Nutrient Contribution

Assessment of contributions based on estimated assumptions

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Contents

Data import

File	Content
Feed composition APO-SUB-2.xlsx	Composition data of commercial and experimental fish feeds
Water quality APO-SUB-2.xlsx	Composition data of tap and rain water
IAFFD FICD.xlsx	Composition of aquafeed raw materials; data downloaded from www.iaffd.com

Data wrangling

Feed

Water

- outliers for rain water were removed

Alkalinity supplements

Results

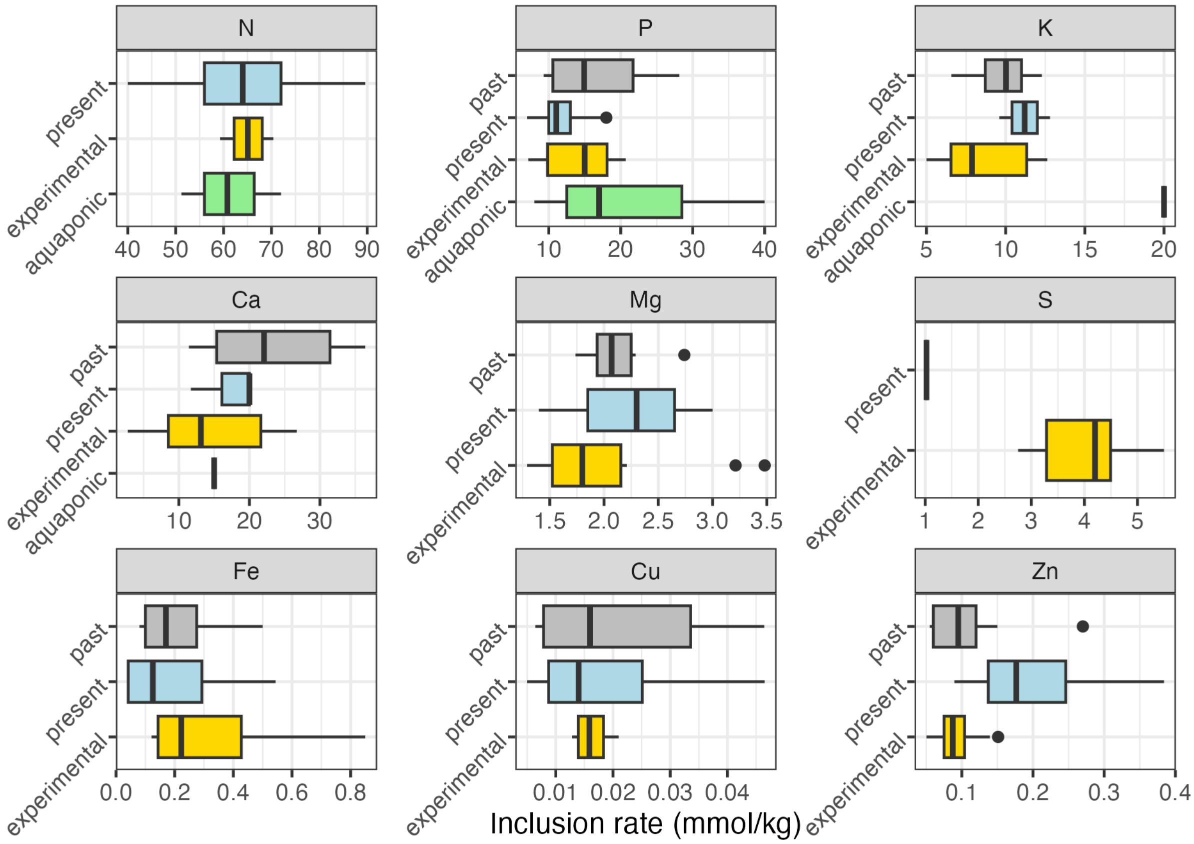
Feed

category	substance	unit	n	min	mean	sd	cv	max
aquaponic	Ca	gkg	1	15.000	15.000			15.000
aquaponic	K	gkg	1	20.000	20.000			20.000
aquaponic	N	gkg	3	51.200	61.333	10.410	0.170	72.000
aquaponic	P	gkg	3	8.000	21.667	16.503	0.762	40.000
commercial	Ca	gkg	5	11.700	17.560	3.686	0.210	20.000
commercial	Cu	gkg	4	0.005	0.020	0.019	0.933	0.046
commercial	Fe	gkg	4	0.040	0.209	0.237	1.136	0.544
commercial	K	gkg	2	9.600	11.200	2.263	0.202	12.800
commercial	Mg	gkg	3	1.400	2.233	0.802	0.359	3.000
commercial	N	gkg	74	40.000	63.862	11.796	0.185	89.600
commercial	P	gkg	68	7.000	11.662	2.444	0.210	18.000

category	substance	unit	n	min	mean	sd	cv	max
commercial	S	gkg	1	1.024	1.024			1.024
commercial	Zn	gkg	4	0.090	0.207	0.127	0.613	0.384
experimental	Ca	gkg	11	2.760	14.646	8.410	0.574	26.710
experimental	Cu	gkg	8	0.013	0.016	0.003	0.179	0.021
experimental	Fe	gkg	8	0.121	0.348	0.297	0.854	0.850
experimental	K	gkg	11	5.000	8.633	2.762	0.320	12.630
experimental	Mg	gkg	11	1.292	2.021	0.727	0.359	3.480
experimental	N	gkg	11	59.257	64.983	4.030	0.062	70.400
experimental	P	gkg	11	7.172	14.104	4.940	0.350	20.700
experimental	S	gkg	11	2.751	4.032	0.868	0.215	5.500
experimental	Zn	gkg	8	0.050	0.093	0.036	0.385	0.151
old	Ca	gkg	9	11.429	22.676	8.952	0.395	36.429
old	Cu	gkg	9	0.006	0.021	0.015	0.728	0.046
old	Fe	gkg	9	0.080	0.207	0.134	0.644	0.500
old	K	gkg	9	6.571	9.485	1.979	0.209	12.286
old	Mg	gkg	9	1.736	2.118	0.300	0.142	2.740
old	P	gkg	9	9.286	16.252	6.371	0.392	28.143
old	Zn	gkg	9	0.055	0.113	0.067	0.597	0.270

Statistics

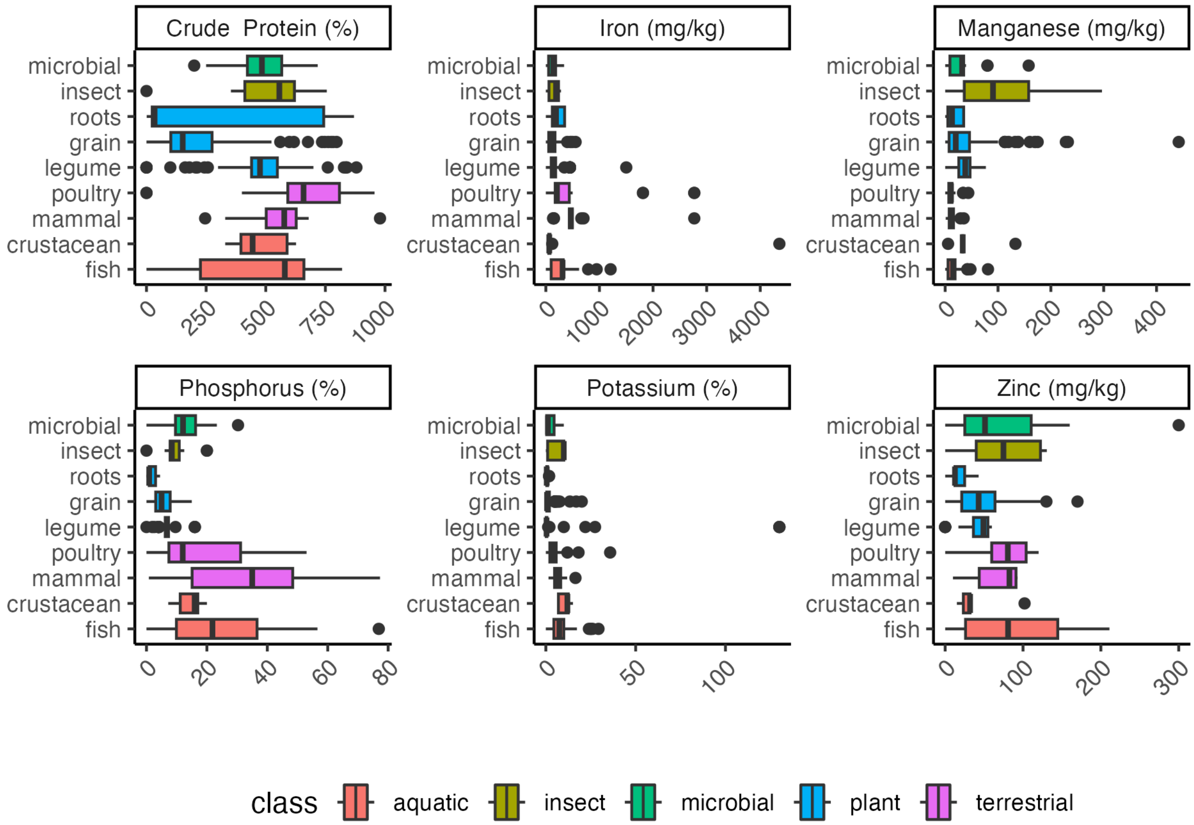
- reliable comparison of nutrient inclusion is only possible for P, considering the number of observations in the dataset.
- comparison of commercial data with aquaponics or experimental feed is also not meaningful due to low sample size
- P: Aquaponics feeds are richer in P compared with commercial feeds and also compared with experimental diets (Tukey test: $p < 0.05$). The smallest difference was found between aquaponics and old diets. The difference between them is non-significant.



Feedstuffs

cat2	analyte	n	mean	sd	cv
aquatic	N (g/kg)	86	556.81	154.06	0.277
aquatic	Fe (mg/kg)	82	258.11	132.10	0.512
aquatic	Mn (mg/kg)	84	17.26	9.02	0.522
aquatic	P (g/kg)	56	17.88	7.38	0.413
aquatic	K (g/kg)	80	8.68	3.33	0.384
aquatic	Zn (mg/kg)	84	90.88	45.03	0.495
insect	N (g/kg)	13	544.69	120.30	0.221
insect	Fe (mg/kg)	13	172.55	86.60	0.502
insect	Mn (mg/kg)	4	32.12	23.23	0.723
insect	P (g/kg)	13	10.62	4.49	0.423
insect	K (g/kg)	13	6.54	4.56	0.697
insect	Zn (mg/kg)	13	83.28	42.72	0.513

cat2	analyte	n	mean	sd	cv
microbial	N (g/kg)	19	493.26	144.74	0.293
microbial	Fe (mg/kg)	17	141.40	85.45	0.604
microbial	Mn (mg/kg)	16	30.05	23.30	0.775
microbial	P (g/kg)	18	14.02	6.55	0.468
microbial	K (g/kg)	15	3.83	4.26	1.110
microbial	Zn (mg/kg)	16	72.12	47.80	0.663
plant	N (g/kg)	192	340.35	228.27	0.671
plant	Fe (mg/kg)	191	148.49	107.09	0.721
plant	Mn (mg/kg)	171	28.28	19.09	0.675
plant	P (g/kg)	194	6.21	3.05	0.491
plant	K (g/kg)	187	1.24	2.04	1.653
plant	Zn (mg/kg)	191	45.51	24.86	0.546
terrestrial	N (g/kg)	40	649.20	171.53	0.264
terrestrial	Fe (mg/kg)	33	293.81	149.65	0.509
terrestrial	Mn (mg/kg)	40	13.21	9.69	0.733
terrestrial	P (g/kg)	27	14.31	9.95	0.695
terrestrial	K (g/kg)	38	5.53	3.45	0.623
terrestrial	Zn (mg/kg)	40	76.15	31.29	0.411



Water

Data origin

Tap water

Table 4: Summary statistics of the chemical composition of tap water. Data was compiled from analysis reports of water supply companies (n = 72). Mean values were estimated using accepted methods for censored data (Helsel, 2012). N is the sum of all nitrogenous species.

analyte	unit	n	min	mean	sd	cv	max
N	µmolL	63	2113.292	2113.284	0.000	0.0	2113.292
P	µmolL	24	0.001	0.888	1.942	218.8	6.949
K	µmolL	51	2.558	65.930	66.357	100.6	358.072
Ca	µmolL	57	82.339	1484.005	815.786	55.0	3418.334

analyte	unit	n	min	mean	sd	cv	max
Mg	µmolL	57	37.029	462.482	333.265	72.1	1781.526
S	µmolL	58	6.746	137.463	139.926	101.8	630.839
B	µmolL	41	0.002	4.862	11.473	235.9	59.014
Fe	µmolL	63	0.000	0.575	2.952	513.5	23.637
Mn	µmolL	55	0.004	0.064	0.125	196.5	0.735
Cu	µmolL	45	0.002	0.232	0.930	401.7	4.721
Zn	µmolL	13	0.008	0.235	0.926	394.6	3.059
Ni	µmolL	41	0.003	0.032	0.050	155.6	0.235
Mo	µmolL	7	0.005	0.008	0.016	209.2	0.052
Na	µmolL	56	4.350	839.220	910.089	108.4	4697.742
Cl	µmolL	51	2.821	762.476	703.350	92.2	3300.144
Al	µmolL	50	0.041	0.651	0.919	141.0	4.485

Rain water

Table 5: Summary statistics of rainwater composition data (n = 18). Analytes with less than 5 dataset records were removed. Outliers were identified by calculating the interquartile range (IQR). Values > 1.5 x IQR were removed from the dataset.

analyte	unit	n	min	mean	sd	cv	max
Ca	µmolL	14	8.98	60.8	41.19	0.677	135.5
Cl	µmolL	14	20.14	96.5	52.18	0.541	197.4
K	µmolL	13	9.78	27.5	21.30	0.775	82.8
Mg	µmolL	13	4.59	12.9	5.44	0.421	24.7
N	µmolL	16	0.00	90.7	52.47	0.579	205.3
Na	µmolL	15	15.61	94.8	70.08	0.739	261.0
S	µmolL	16	16.17	44.6	24.22	0.543	88.5

Combined

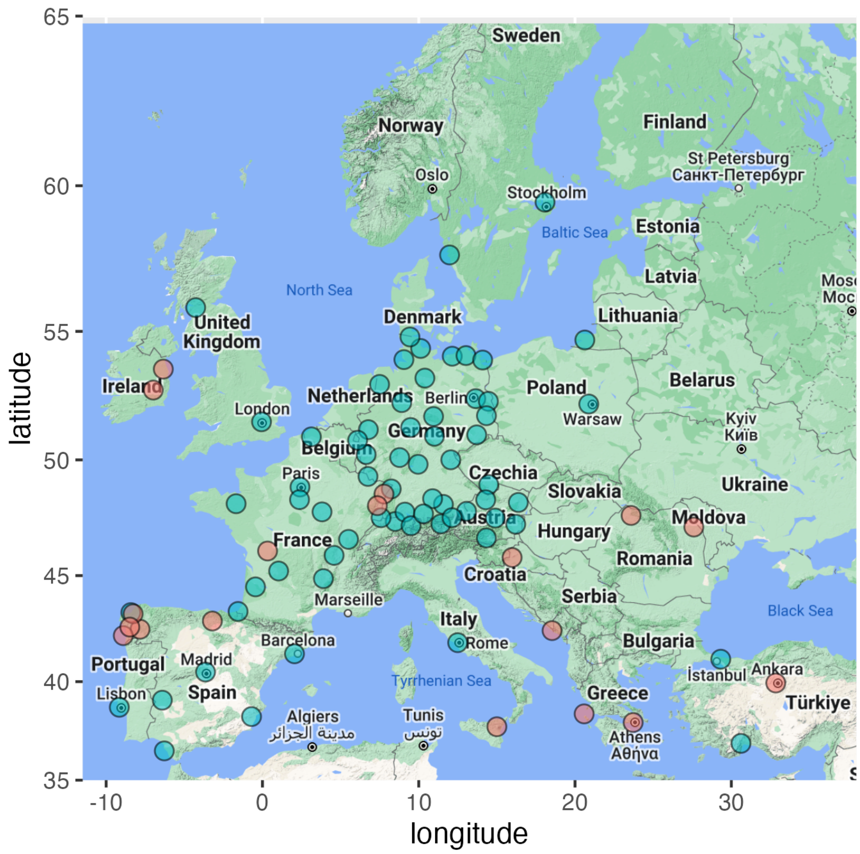


Figure 1: Origins of data included into the water dataset. Blue dots: Drinking water analysis reports. Red dots: Rain water analyses.

analyte	unit	mean_tap	mean_rain	significance	tap:rain ratio
N	µmolL	2113.284	90.7	lower	23
P	µmolL	0.888			
K	µmolL	65.930	27.5	lower	2
Ca	µmolL	1484.005	60.8	lower	24
Mg	µmolL	462.482	12.9	lower	36
S	µmolL	137.463	44.6	lower	3
B	µmolL	4.862			
Fe	µmolL	0.575			
Mn	µmolL	0.064			
Cu	µmolL	0.232			
Zn	µmolL	0.235			
Ni	µmolL	0.032			
Mo	µmolL	0.008			
Na	µmolL	839.220	94.8	lower	9
Cl	µmolL	762.476	96.5	lower	8
Al	µmolL	0.651			

- All substance concentrations that are known for both tap and rain water are significantly lower in rain water ($p < 0.05$).

Alkalinity supplements

Nutrient contribution

Initial assumptions

We assume a recirculation aquaculture system (RAS) has a total volume of $\mathrm{m^3}$ of which $\mathrm{m^3}$ are used as rearing volume for the stock. Furthermore, we assume a stocking density of $\mathrm{kg\,m^{-3}}$, referred to the rearing volume of the system. The feeding rate shall be set to $\%\,\mathrm{d^{-1}}$ of the total biomass and a water exchange rate of $\%\,\mathrm{d^{-1}}$ of the total system volume shall be maintained.

Based on these inputs, a biomass of kg, a total weight of kg feed fed per day, a daily exchanged volume of $\mathrm{m^3\,d^{-1}}$ freshwater and $\mathrm{L\,kg^{-1}}$ exchanged water per weight unit feed fed is calculated.

To estimate the mass contribution of source water and feed to the total amount of nutrients that are entering the system, it is assumed that the RAS operator is using tap water as freshwater source and analysis results from water treatment plants are thus taken as data input. Furthermore, the average of the nutrient profile of a number of commercial fish feeds is used.

Data preparation

Feed

Consideration of digestibility and retention

Assumptions with regards to the digestibility of nutrients in the feeds are the following:

- **N** ADC ranging between 85-95%
- **P** ADC ranging between 35-45% [@Sugiura2018]
- all other nutrient ADC ranging between 45-55%

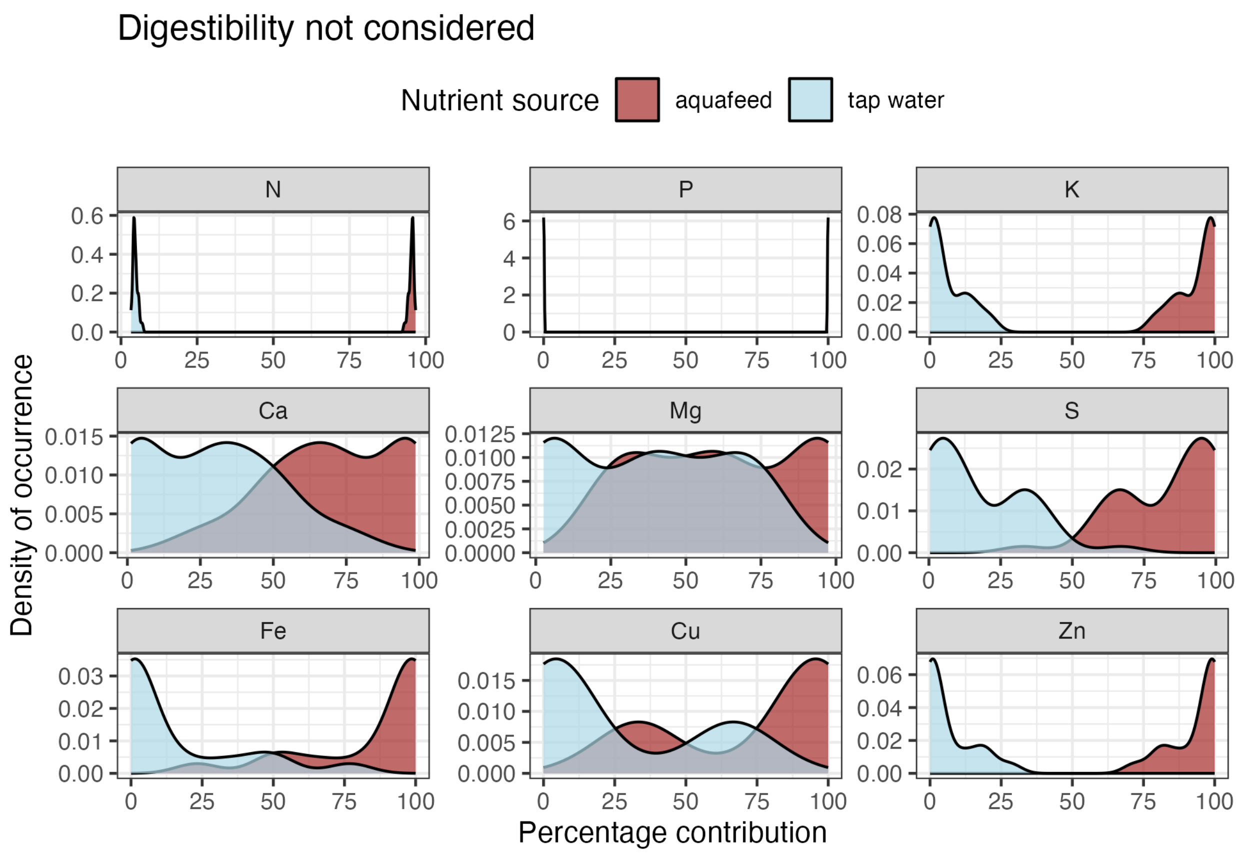
Retention assumptions are based on [@Roy2022]. These were derived from Tilapia, though.

Consideration of assumptions

Tap water

Rain water

Permutation analysis



After consideration of nutrient digestibility, two scenarios occur: 1. still majority of nutrient input by feed 2. 3. equal contribution of water and feed possible

- tap water can contribute a share of N comparable to aquafeeds in some cases
- the probability that the majority of K will originate from aquafeeds is 100%
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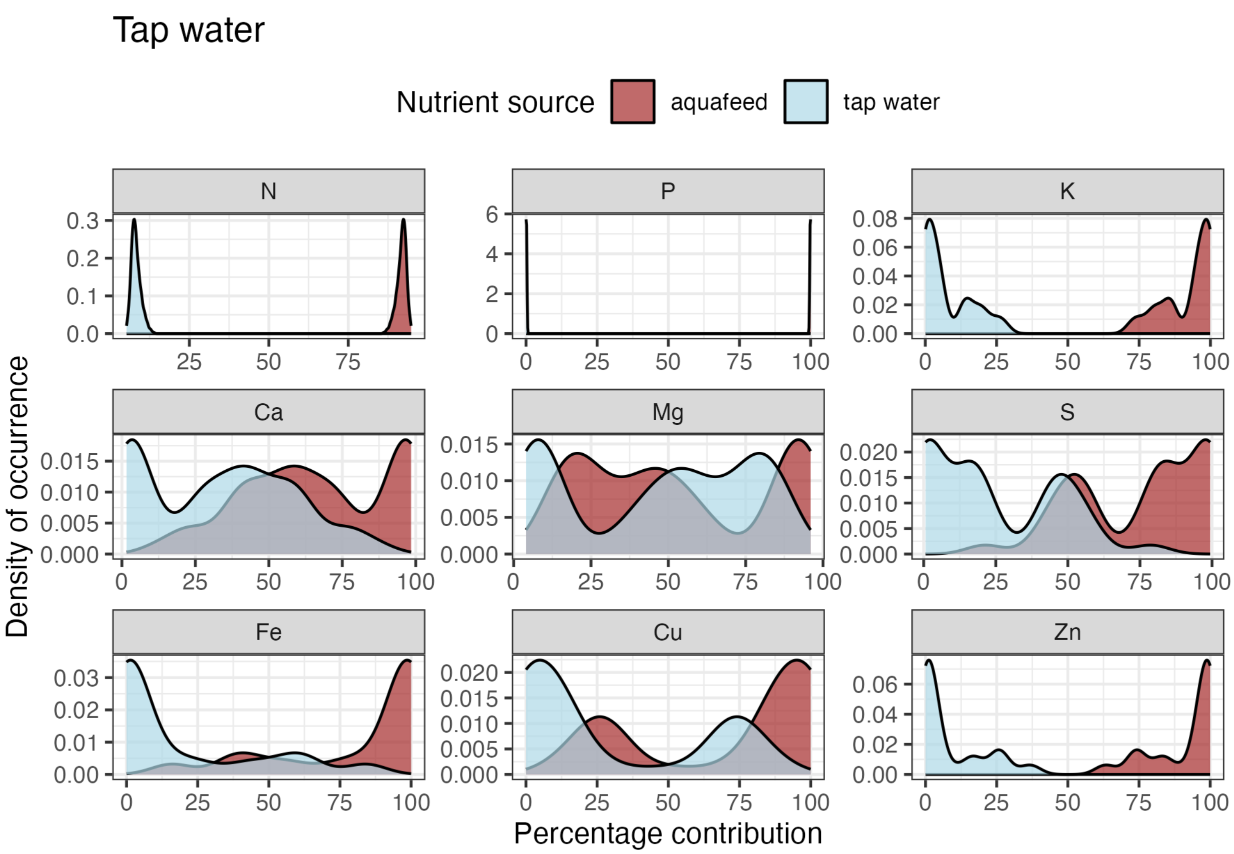
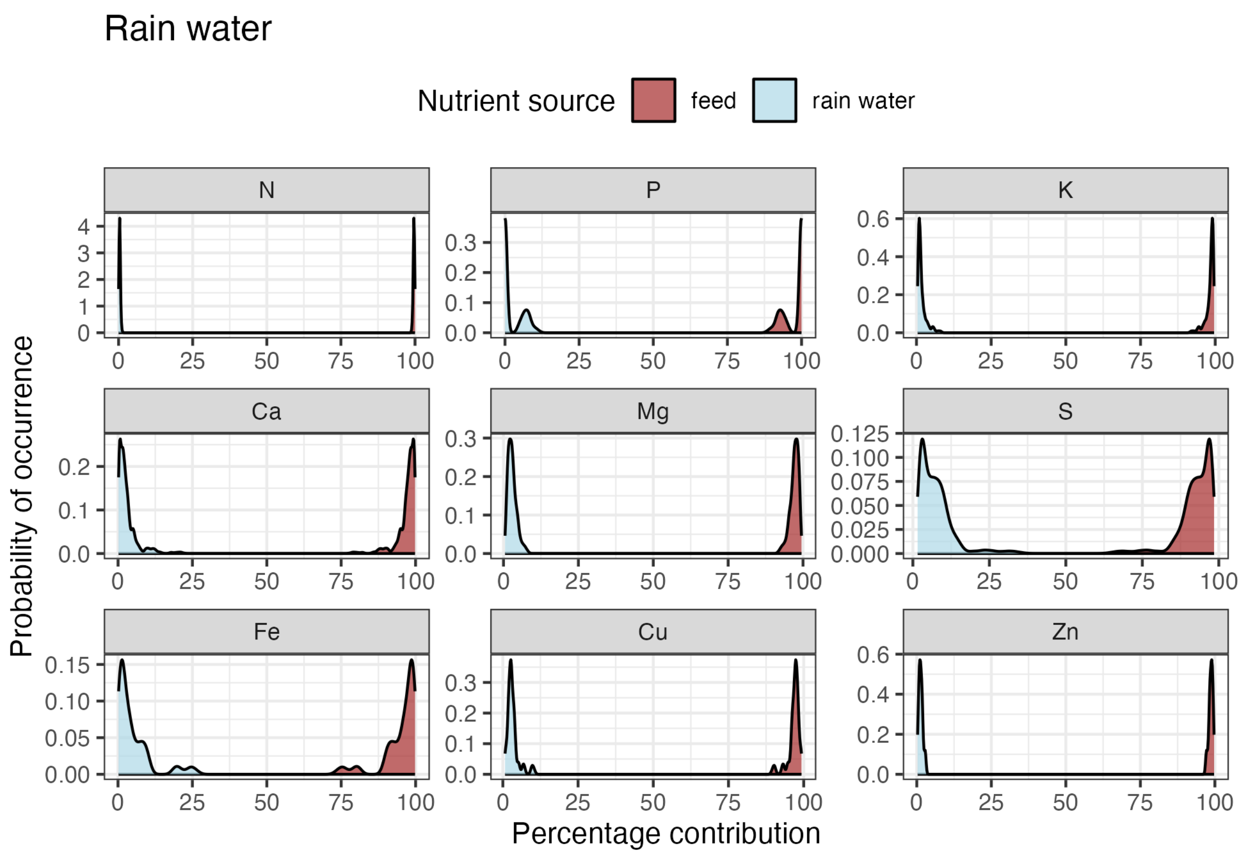


Figure 2: Distribution of the expected percentage contributions of fish feed and tap water to the total nutrient input in aquaculture facilities Data were generated through permutation.



Rain water
Nutrient source
feed
rain water
N
P
K
Ca
Mg
S
Fe
Cu
Zn
Probability of occurrence
Percentage contribution