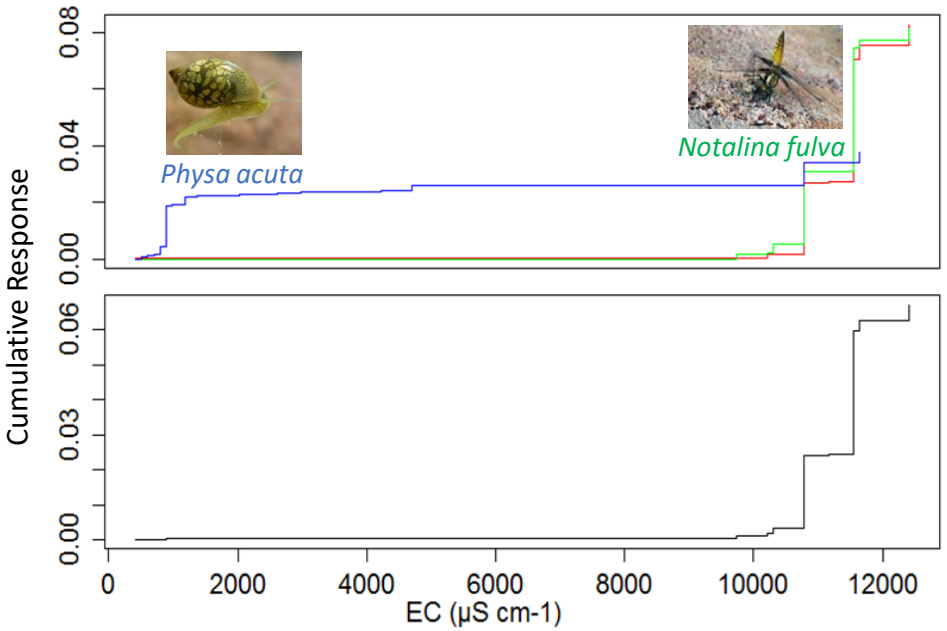
Electrical conductivity appears to be the most significant driver of the macroinvertebrate community of the **35 Wetlands**

Overall Thresholds of Elect. Conductivity



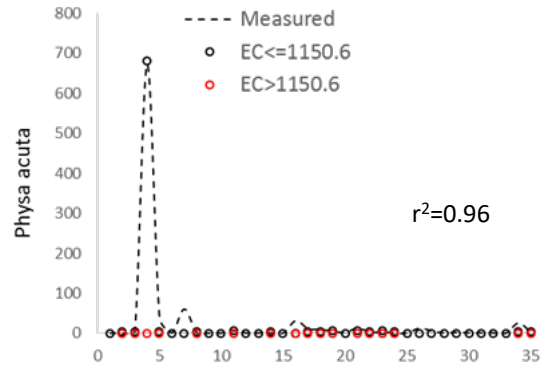
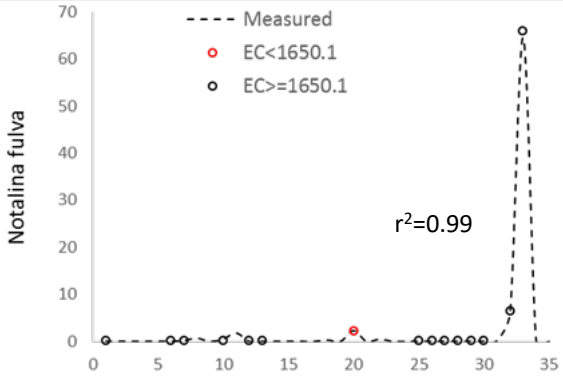
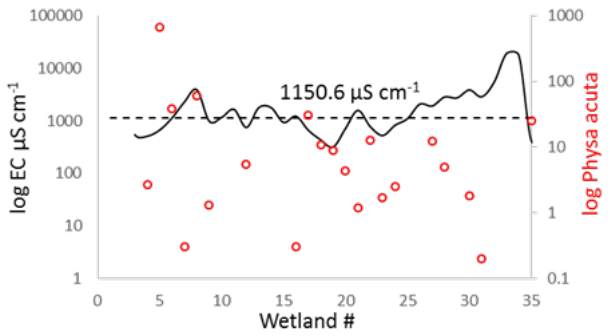
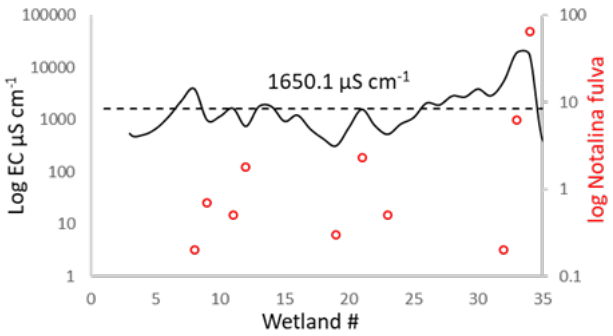
The data density of electrical conductivity of the **35 Wetlands** is highest in the range between 320 and 2500 µS cm^{-1} pointing at fresh water conditions and 10,000 to 12,000 µS cm^{-1} referring to highly saline conditions

Strongest Responding Taxa to Elect. Conductivity



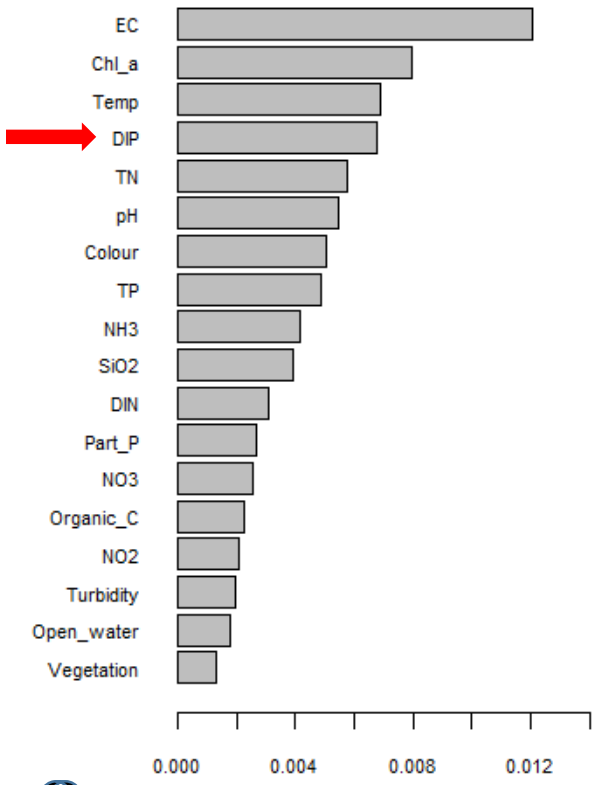
Physa acuta shows the strongest gradient to electrical conductivity at ~ 900 µS cm^{-1} and caddisfly *Notalina fulva* at ~ 11700 µS cm^{-1}

Results: HEA Modelling of *Physa acuta* and *Notalina fulva* solely depending on EC across the 35 Wetlands

Physa acuta = f(EC)	*Notalina fulva*= f(EC)
yes — EC<=1150.6? — no *Physa acuta* = ((27.033/((EC-160.072)-511.158))+5.349) *Physa acuta* = (((-378.712)/((EC/(-7.937)+497.196)))/(-31.433))	yes — EC>=1650.1? — no *Notalina* = (165.955/(EC+(ln(EC)*(-206.481)))) *Notalina* = ((ln(|(EC-362.776)|)-8.51)/(ln(EC^2)-19.534))
	
	

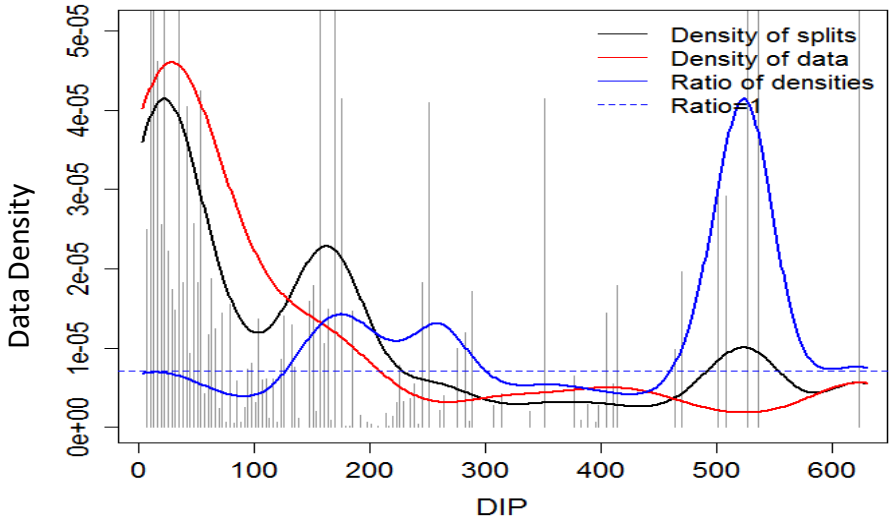
Results: GF based Analysis of DIP Thresholds across the 35 Wetlands

r^2-weighted Driver Significance



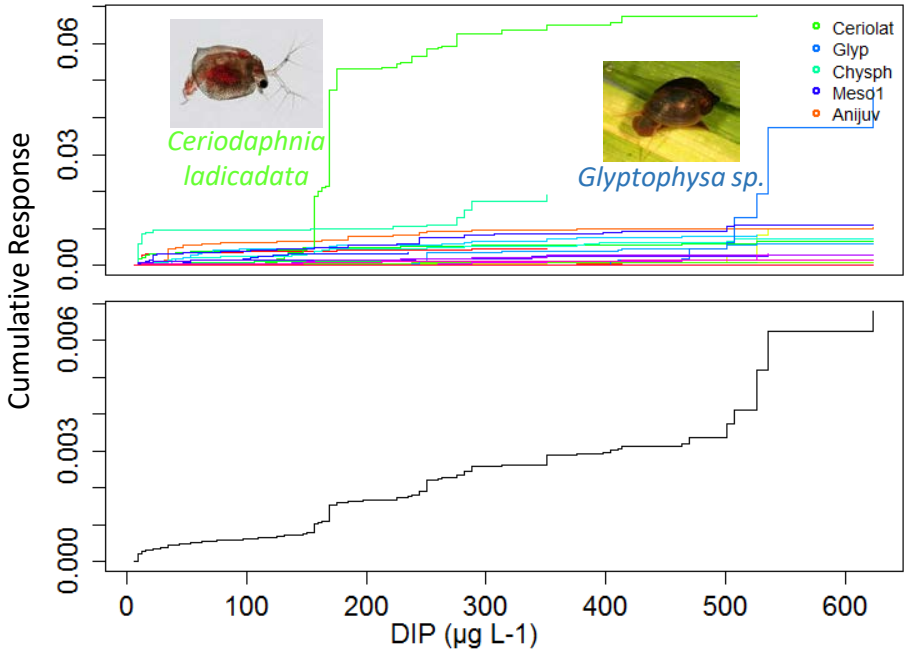
Dissolved inorganic phosphorus DIP appears to be the most significant nutrient driver of the macroinvertebrate community of the **35 Wetlands**

Overall Thresholds of DIP



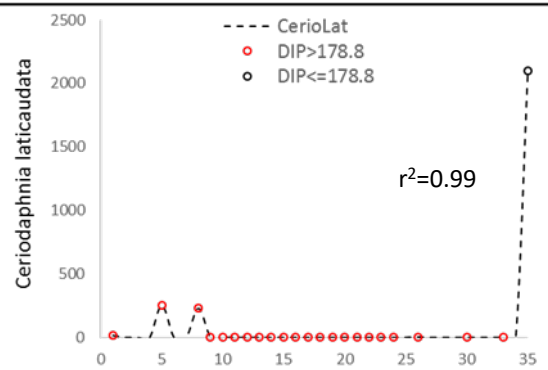
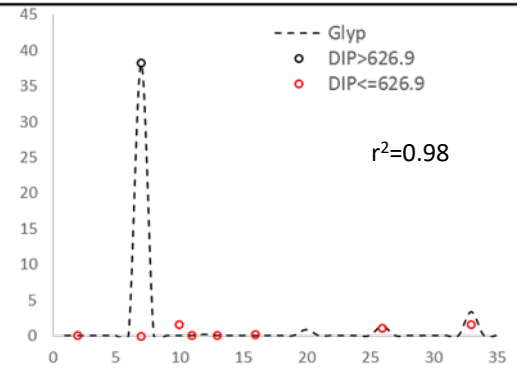
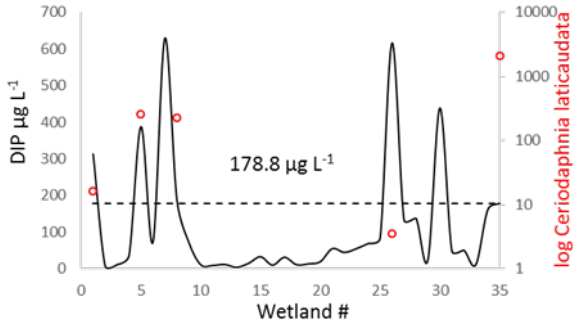
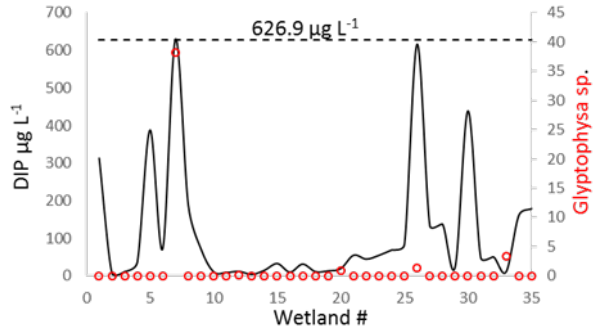
The data density of DIP of the **35 Wetlands** is highest in the range between 0 and 200 µg L^{-1} typical for oligotrophic conditions, and between 460 and 540 µg L^{-1} indicating hypertrophic conditions

Strongest Responding Taxa to Diss Inorg Phosphorus



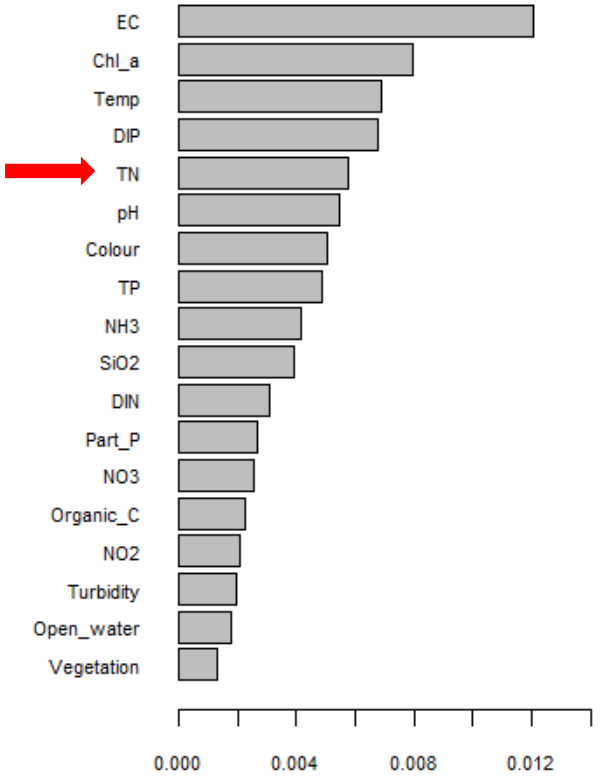
Cladocera *Ceriodaphnia ladicaudata* shows the strongest gradient to DIP at ~180 µg L^{-1} and snail *Glyptophysa sp.* at ~540 µg L^{-1}

Results: HEA Modelling of *Ceriodaphnia ladicaudata* and *Glyptophysa* solely depending on DIP across the 35 Wetlands

Ceriodaphnia laticaudata= f(DIP)	*Glyptophysa sp.*= f(DIP)
yes — DIP>178.8? — no *Ceriodaphnia* = ((((-453.455)/ln(|DIP|))/(DIP-388.107))+((DIP-321.910)*(-1.723))) *Ceriodaphnia* = (((367.642/ln(DIP))+((DIP-167.173)*DIP))+ln(DIP))	yes — DIP>626.9 ? — no *Glyptophysa* = 38.291 *Glyptophysa* = ((-9.14)/(((DIP/14.582)-42.258)*(10.834-DIP)))
	
	

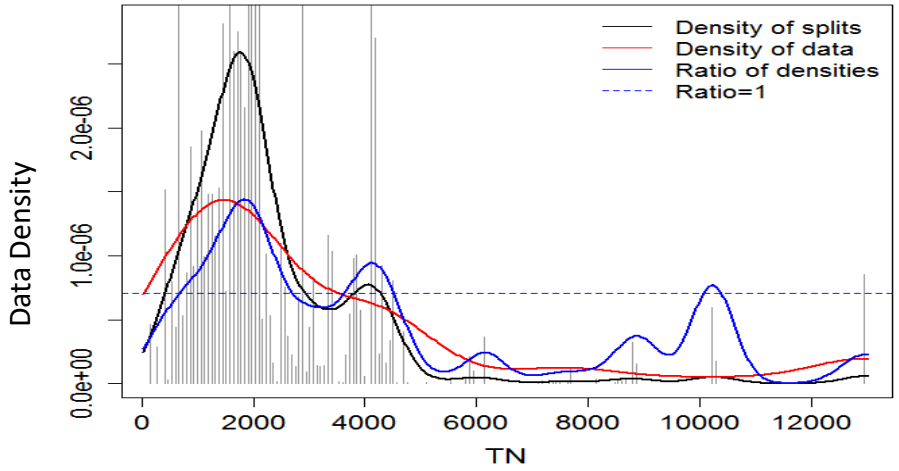
Results: GF based Analysis of TN Thresholds across the 35 Wetlands

r^2-weighted Driver Significance



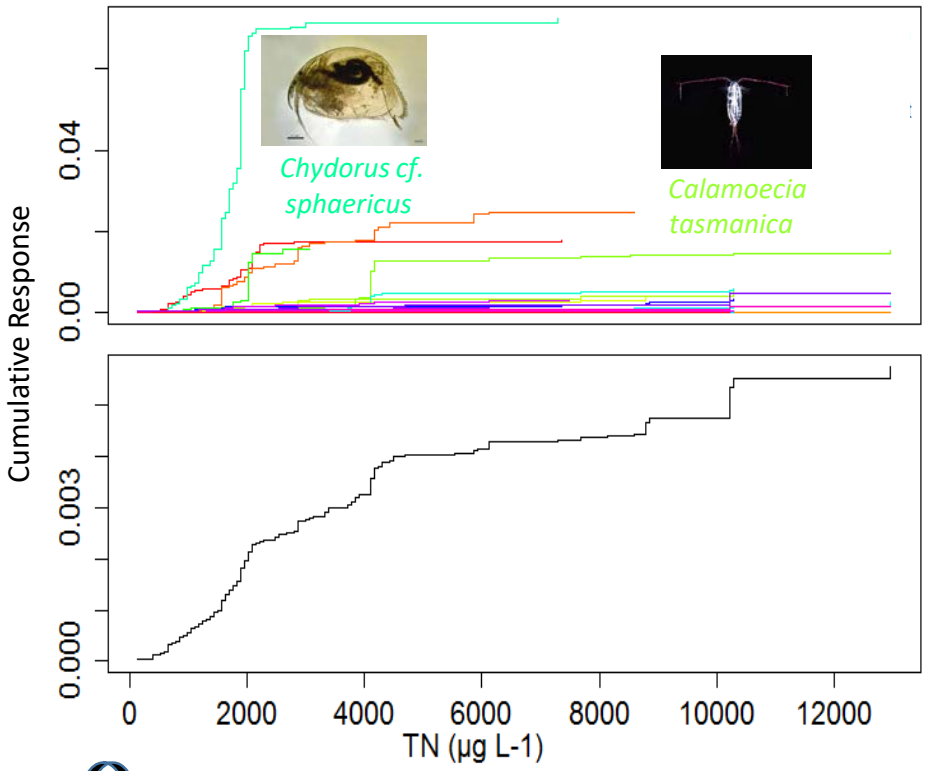
Total nitrogen appears to be another significant nutrient driver of the macroinvertebrate community of the **35 Wetlands**

Overall Thresholds of TN



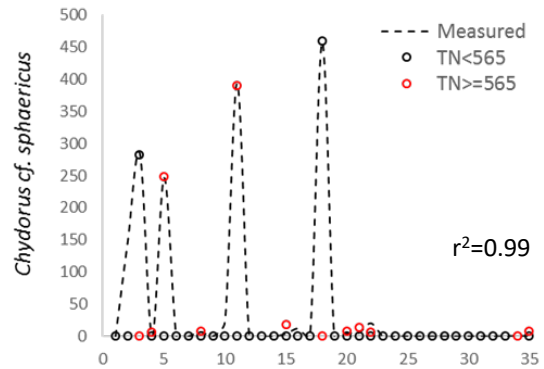
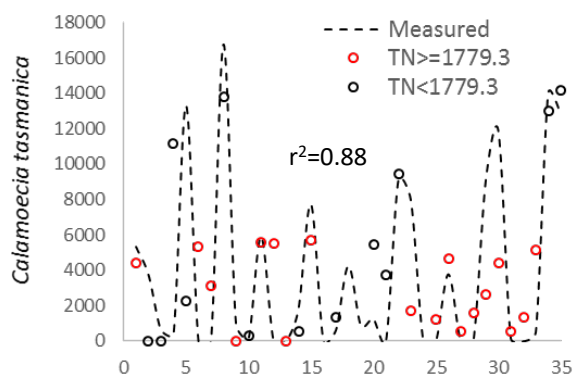
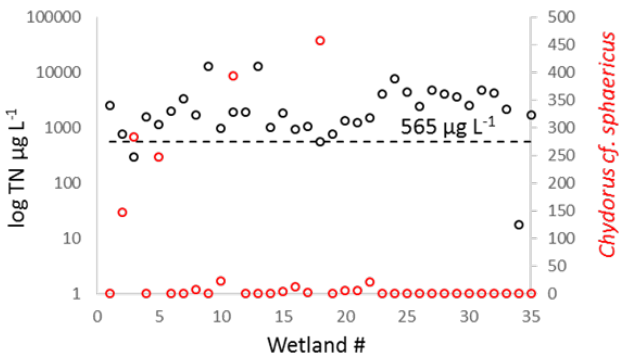
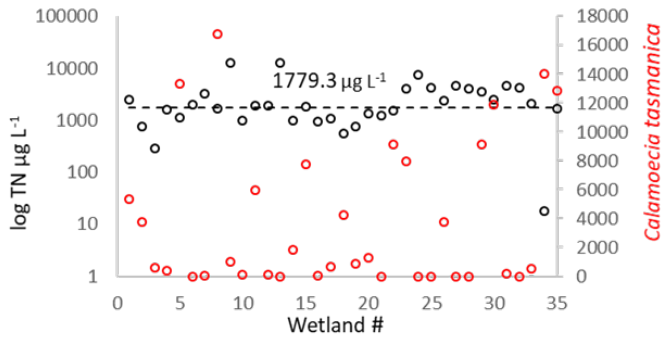
The data density of TN across the **35 Wetlands** is highest in the range between 20 and 2000 µg L^{-1} typical for oligotrophic conditions

Strongest Responding Taxa to Total Nitrogen



Cladocera *Chydorus cf. sphaericus* shows the strongest gradient to TN between 1500 and 1700 µg L^{-1} and copepod *Calamoecia tasmanica* at 4100 µg L^{-1}

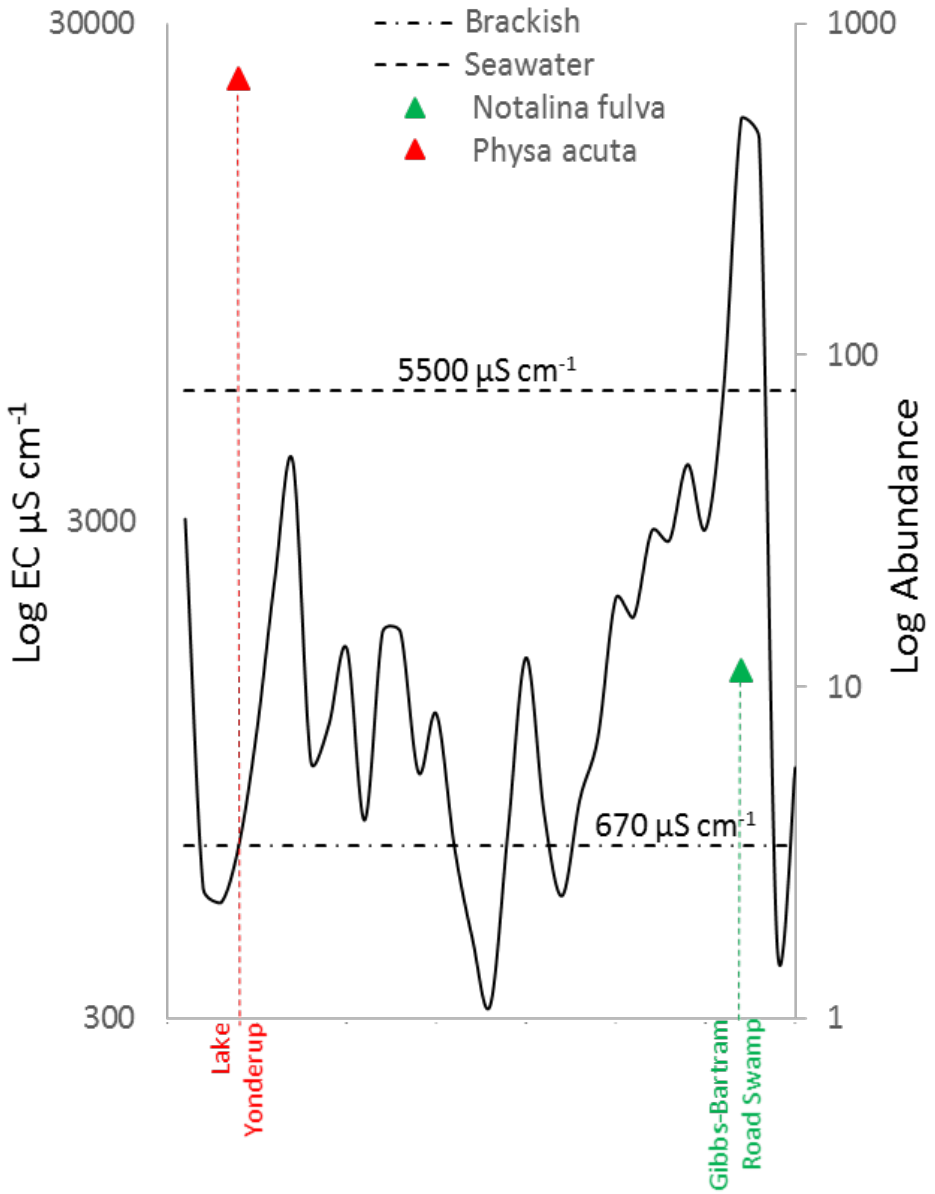
Results: HEA Modelling of *Chydorus cf. sphaericus* and *Calamoecia tasmanica* solely depending on TN across the 35 Wetlands

Chydorus cf. sphaericus = f(TN)	*Calamoecia tasmanica* = f(TN)
yes — TN<565? — no *Chydorus* = (((TN+(TN/(-4.4)))+31.152)+(((TN-137.946)*(TN/19.979))/exp((TN/64.659)))) *Chydorus* = ((462.103/(10.439-(TN/108.377)))/(((-21.59)-(TN/(-17.609)))-86.137))	yes — TN>=1779.3? — no *Calamoecia* = ((((651.818-TN)-TN+20.204))*0.89)+(((21.848/TN)+16.761)*499.04)) *Calamoecia* = ((((499.291-TN)+264.154)*(TN*(-0.01)))+(((498.195/TN)-3.993)*551.047))
	
	

Results: Comparison of Driver Thresholds identified by GF and HEA

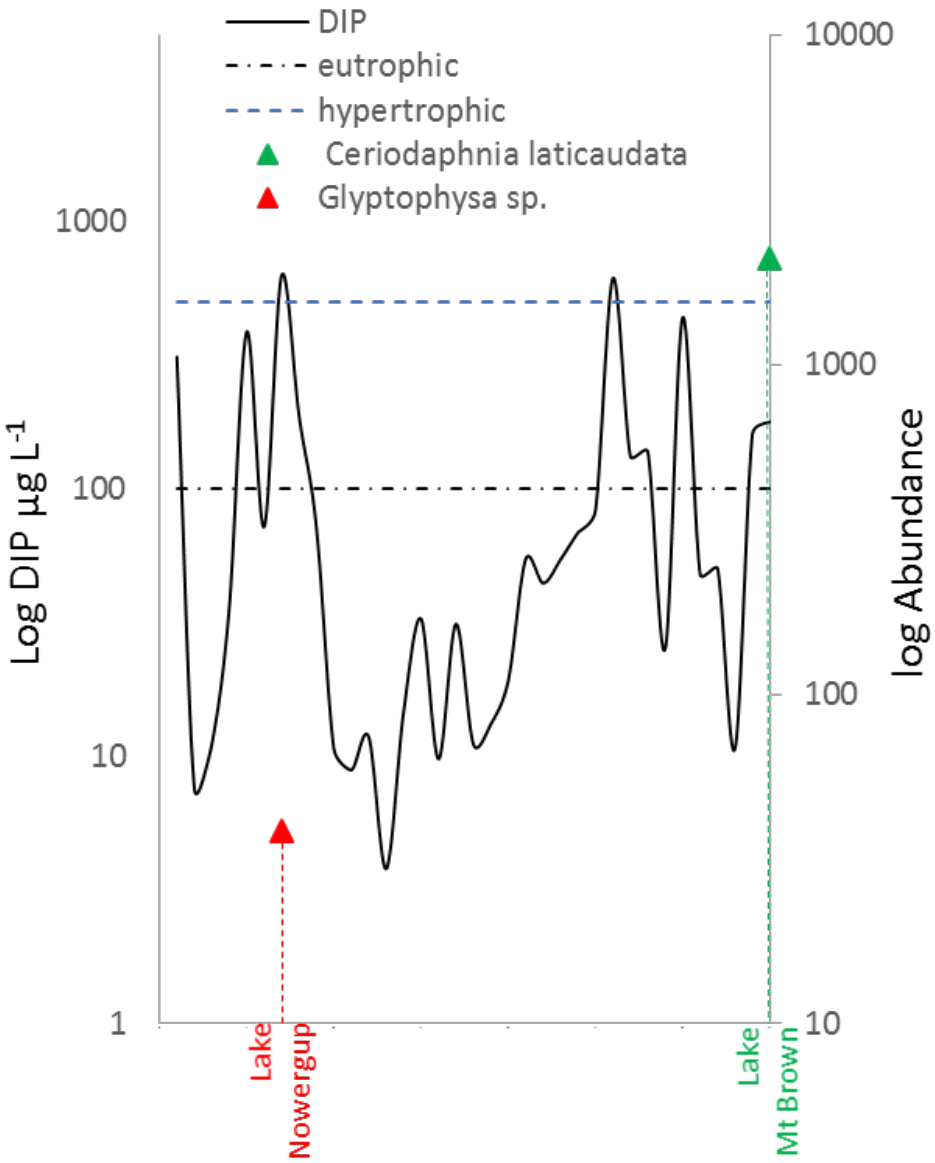
	Strongest Responding Macroinvertebrate Taxa	GF Thresholds	HEA Thresholds
EC	*Physa acuta*	~ 900 µS cm^{-1}	1150.6 µS cm^{-1}
	Notalina fulva	~ 11700 µS cm^{-1}	1650.1 µS cm^{-1}
DIP	*Ceriodaphnia ladicaudata*	~ 180 µg L^{-1}	178.8 µg L^{-1}
	Glyptophysa sp.	~ 540 µg L^{-1}	626.9 µg L^{-1}
TN	*Chydorus cf. sphaericus*	~ 1800 µg L^{-1}	565 µg L^{-1}
	Calamoecia tasmanica	~ 4100 µg L^{-1}	1779.3 µg L^{-1}

Results: Pinpointing Wetlands with different Salinity Levels by EC-sensitive Macroinvertebrate Taxa



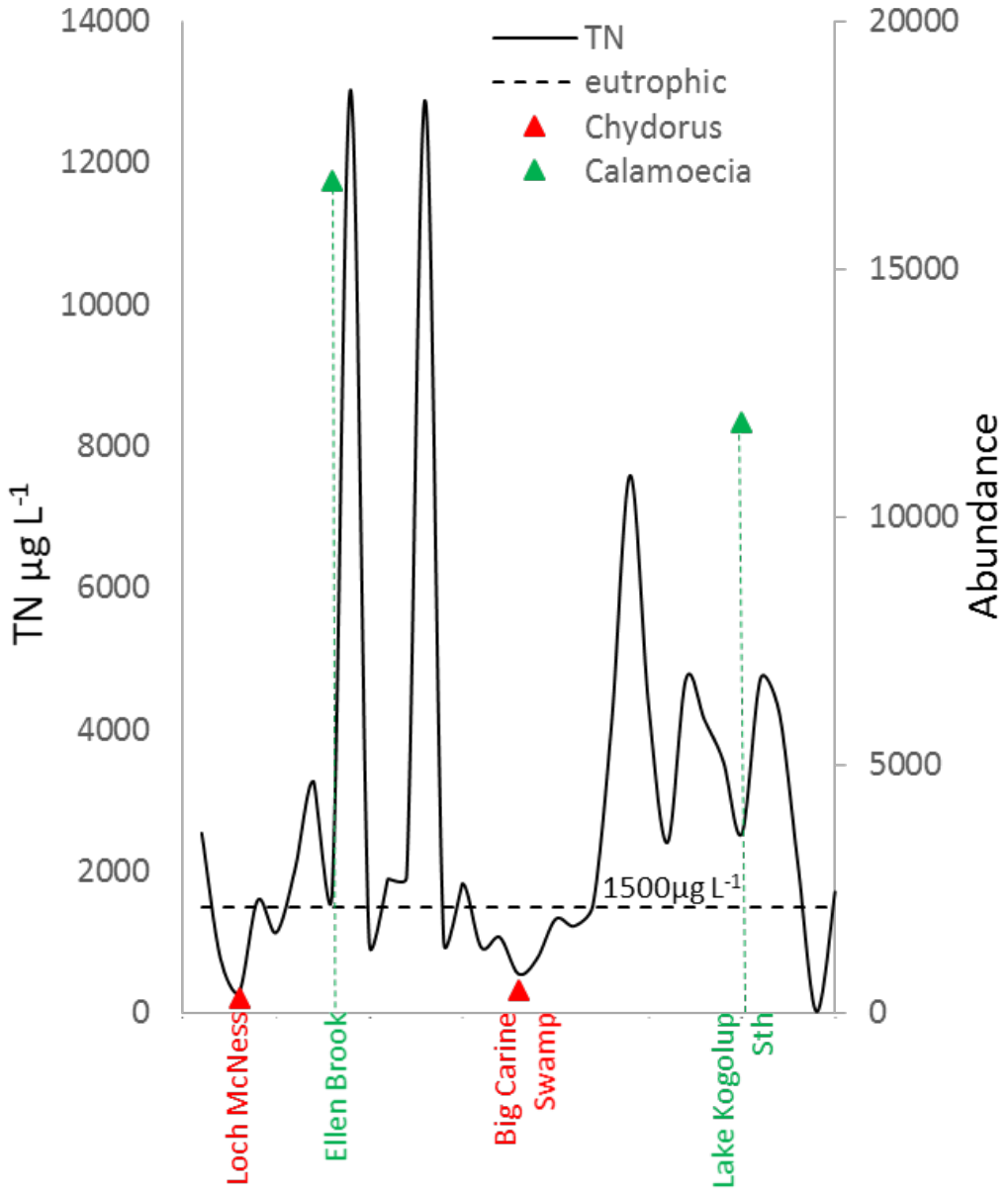
The highest abundance of *Physa acuta* across the 35 wetlands suggests that Lake Youderup (wetland 4) has fresh to brackish water conditions whilst the highest abundance of *Notalina fulva* indicates seawater-like salinity levels for Gibbs-Bartram Road Swamp (wetland 32)

Results: Pinpointing Wetlands with different Eutrophication Levels by DIP-sensitive Macroinvertebrate Taxa



The highest abundance of *Glyptophysa sp.* across the 35 wetlands suggests that Lake Nowergup (wetland 7) has hypereutrophic conditions conditions whilst the highest abundance of *Ceriodaphnia ladicaudata* indicates lower eutrophic conditions for Lake Mt Brown (wetland 35)

Results: Pinpointing Wetlands with different Eutrophication Levels by TN-sensitive Macroinvertebrate Taxa



The highest abundances of *Chydorus cf. sphaericus* across the 35 wetlands suggest that Loch McNess (wetland 2) and Big Craine Swamp (wetland 18) have mesotrophic conditions whilst the highest abundances of *Calamoecia tasmanica* indicate eutrophic conditions for Ellen Brook (wetland 8) and Lake Kogolup South (wetland 30)

Conclusions:

(1) Do driver thresholds for strongest responding macroinvertebrate species revealed by GF correspond with driver thresholds identified by HEA?

Driver thresholds discovered by GF and HEA for strong responding macroinvertebrate species corresponded well for DIP but were generally higher for EC and TN thresholds by GF than by HEA.

(2) Do driver thresholds revealed by GF and HEA identify indicator species for different salinity and eutrophication levels in the wetlands?

High abundances of the invasive species *Physa acuta* appeared to be indicative for low salinity and that of *Notalina fulva* for high salinity.
High abundances of *Ceriodaphnia ladicaudata* and of *Chydorus cf. sphaericus* suggested moderate eutrophication whilst *Glyptophysa sp.* and *Calamoecia tasmanica* indicated hypertrophic conditions.

(3) Would indicator species allow to identify restoration "hotspots" across the 35 wetlands?

Based on the 6 discovered potential indicator species, the wetland 4 (being part of a national park) had fresh- to brackish water conditions whilst wetland 32 adjacent to horticulture areas appeared to be highly saline.
With regards to nutrient levels, wetlands 2, 18 and 35 were identified as having low eutrophication levels whilst wetlands 7 (adjacent to farmland and piggery), 8 and 30 (both adjacent to horticulture and farmland) appeared to be highly eutrophic.