

Response of stream macroinvertebrates to changes in salinity and the development of a salinity index

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Abstract. Many streams and wetlands have been affected by increasing salinity, leading to significant changes in flora and fauna. The study investigates relationships between macroinvertebrate taxa and conductivity levels ($\mu\text{S cm}^{-1}$) in Queensland stream systems. The analysed dataset contained occurrence patterns of frequently found macroinvertebrate taxa from edge (2580 samples) and riffle (1367 samples) habitats collected in spring and autumn over 8 years. Sensitivity analysis with predictive artificial neural network models and the taxon-specific mean conductivity values were used to assign a salinity sensitivity score (SSS) to each taxon (1—very tolerant, 5—tolerant, 10—sensitive). Salinity index (SI) based on the cumulative SSS was proposed as a measurement of change in macroinvertebrate communities caused by salinity increase. Changes in macroinvertebrate communities were observed at relatively low salinities, with SI rapidly decreasing to $\sim 800\text{--}1000 \mu\text{S cm}^{-1}$ and decreasing further at a slower rate. Natural variability and water quality factors were ruled out as potential primary causes of the observed changes by using partial canonical correspondence analysis and subsets of the data with only good water quality.

Appendix 1. Taxon-specific conductivity ranges, trends shown by sensitivity analysis with multilayer perceptron (MLP) and salinity sensitivity score—edge habitat

Taxa	Minimum conductivity ($\mu\text{S cm}^{-1}$)	Maximum conductivity ($\mu\text{S cm}^{-1}$)	Mean conductivity ($\mu\text{S cm}^{-1}$)	Probability of occurrence with increase in salinity (artificial neural network models)	Salinity sensitivity score
Acarina	6	11730	319.98	Decreasing	5
Aeshnidae	31	4500	426.68	Decreasing	5
Ancylidae	30	2560	453.59	Decreasing	5
Atyidae	22	12000	369.38	Decreasing	5
Baetidae	6	11730	344.33	Decreasing	5
Caenidae	22	11730	332.39	Decreasing	5
Calamoceratidae	6	5570	331.27	Decreasing	5
Ceratopogonidae	20	11730	344.55	Unimodal	5
Cladocera	25	12000	385.05	Unimodal	5
Coenagrionidae	6	12000	383.71	Increasing	1
Copepoda	20	12000	377.84	Increasing	1
Corbiculidae	45	2150	449.46	Decreasing	5
Corduliidae	23	2980	291.92	Decreasing	10
Corixidae	20	11730	365.64	Decreasing	5
Culicidae	20	11730	423.85	Increasing	1
DugesIIDae	6	2460	264.91	Decreasing	10
Dytiscidae	6	12000	396.93	Increasing	1
Ecnomidae	23	11730	331.92	Increasing	5
Elmidae	22	3100	236.68	Decreasing	10
Gerridae	25	5600	315.68	Decreasing	5
Gomphidae	6	12000	296.9	Decreasing	10
Gyrinidae	6	5600	316.51	Increasing	5
Helicopsychidae	22	1387	232.26	Decreasing	10
Hydraenidae	20	11730	455.97	Increasing	1
Hydrometridae	20	5990	443.82	Increasing	1
Hydrophilidae	6	6010	360.73	Increasing	5
Hydropsychidae	6	2780	252.41	Decreasing	10
Hydroptilidae	28	5990	292.47	Decreasing	10
Isostictidae	28	5600	377.17	Increasing	5
Leptoceridae	6	11730	340.68	Decreasing	5
Leptophlebiidae	6	3910	289.84	Decreasing	10
Libellulidae	6	11730	328.34	Increasing	5
Lymnaeidae	39	6010	558.99	Unimodal	1
Mesoveliidae	31	6010	402.37	Increasing	1
Naucoridae	28	5990	492.26	Increasing	1
Nepidae	20	5570	359.48	Increasing	1
Notonectidae	30	6010	413.87	Decreasing	5
Oligochaeta	20	11730	378.67	Decreasing	5
Orthocladiinae	6	11730	330.63	Decreasing	5
Ostracoda	6	6010	368.19	Increasing	1
Palaemonidae	6	12000	321.47	Decreasing	5
Parastictidae	33	12000	495.54	Increasing	1
Planorbidae	37	11730	512.04	Increasing	1
Pleidae	20	11730	398.44	Unimodal	5
Protoneuridae	6	12000	375.42	Unimodal	5
Psephenidae	22	5600	393.76	Decreasing	5
Pyralidae	22	3200	264.54	Decreasing	10
Scirtidae	23	5600	367.29	Increasing	5
Simuliidae	6	2460	293.57	Decreasing	10
Staphylinidae	29	5990	433.01	Increasing	1
Stratiomyidae	52	5570	569.25	Decreasing	5
Tabanidae	42	5990	420.93	Increasing	1
Tanypodinae	6	11730	352.31	Decreasing	5
Temnocephalidea	27	3040	280.85	Decreasing	10
Thiaridae	30	12000	449.26	Increasing	1
Tipulidae	6	2980	228.14	Decreasing	10
Veliidae	20	8700	354.81	Decreasing	5

^A1—very tolerant, 5—tolerant, 10—sensitive.

Appendix 2. Taxon-specific conductivity ranges, trends shown by sensitivity analysis with MLP and salinity sensitivity score—riffle habitat

Taxa	Minimum conductivity ($\mu\text{S cm}^{-1}$)	Maximum conductivity ($\mu\text{S cm}^{-1}$)	Mean conductivity ($\mu\text{S cm}^{-1}$)	Probability of occurrence with increase in salinity (artificial neural network models)	Salinity sensitivity score ^A
Acarina	26	4500	240.74	Decreasing	5
Aeshnidae	22	1574	141.57	Decreasing	10
Ancylidae	51	1389	357.04	Increasing	1
Atyidae	31	5600	378.71	Increasing	1
Baetidae	22	4500	273.2	Decreasing	5
Caenidae	26	5600	325.14	Increasing	5
Calamoceratidae	26	3200	292.44	Increasing	5
Ceratopogonidae	22	4500	260.86	Decreasing	5
Cladocera	45	1515	321.2	Increasing	5
Coenagrionidae	30	4500	479.42	Increasing	1
Copepoda	37	4500	421.14	Increasing	1
Corbiculidae	47	3200	472.16	Increasing	1
Corduliidae	22	5600	319.29	Increasing	5
Corixidae	38	3200	383.92	Increasing	1
Culicidae	60	4500	564.81	Increasing	1
Dolichopodidae	40.4	5600	358.51	Increasing	1
Dugesiiidae	22	3200	248.96	Decreasing	10
Dytiscidae	44	5600	489.3	Increasing	1
Ecnomidae	27	5600	376.22	Increasing	1
Elmidae	22	5600	254.91	Decreasing	10
Gerridae	42	4700	418.22	Increasing	1
Gomphidae	22	5600	250.76	Decreasing	10
Gyrinidae	44.4	5600	478.08	Increasing	1
Helicopsychidae	22	1423	270.52	Decreasing	5
Hydraenidae	31.3	4700	503.67	Increasing	1
Hydrobiosidae	26.6	1696	215.26	Decreasing	10
Hydrometridae	175	1574	769	Increasing	1
Hydrophilidae	22	5600	366.29	Increasing	1
Hydropsychidae	22	5600	295.14	Decreasing	5
Hydroptilidae	26	4500	295.87	Increasing	5
Isostictidae	90	636	384.6	Decreasing	5
Leptoceridae	22	5600	300.02	Increasing	5
Leptophlebiidae	22	5600	266.62	Decreasing	10
Libellulidae	27	5600	294.43	Increasing	5
Lymnaeidae	70	2094	513.88	Increasing	1
Mesoveliidae	43	1750	283.5	Increasing	5
Naucoridae	39	2094	233.45	Increasing	5
Nepidae	108	757	305.14	Increasing	5
Notonectidae	40	1610	327.14	Increasing	5
Oligochaeta	26.6	5600	313.54	Decreasing	5
Orthoclaadiinae	26	4500	286.9	Decreasing	5
Ostracoda	38	5600	420.03	Increasing	1
Palaemonidae	22	4500	262.24	Decreasing	5
Parastictidae	39	4500	402.02	Decreasing	5
Philopotamidae	26	5600	238.26	Decreasing	10
Planorbidae	52	4500	568.18	Increasing	1
Pleidae	81	968	373.56	Increasing	5
Protoneuridae	40	1450	403.35	Increasing	5
Psephenidae	22	5600	283.46	Increasing	5
Pyralidae	26.6	3100	236.69	Decreasing	10
Scirtidae	30	4700	246.34	Decreasing	10
Simuliidae	22	4700	304.14	Decreasing	5
Staphylinidae	32	769	228.73	Decreasing	10
Stratiomyidae	56	5600	828.59	Increasing	1
Tabanidae	26	4700	298.49	Increasing	5
Tanypodinae	22	5600	286.43	Decreasing	5
Temnocephalidea	43	666	246.58	Decreasing	10
Thiaridae	38	5600	483.59	Increasing	1
Tipulidae	22	1951	218.03	Decreasing	10
Veliidae	40	5600	362.51	Increasing	1

^A1—very tolerant, 5—tolerant, 10—sensitive.