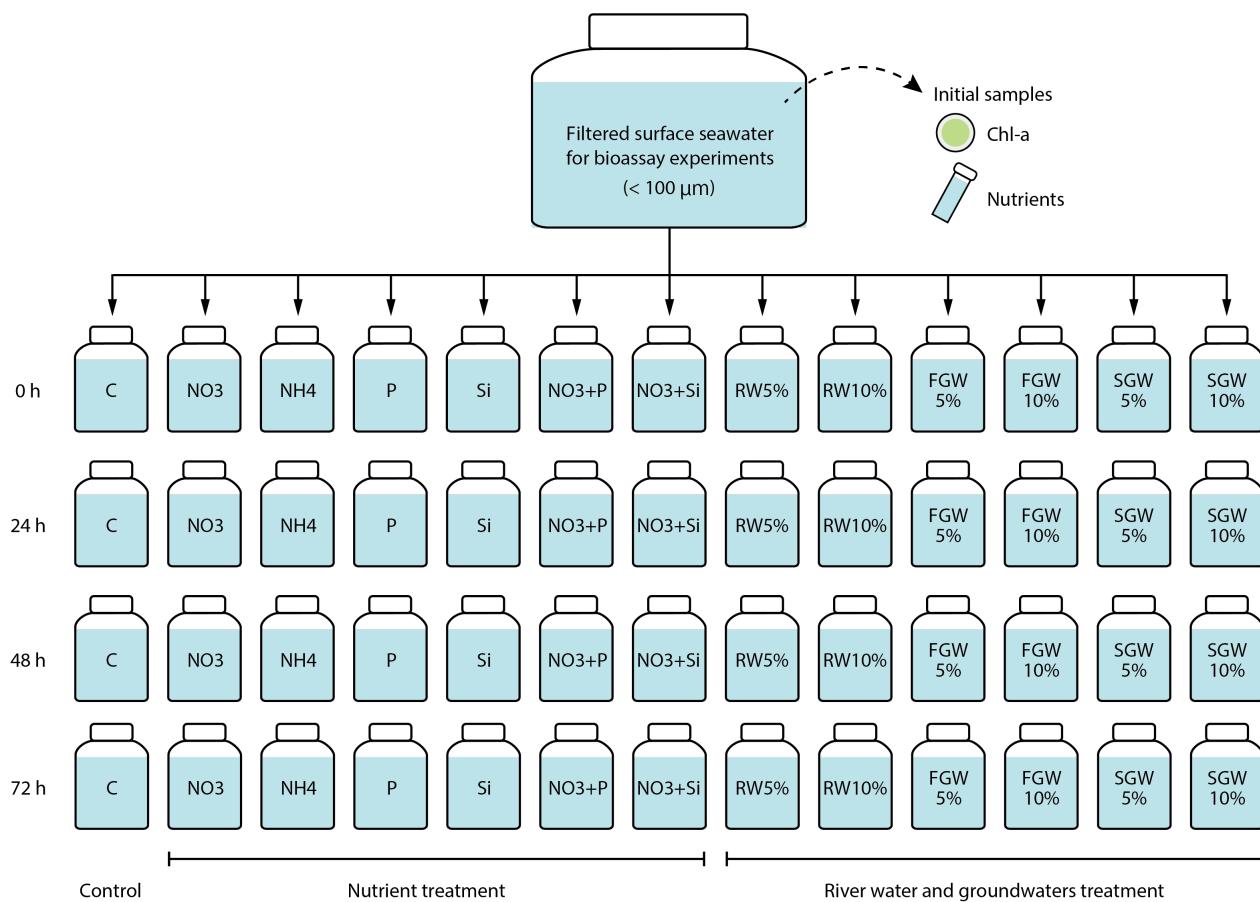
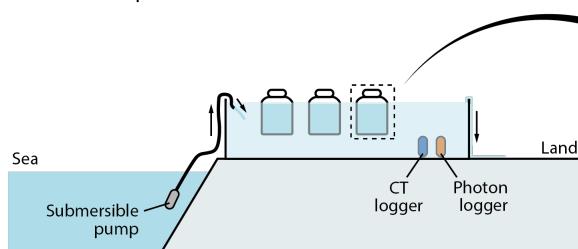


Fig. S1. Relationships of salinity with radium isotope (^{224}Ra and ^{228}Ra) activities in summer and autumn 2018. Open symbols indicate surface seawater observations at Station M5–9 and KB. Blue triangles, orange squares, yellow inverted triangles, and green circles represent the endmembers of river water, fresh groundwater, saline groundwater, and offshore seawater, respectively. Error bars show the standard deviation of samples. Solid lines (gray) are conservative mixing lines among water sources.

(a) Nutrients addition treatments



(b) Incubation experiment



(c) Sampling from each incubated bottle

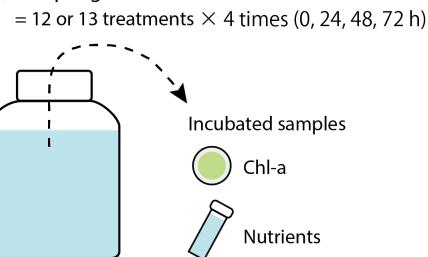


Fig. S2. Illustration of bioassay experiment procedure, including (a) nutrients addition treatments, (b) incubation experiment, and (c) sampling from each incubated bottle. Treatments include control (C), nitrate (NO₃), ammonium (NH₄), phosphate (P), silicate (Si), nitrate + phosphate (NO₃+P), nitrate + silicate (NO₃+Si), river water (RW), fresh groundwater (FGW), and saline groundwater (SGW). 5% and 10% represent ratio of addition volume relative to the bottle volume.

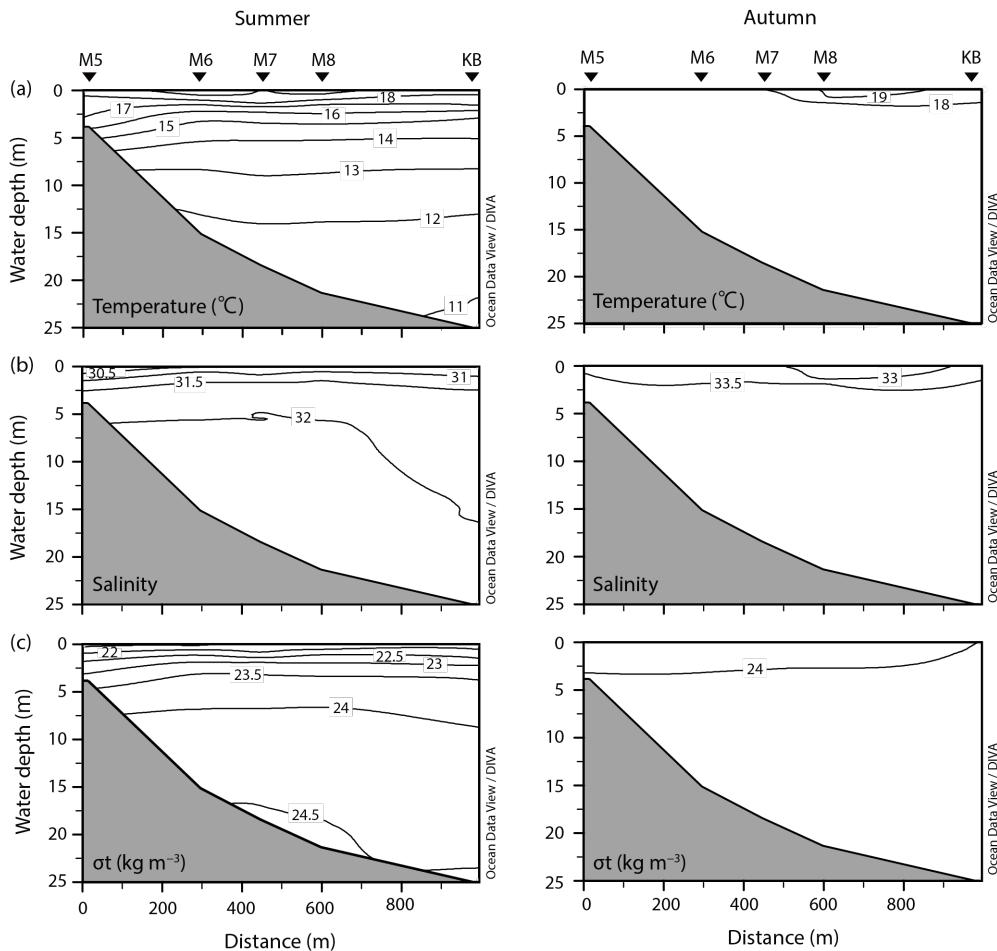


Fig. S3. Longitudinal distributions of (a) temperature ($^{\circ}\text{C}$), (b) salinity, and (c) density (σ_t) (kg m^{-3}) from Stn. M5 to Stn. KB in summer and autumn 2018. Intervals for contour lines are 1°C for temperature, 0.5 for salinity, and 0.5 kg m^{-3} for σ_t .

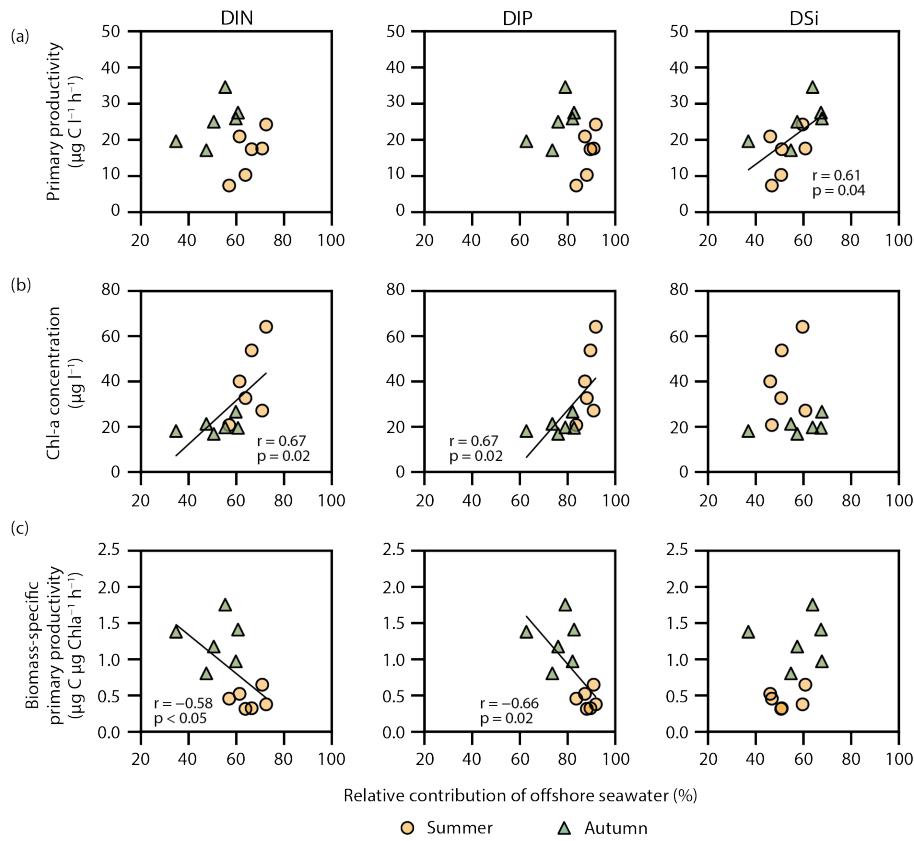


Fig. S4. Scatter diagrams of offshore seawater contributions to nutrients relative to (a) primary productivity, (b) chlorophyll-a concentrations, and (c) biomass-specific primary productivity in 2018. Circles and triangles represent observed values at each sampling station in summer and autumn, respectively.

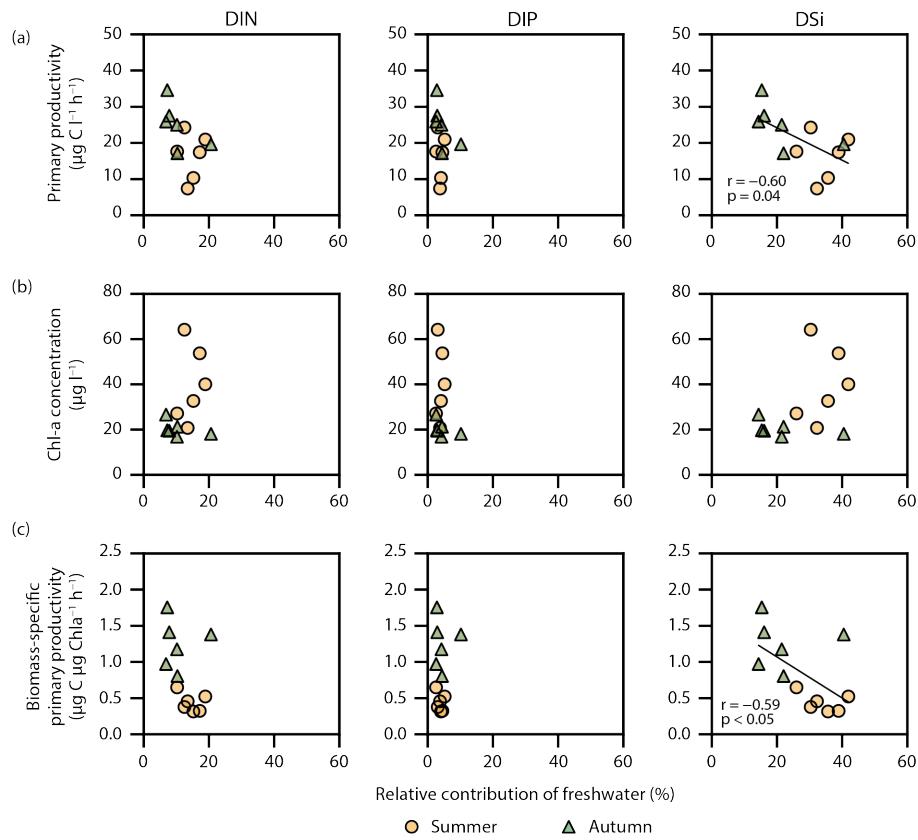


Fig. S5. Scatter diagrams of freshwater contributions to nutrients relative to (a) primary productivity, (b) chlorophyll-a concentrations, and (c) biomass-specific primary productivity in 2018. Circles and triangles represent observed values at each sampling station in summer and autumn, respectively.

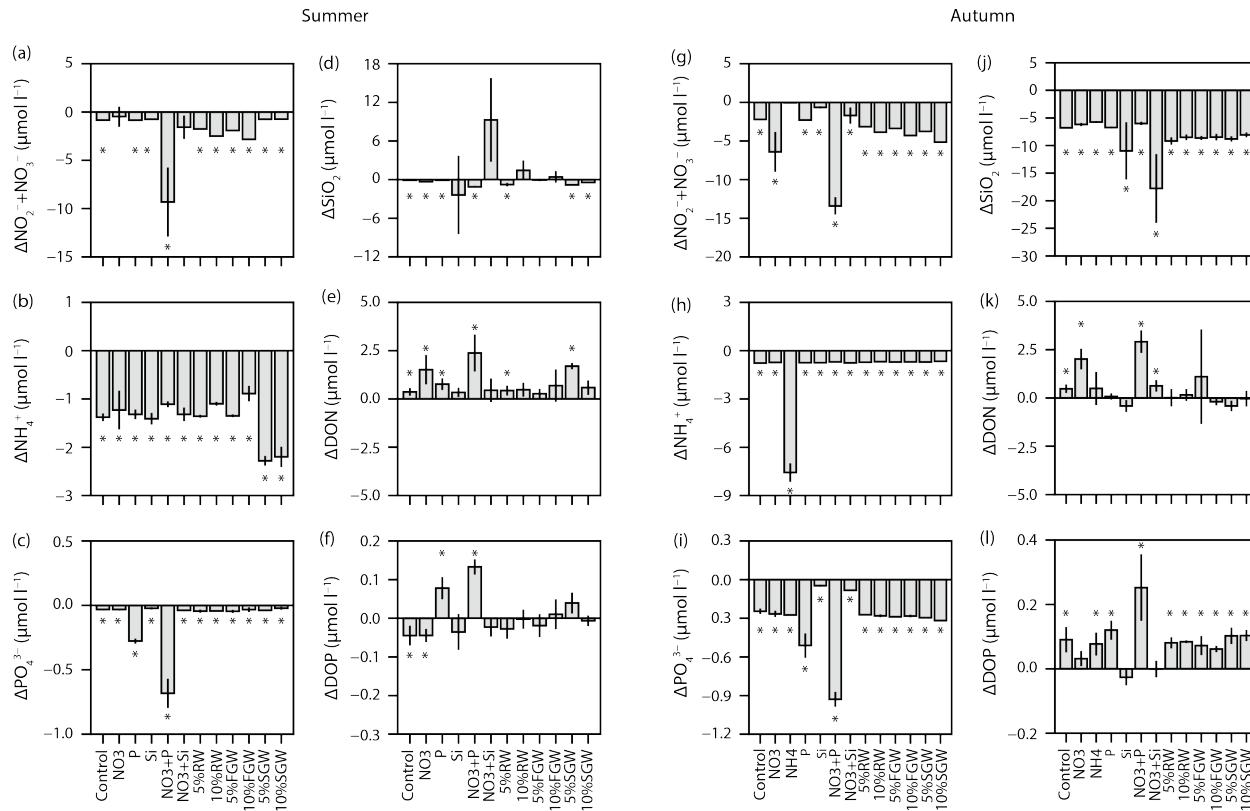


Fig. S6. Changes in $\text{NO}_2^- + \text{NO}_3^-$, NH_4^+ , PO_4^{3-} , SiO_2 , DON, and DOP in the incubated seawater of each treatment over 72 h in summer and autumn 2020. Asterisks are the significant difference in concentration between 0 h and 72 h (Student's t-test, $p < 0.05$). Negative or positive values represent the decrease or increase in concentration inside the incubation bottles of each treatment, respectively. Error bars represent the propagation of errors based on standard deviations of triplicated samples in incubation times of 0 and 72 h.

Table S1. Summary of environmental parameters measured at each sampling site in summer and autumn 2018. Data for dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), dissolved silica (DSi) concentrations and radium activities are sourced from Nakajima et al. (2021). DON: dissolved organic nitrogen; DOP: dissolved organic phosphorus; DIC: dissolved inorganic carbon.

Site	Temperature °C	Salinity	Chl-a µg l⁻¹	PP µg C h⁻¹	P _B µg C µg Chl-a⁻¹ h⁻¹	Phytoplankton density ×10² cells ml⁻¹	Diatoms %	Cryptophytes %	Dinophytes %	Others %	DIN µmol l⁻¹	DIP µmol l⁻¹	DSi µmol l⁻¹	DON µmol l⁻¹	DOP µmol l⁻¹	DIC dpm 100 l⁻¹	²²⁴ Ra dpm 100 l⁻¹	²²⁸ Ra dpm 100 l⁻¹
Summer																		
M5	18.4	30.0	40.0	20.9	0.5	2.1	79.1	13.6	3.6	3.8	0.98	<0.04	106.74	2.16	0.26	1924.3	50.7±1.1	26.8±2.2
M6	19.5	30.5	32.7	10.3	0.3	2.3	88.2	8.9	2.1	0.8	1.20	<0.04	63.94	1.10	0.35	1953.4	30.9±0.5	20.3±1.2
M7	19.0	31.0	64.2	24.3	0.4	5.9	12.1	78.6	4.5	4.8	0.85	<0.04	7.38	0.80	0.34	1934.3	45.3±1.0	25.0±1.3
M8	19.1	30.4	53.7	17.4	0.3	4.8	19.9	75.7	1.9	2.6	1.45	<0.04	70.46	1.36	0.39	1921.0	33.4±0.8	21.7±1.4
M9	19.6	31.2	27.1	17.6	0.6	3.6	36.5	59.3	2.5	1.8	0.45	0.07	155.06	2.91	0.51	1934.3	31.2±0.7	25.0±1.3
KB	18.2	30.4	20.7	7.4	0.4	3.0	39.4	56.0	3.1	1.6	0.46	<0.04	5.94	0.68	0.46	1957.6	18.6±0.6	15.6±1.1
Autumn																		
M5	18.3	33.1	21.3	17.1	0.8	1.1	75.9	6.6	3.6	13.9	4.06	0.13	10.62	0.63	0.82	2031.1	26.9±0.9	19.8±0.2
M6	18.4	33.2	26.6	25.9	1.0	1.7	93.0	2.2	1.3	3.5	3.63	0.24	8.72	<0.28	0.59	n.d.	16.9±0.6	18.4±1.2
M7	18.1	33.2	19.7	34.6	1.8	1.0	67.0	5.3	3.8	23.8	3.07	0.10	7.79	<0.28	0.74	2018.6	15.3±0.7	16.6±0.3
M8	16.9	32.6	18.1	19.6	1.1	1.4	88.7	2.3	0.9	8.2	4.16	0.16	12.39	<0.28	0.64	1997.8	29.4±0.9	20.3±0.5
M9	17.9	33.1	16.8	25.0	1.5	1.1	78.1	3.2	3.1	15.6	3.85	0.16	11.76	<0.28	0.78	1993.6	20.6±0.8	19.9±2.5
KB	17.6	33.2	19.5	27.5	1.4	1.5	96.8	1.7	0.0	1.5	2.79	0.10	8.91	<0.28	0.69	2010.3	18.2±0.7	15.8±0.9

Table S2. Endmembers of salinity, radium isotope (^{224}Ra and ^{228}Ra) activity, and nutrient concentrations used for mixing model analysis in summer and autumn 2018. Data are sourced from Nakajima et al. (2021). DIN: dissolved inorganic nitrogen; DIP: dissolved inorganic phosphorus; DSi: dissolved silica; FW: fresh water; RW: river water; FGW: fresh groundwater; SGW: saline groundwater; OW: offshore seawater.

Salinity	^{224}Ra		^{228}Ra	DIN $\mu\text{mol l}^{-1}$	DIP	DSi
	dpm	100 l^{-1}				
Summer						
FW	0.1	6.2	4.9	29.5	0.3	241.9
RW	0.1	6.5	4.7	20.4	0.2	231.7
FGW	0.1	6.0	5.2	38.6	0.4	252.1
SGW	26.3 ± 1.4	777.4 ± 260.7	513.8 ± 190.5	39.7 ± 25.4	0.6 ± 0.3	89.6 ± 18.3
OW	32.7	33.0	13.7	7.9	0.5	22.0
Autumn						
FW	0.1	7.3	6.2	29.5	0.4	259.5
RW	0.1	8.7	7.2	20.4	0.3	267.0
FGW	0.1	6.0	5.2	38.6	0.4	252.1
SGW	26.3 ± 1.4	777.4 ± 260.7	513.8 ± 190.5	39.7 ± 25.4	0.6 ± 0.3	89.6 ± 18.3
OW	33.4	6.4	10.8	1.1	0.1	5.0

Table S3. The relative contributions of freshwater (FW), saline groundwater (SGW), and offshore seawater (OW) to water and nutrients concentration in surface seawater, estimated using mixing model analysis and subsequent Eqs. 5–7.

Si te	Water			DIN			DIP			DSi		
	f _{FW} (%)	f _{SGW} (%)	f _{OW} (%)	f _{FW-N} (%)	f _{SGW-N} (%)	f _{OW-N} (%)	f _{FW-P} (%)	f _{SGW-P} (%)	f _{OW-P} (%)	f _{FW-Si} (%)	f _{SGW-Si} (%)	f _{OW-Si} (%)
Summer												
M5	7.2	5.6	87.2	18.9	19.7	61.4	5.2	7.6	87.3	41.9	12.1	46.1
M6	5.7	5.9	88.5	15.2	20.9	63.8	4.1	7.9	88.0	35.6	13.7	50.7
M7	4.3	3.8	92.0	12.5	15.0	72.5	3.1	5.1	91.8	30.3	10.0	59.6
M8	6.2	4.4	89.4	17.2	16.4	66.4	4.5	5.9	89.6	38.9	10.2	50.9
M9	3.6	4.9	91.6	10.3	18.9	70.9	2.5	6.6	90.9	26.0	13.2	60.8
KB	5.3	9.7	85.1	13.5	29.5	57.0	3.8	12.6	83.6	32.3	21.0	46.7
Median	5.5	5.3	88.9	14.4	19.3	65.1	3.9	7.1	88.8	33.9	12.7	50.8
Quartile deviation	0.8	0.7	1.7	2.0	1.8	3.9	0.6	0.9	1.6	3.6	1.5	4.9
Autumn												
M5	0.8	2.3	97.0	10.3	42.2	47.4	4.4	22.0	73.6	22.0	23.2	54.7
M6	0.4	1.5	98.2	6.8	33.3	59.8	2.6	15.3	82.1	14.3	17.9	67.7
M7	0.5	1.8	97.8	7.2	37.4	55.3	2.8	18.2	79.0	15.3	20.8	63.8
M8	2.0	3.3	94.8	20.6	44.6	34.7	10.2	27.1	62.7	40.5	22.7	36.9
M9	0.7	2.0	97.3	10.2	39.2	50.5	4.2	19.8	76.0	21.5	21.2	57.4
KB	0.5	1.4	98.2	7.8	31.4	60.7	2.9	14.4	82.7	16.0	16.6	67.3
Median	0.6	1.9	97.6	9.0	38.3	52.9	3.6	19.0	77.5	18.7	21.0	60.6
Quartile deviation	0.1	0.3	0.5	1.5	3.6	5.2	0.8	2.7	3.6	3.2	1.8	5.5

Table S4. Temperature, light intensity during the incubation by ¹³C tracer method, nutrients concentration in surface seawater, and limiting factors (F_T , F_I , and F_N) for primary production using Eqs. 2–4.

	Temperature	F_T	Light $\mu\text{mol m}^{-2} \text{s}^{-1}$	F_I	DIN $\mu\text{mol l}^{-1}$	DIP $\mu\text{mol l}^{-1}$	F_N
Summer							
Median	19.2	0.97	609.6	0.92	0.92	0.04	0.17
25%	19.0	0.97	408.8	1.00	0.56	0.04	0.17
75%	19.4	0.97	760.1	0.80	1.15	0.04	0.17
Autumn							
Median	18.7	0.96	331.7	0.97	3.74	0.14	0.43
25%	18.6	0.96	230.5	0.86	3.21	0.11	0.37
75%	18.7	0.96	441.9	1.00	4.01	0.16	0.45

Table S5. Nutrient properties and salinity of river water (RW), fresh groundwater (FGW), and saline groundwater (SGW) used for bioassay experiments in 2020.

	DIN μmol l ⁻¹	NO ₂ ⁻ + NO ₃ ⁻ μmol l ⁻¹	NH ₄ ⁺ μmol l ⁻¹	DIP μmol l ⁻¹	DSi μmol l ⁻¹	DIN:DIP:DSi	Salinity
Summer							
River water (RW)	20.9	20.9	<0.07	0.28	235.7	74:1:830	0.1
Fresh groundwater (FGW)	26.1	26.1	<0.07	0.34	219.0	77:1:648	0.1
Saline groundwater (SGW)	13.6	0.5	13.1	0.14	106.6	99:1:780	26.2
Autumn							
River water (RW)	21.3	21.2	0.1	0.30	226.7	71:1:750	0.1
Fresh groundwater (FGW)	25.5	25.5	<0.07	0.34	208.7	76:1:619	0.1
Saline groundwater (SGW)	34.6	34.2	0.4	0.77	96.5	45:1:125	24.3