



Supplement of

Net ecosystem production of coral communities persisting under marginal environmental conditions

Timothy B. King et al.

Correspondence to: Alex S. J. Wyatt (wyatt@ust.hk)

The copyright of individual parts of the supplement might differ from the article licence.

Contents of this file

Figures S1 to S8

Tables S1 to S5

Introduction

This Supporting Information provides supplementary tables and figures that support the analyses and interpretations presented in the main manuscript. Supplementary tables include summary statistics of all measured environmental variables for each deployment, as well as complete outputs from the statistical analyses referenced in the main text. Supplementary figures present additional visualizations of environmental and meteorological conditions, including temporal patterns, variability, and relationships among measured variables that complement the primary results. Periods of missing data reflect sensor malfunctions or intervals during which the physical conditions required for valid gradient flux measurements were not met.

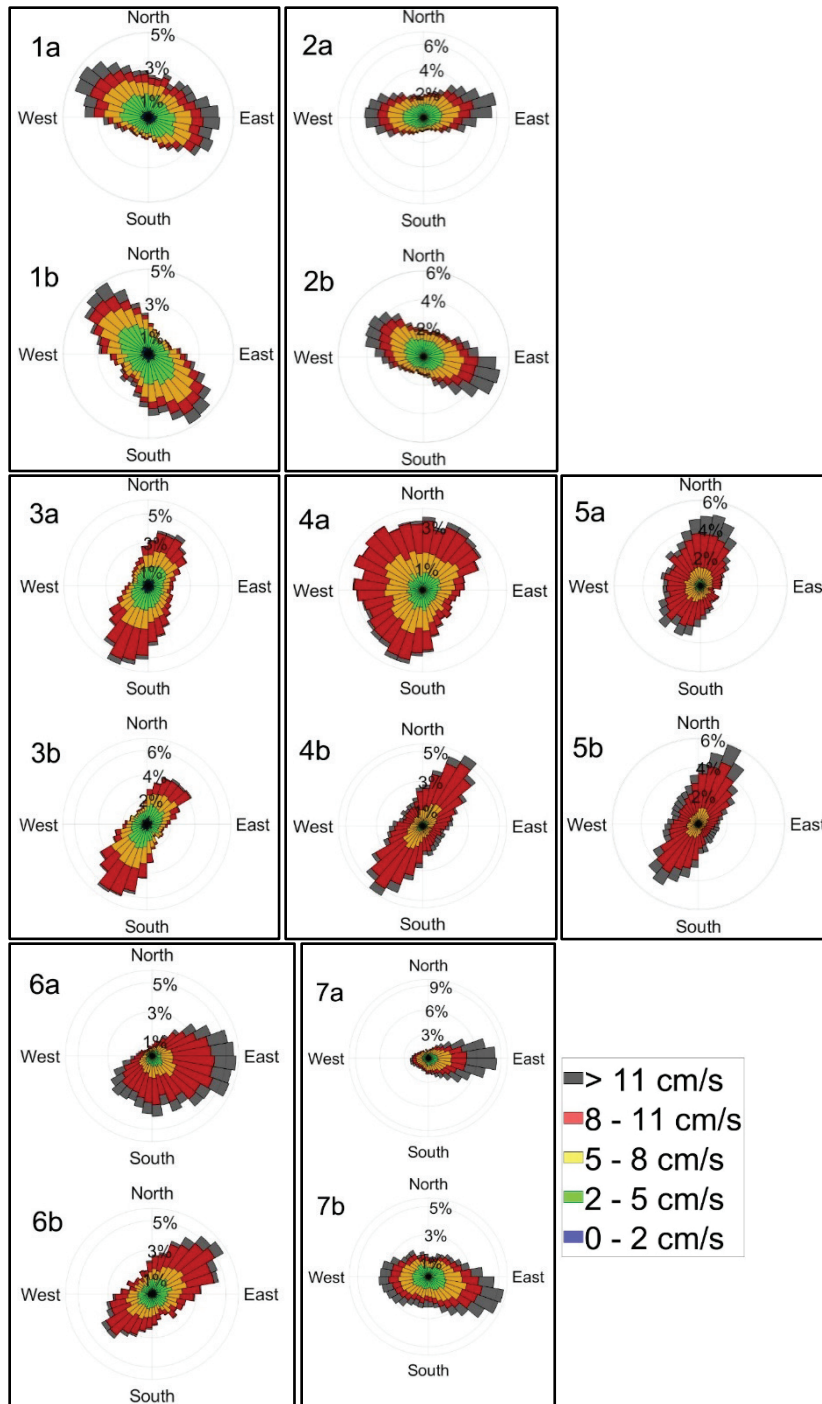


Figure S1. Water current speeds and directions from both top (letter a) and bottom (letter b) velocimeters for each deployment in both seasons. Percentages indicate the percentage of datapoints that fall into that velocity range. Dry season deployments at Sham Wan (1a, b), Sharp Island (3a, b) and Tung Ping Chau (6a, b) are shown in column 1. Wet season deployments at Sham Wan (2a, b), Sharp Island Oct (4a, b), Sharp Island May (5a, b), and Tung Ping Chau (7a, b) are shown in columns 2 and 3.

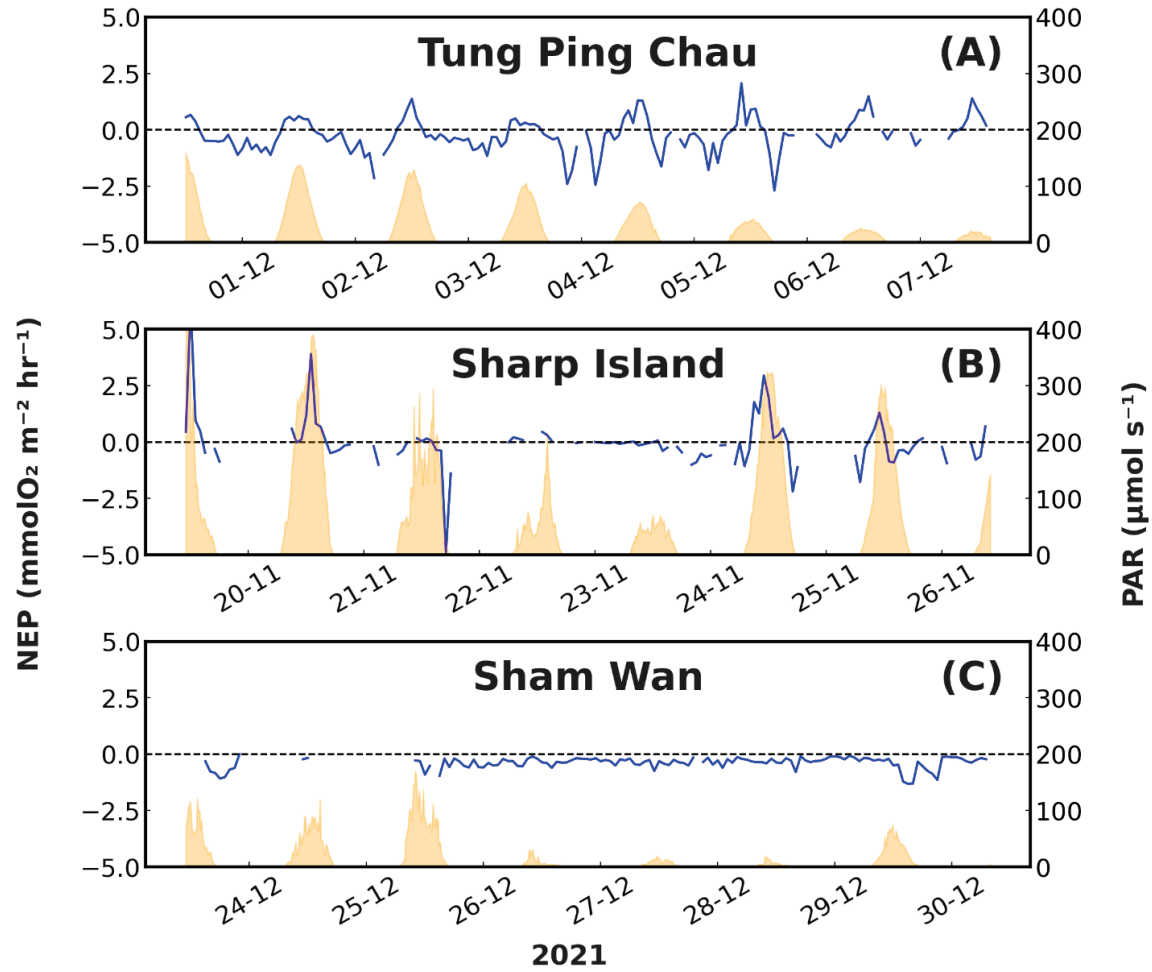


Figure S2. Time series of NEP (blue lines) during the dry season overlaid on in situ PAR data (orange shading) for (A) Tung Ping Chau, (B) Sharp Island, and (C) Sham Wan. Breaks in the NEP/NEC time series represent periods when conditions necessary for gradient flux calculations were not met. A sea urchin was found nested on top of the PAR sensor at Tung Ping Chau during the sensor retrieval, which may have affected PAR measurements during this time.

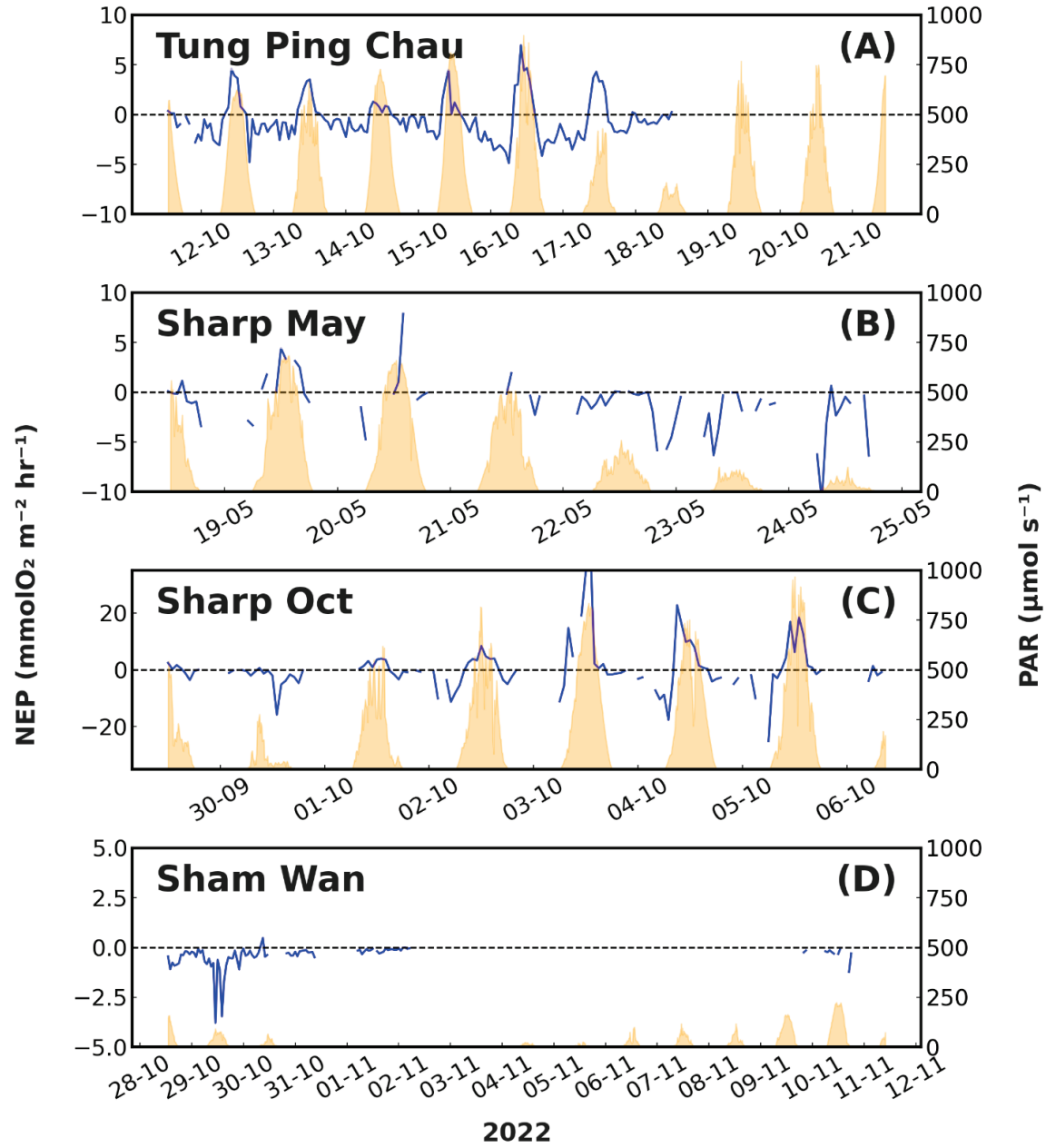


Figure S3. Wet season NEP time series overlaid on PAR data for (A) Tung Ping Chau, (B) Sharp Island in May, (C) Sharp Island in October and (D) Sham Wan. The red line represents the NEC, and the blue line indicates the NEP data. The large gaps in metabolism data for Sham Wan was due to the bottom depth O_2 sensor malfunction. Other gaps in the time series represent periods when conditions necessary for gradient flux calculations were not met.

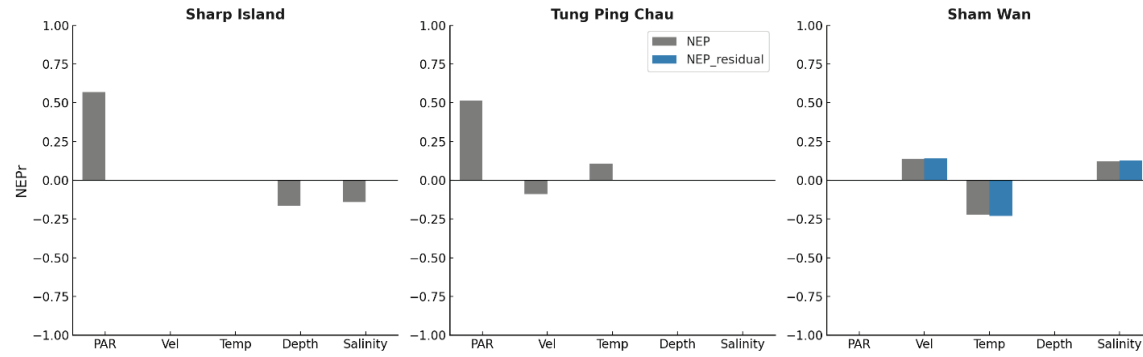


Figure S4. Pearson correlation coefficients between NEP (grey bars) and NEP residuals after removal of the PAR effect (blue bars) with measured environmental variables during the dry season at the three deployment sites. Only statistically significant correlations ($p < 0.05$) are shown. The y-axis (NEPr) denotes correlation strength.

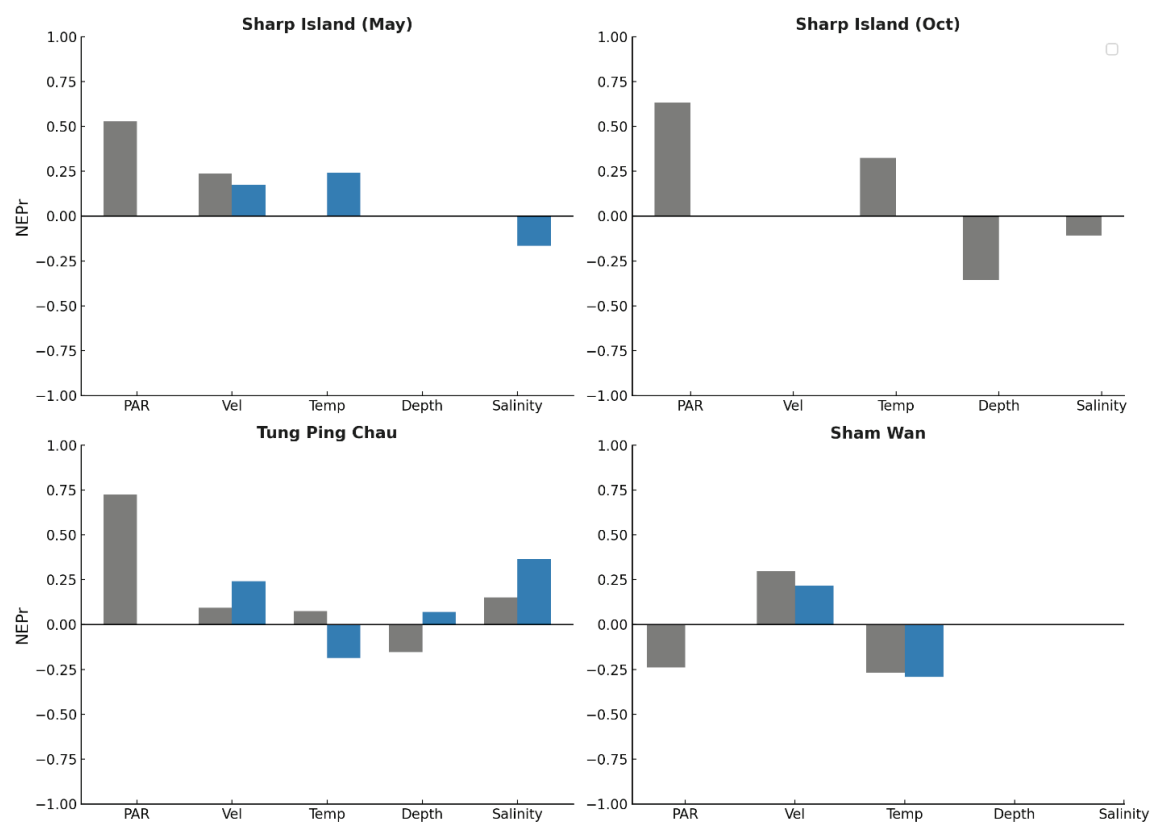


Figure S5. Pearson correlation coefficients between NEP (grey bars) and NEP residuals after removal of the PAR effect (blue bars) with measured environmental variables during the wet season at the three deployment sites. Only statistically significant correlations ($p < 0.05$) are shown. The y axis (NEPr) denotes correlation strength.

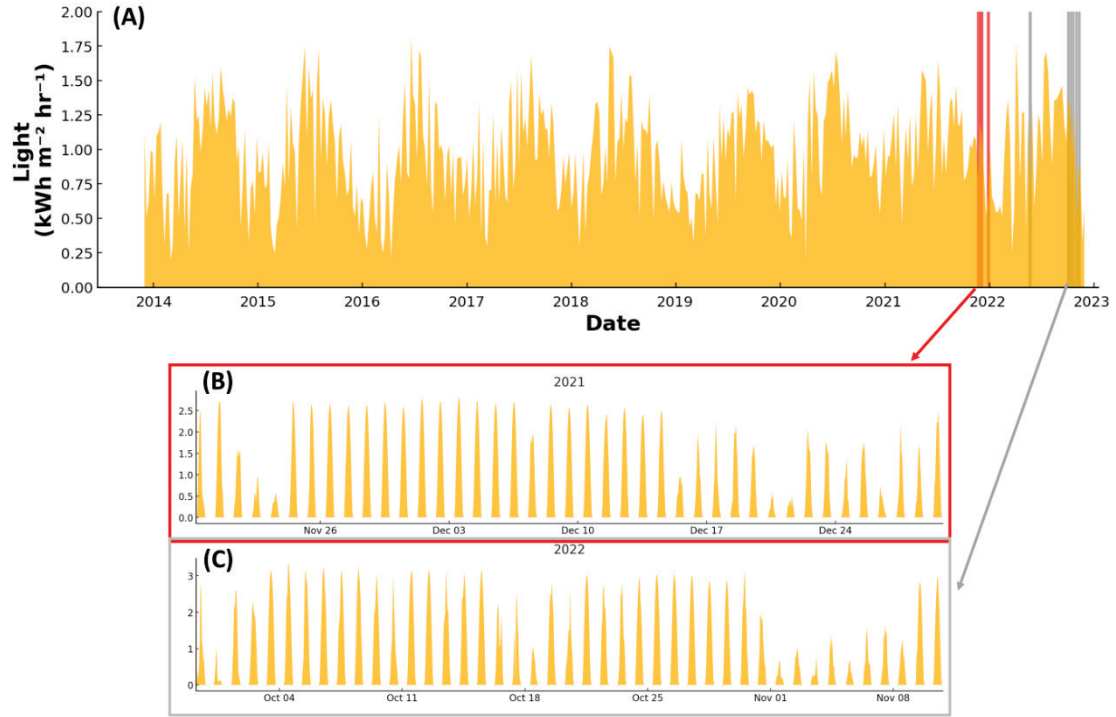


Figure S6. Weekly averaged global solar radiation ($\text{kWh m}^{-2} \text{hr}^{-1}$) from (A) November 2013 to December 2022, measured at the Hong Kong Observatory weather station in Sai Kung. The red and grey shadings highlight the deployment times of this study for dry season and wet season, respectively. Inlet plots of the global solar radiation during the deployments during the (B) dry season and (C) wet season.

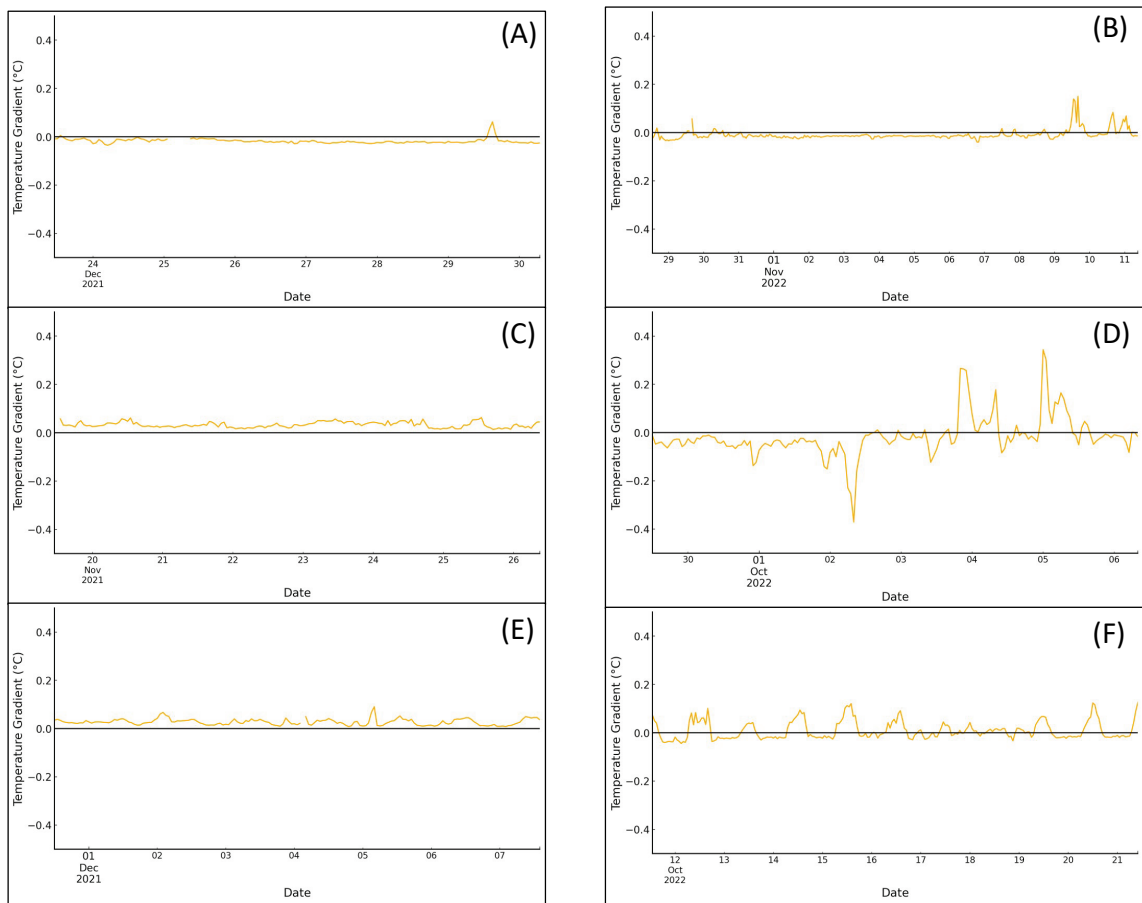


Figure S7. Temperature gradient between top and bottom temperature sensors for the study deployments. Sham Wan (A) dry season and (B) wet season are in row one. Sharp Island (C) dry season and (D) wet season are in row two. Tung Ping Chau (E) dry season and (F) wet season are in row 3.

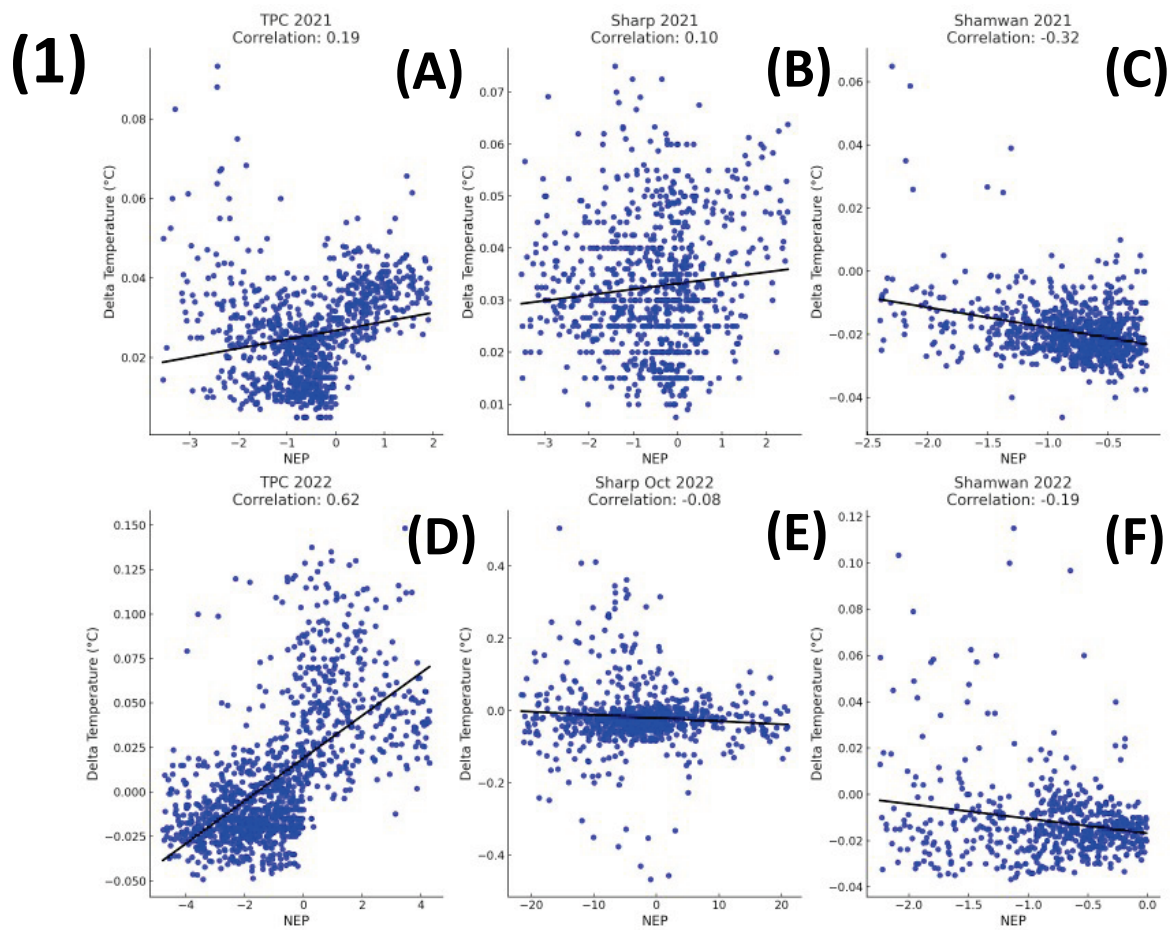


Figure S8. Linear regressions of the temperature gradient (top sensor temperature – bottom sensor temperature) and metabolic rates. Figure 1 shows NEP rates in the dry season for Sham Wan (1a), Sharp Island (1b), and Tung Ping Chau (1c); wet season NEP rates are shown for Sham Wan (1d), Sharp Island (1e) and Tung Ping Chau (1f).

Table S1. Environmental Protection Department (EPD) data summary statistics for Sept/Oct 2022 (wet season) and Dec 2021/Jan 2022 (dry season). Mann-Whitney test results to test significance of difference of means between seasons.

Variable	Dry Season Mean	Min	Max	SEM	Range	Wet Season Mean	Min	Max	SEM	Range	Mann- Whitney p-value
Chlorophyll- a (µg/L)	2.90	0.2	41	0.36	40.8	3.20	0.2	18	0.26	17.8	0.079
DO saturation (%)	86.43	57	128	0.74	71	82.61	46	116	0.88	70	0.00033
Dissolved Oxygen (mg/L)	6.45	4.3	10.1	0.06	5.8	5.42	3	7.6	0.06	4.6	1.14E-29
Dissolved Oxygen (µmol/kg)	1.97.3	131.6	309.1	1.77	177.5	165.9	91.8	232.6	1.79	140.8	1.14E-29
pH	7.56	6.5	8	0.02	1.5	7.73	7	8.2	0.03	1.2	0.0013
Salinity (psu)	33.15	18.8	34.4	0.13	15.6	31.10	17.5	33.9	0.19	16.4	2.90E-35
Temperature (°C)	20.20	17.6	22.5	0.09	4.9	28.39	24.6	31.2	0.11	6.6	6.66E-58
Total N (mg/L)	0.70	0.2	4.97	0.03	4.77	0.54	0.11	5.68	0.04	5.57	1.14E-12
Turbidity (NTU)	19.32	5.2	183.9	2.13	178.7	27.93	0.9	384.2	4.32	383.3	0.0035

Table S2. Kruskal-Wallis and Dunn's post-hoc result of significant difference of HKO-derived global solar radiation, wind speed, and rainfall between deployments within the dry season and wet season.

HKO variable	KRUSKAL-WALLIS H-VALUE	KRUSKAL-WALLIS P-VALUE	SIGNIFICANT PAIRWISE DIFFERENCE
<i>Global solar radiation, dry season</i>	10.29	0.0058	TPC vs Sham Wan
<i>Wind speed, dry season</i>	42.4	0.0	Sharp vs TPC; TPC vs Sham Wan
<i>Rainfall, dry season</i>	26.6	0.0	Sharp vs Sham Wan; TPC vs Sham Wan
<i>Global solar radiation, wet season</i>	10.9	0.0043	TPC vs Sham Wan
<i>Wind speed, wet season</i>	27.0	0.0	Sharp vs TPC; Sharp vs Sham Wan
<i>Rainfall, wet season</i>	23.8	0.0	Sharp vs Sham Wan; TPC vs Sham Wan

Table S3. Mean ($\pm$ SE), minimum (min), and maximum (max) measured environmental variables for each location during the dry season. Values are 10-minute averages. Bottom sensor indicates the sensor placed closest to the benthos. Top sensor indicates the sensor placed higher in the water column.

Variable	Tung Ping Chau	Sharp	Sham Wan
Date Range	30 Nov- 7 Dec 2021	19-26 Nov 2021	23-30 Dec 2021
Velocity, top (m s^{-1}) - Mean	0.045 (± 0.025)	0.028 (± 0.015)	0.066 (± 0.044)
Velocity, top (m s^{-1}) - Min	5.0e-03	5.0e-03	4.0e-03
Velocity, top (m s^{-1}) - Max	0.31	0.17	0.36
Velocity, bottom (m s^{-1}) - Mean	0.039 (± 0.019)	0.033 (± 0.016)	0.070 (± 0.041)
Velocity, bottom (m s^{-1}) - Min	7.0e-03	7.0e-03	8.0e-03
Velocity, bottom (m s^{-1}) - Max	0.27	0.28	0.39
Δ Velocity (top–bottom) (m s^{-1}) - Mean	0.006 (± 0.027)	-0.005 (± 0.020)	-0.004 (± 0.044)
Δ Velocity (top–bottom) (m s^{-1}) - Min	-0.24	-0.25	-0.37
Δ Velocity (top–bottom) (m s^{-1}) - Max	0.25	0.1	0.19
Temperature, top ($^{\circ}\text{C}$) - Mean	21.866 (± 0.368)	23.389 (± 0.600)	20.424 (± 0.345)
Temperature, top ($^{\circ}\text{C}$) - Min	21	22	20
Temperature, top ($^{\circ}\text{C}$) - Max	23	24	21
Temperature, bottom ($^{\circ}\text{C}$) - Mean	21.838 (± 0.370)	23.356 (± 0.600)	20.442 (± 0.341)
Temperature, bottom ($^{\circ}\text{C}$) - Min	21	22	20

Temperature, bottom (°C) - Max	23	24	21
PAR ($\mu\text{mol m}^{-2} \text{s}^{-1}$) - Mean	19.277 (± 33.482)	51.767 (± 91.819)	12.044 (± 27.019)
PAR ($\mu\text{mol m}^{-2} \text{s}^{-1}$) - Min	-0.4	-0.39	-0.52
PAR ($\mu\text{mol m}^{-2} \text{s}^{-1}$) - Max	1.7e+02	6e+02	2.2e+02
DO, top ($\mu\text{mol kg}^{-1}$) - Mean	208.061 (± 8.515)	195.358 (± 14.662)	210.373 (± 6.764)
DO, top ($\mu\text{mol kg}^{-1}$) - Min	1.8e+02	1.5e+02	1.9e+02
DO, top ($\mu\text{mol kg}^{-1}$) - Max	2.3e+02	2.4e+02	2.3e+02
DO, bottom ($\mu\text{mol kg}^{-1}$) - Mean	206.357 (± 11.206)	191.940 (± 17.421)	208.426 (± 7.120)
DO, bottom ($\mu\text{mol kg}^{-1}$) - Min	1.8e+02	1.4e+02	1.9e+02
DO, bottom ($\mu\text{mol kg}^{-1}$) - Max	2.3e+02	2.7e+02	2.3e+02
ΔDO (top–bottom) ($\mu\text{mol kg}^{-1}$) - Mean	1.704 (± 4.371)	3.418 (± 8.714)	1.946 (± 1.726)
ΔDO (top–bottom) ($\mu\text{mol kg}^{-1}$) - Min	-15	-44	-4.4
ΔDO (top–bottom) ($\mu\text{mol kg}^{-1}$) - Max	25	54	15
pH, top - Mean	8.048 (± 0.016)	7.990 (± 0.028)	8.038 (± 0.010)
pH, top - Min	8	7.9	8
pH, top - Max	8.1	8.1	8.1
pH, bottom - Mean	7.978 (± 0.021)	7.959 (± 0.032)	8.014 (± 0.011)
pH, bottom - Min	7.9	7.8	8

pH, bottom - Max	8	8	8
Δ pH (top-bottom) - Mean	0.070 (± 0.009)	0.031 (± 0.022)	0.024 (± 0.008)
Δ pH (top-bottom) - Min	0.046	-0.039	-9.0e-03
Δ pH (top-bottom) - Max	0.13	0.14	0.064
Depth, top (m) - Mean	3.446 (± 0.566)	3.017 (± 0.497)	5.320 (± 0.433)
Depth, top (m) - Min	2.2	2	4.2
Depth, top (m) - Max	4.8	4	6.4
Depth, bottom (m) - Mean	3.827 (± 0.564)	3.341 (± 0.495)	5.781 (± 0.430)
Depth, bottom (m) - Min	2.6	2.4	4.7
Depth, bottom (m) - Max	5.2	4.3	6.9
Salinity (psu) - Mean	33.773 (± 0.060)	33.369 (± 0.055)	34.006 (± 0.054)
Salinity (psu) - Min	34	32	34
Salinity (psu) - Max	34	33	34

Table S4. Mean ($\pm$ SE), minimum (min), and maximum (max) measured environmental variables for each location during the wet season. Values are 10-minute averages. Bottom sensor indicates the sensor placed closest to the benthos. Top sensor indicates the sensor placed higher in the water column.

Variable	Tung Ping Chau	Sharp, May	Sharp, October	Sham Wan
Date range	11–21 Oct 2022	18–24 May 2022	29 Sep–6 Oct 2022	28 Oct–11 Nov 2022
Velocity, top (m s ⁻¹) - Mean	0.0864 ($\pm$ 0.0012)	0.0298 ($\pm$ 0.0003)	0.0405 ($\pm$ 0.0004)	0.0729 ($\pm$ 0.0009)
Velocity, top - Min	0.029	8.3e-03	0.019	0.014
Velocity, top - Max	0.44	0.068	0.085	0.33
Velocity, bottom (m s ⁻¹) - Mean	0.0765 ($\pm$ 0.0009)	0.0444 ($\pm$ 0.0007)	0.0463 ($\pm$ 0.0005)	0.0731 ($\pm$ 0.0009)
Velocity, bottom - Min	0.028	0.016	0.02	0.025
Velocity, bottom - Max	0.21	0.22	0.14	0.27
Δ Velocity (top–bottom) - Mean	0.0099 ($\pm$ 0.0012)	–0.0145 ($\pm$ 0.0009)	–0.0058 ($\pm$ 0.0006)	–0.0002 ($\pm$ 0.0003)
Δ Velocity - Min	–0.1463	–0.2023	–0.1120	–0.0489
Δ Velocity - Max	0.25	0.025	0.043	0.07
Temperature, top (°C) - Mean	26.8287 ($\pm$ 0.0246)	25.6813 ($\pm$ 0.0157)	29.1073 ($\pm$ 0.0150)	23.7402 ($\pm$ 0.0205)
Temperature, top - Min	25	25	28	23
Temperature, top - Max	29	27	30	26
Temperature, bottom (°C) - Mean	26.8188 ($\pm$ 0.0246)	25.6104 ($\pm$ 0.0165)	29.1252 ($\pm$ 0.0141)	23.7489 ($\pm$ 0.0206)
Temperature, bottom - Min	25	25	28	23

Temperature, bottom - Max	29	27	30	26
PAR ($\mu\text{mol m}^{-2} \text{ s}^{-1}$) - Mean	140.0732 (± 5.7925)	104.6570 (± 5.7695)	128.8450 (± 6.9352)	13.8442 (± 0.7908)
PAR - Min	-0.0522	-0.1679	-0.0632	-0.0447
PAR - Max	9e+02	6.8e+02	9.7e+02	2.2e+02
DO, top ($\mu\text{mol kg}^{-1}$) - Mean	186.6869 (± 0.3467)	197.4749 (± 0.5729)	174.4693 (± 0.5113)	198.2213 (± 0.1839)
DO, top - Min	1.6e+02	1.4e+02	1.1e+02	1.8e+02
DO, top - Max	2.3e+02	2.6e+02	2.1e+02	2.4e+02
DO, bottom ($\mu\text{mol kg}^{-1}$) - Mean	184.8207 (± 0.3943)	185.5327 (± 1.0171)	165.3198 (± 1.1850)	193.7624 (± 0.3107)
DO, bottom - Min	1.5e+02	99	65	1.7e+02
DO, bottom - Max	2.3e+02	2.7e+02	3.3e+02	2.2e+02
ΔDO (top-bottom) - Mean	1.8661 (± 0.1018)	11.9423 (± 0.8039)	9.1495 (± 1.0165)	3.562 (± 0.1663)
ΔDO - Min	-10.5885	-63.8649	-143.3502	-4.1065
ΔDO - Max	20	90	1.2e+02	23
pH, top - Mean	7.9942 (± 0.0006)	7.9957 (± 0.0012)	7.9807 (± 0.0011)	7.947 (± 0.0004)
pH, top - Min	7.9	7.9	7.9	7.9
pH, top - Max	8	8.1	8	8
pH, bottom - Mean	7.9218 (± 0.0007)	7.9452 (± 0.0018)	7.8908 (± 0.0019)	7.8862 (± 0.0004)
pH, bottom - Min	7.8	7.8	7.7	7.8

pH, bottom - Max	8	8	8	7.9
Δ pH (top-bottom) - Mean	0.0724 (± 0.0003)	0.0505 (± 0.0015)	0.0899 (± 0.0018)	0.0607 (± 0.0003)
Δ pH - Min	0.053	-0.0607	-0.0673	-0.0413
Δ pH - Max	0.12	0.22	0.3	0.12
Depth, top (m) - Mean	2.1819 (± 0.0114)	3.3164 (± 0.0180)	2.9773 (± 0.0152)	5.1808 (± 0.0114)
Depth, top - Min	1.4	2.3	2.1	4
Depth, top - Max	3	4.4	3.9	6.3
Depth, bottom (m) - Mean	2.7732 (± 0.0113)	3.6946 (± 0.0182)	3.5846 (± 0.0151)	5.6563 (± 0.0115)
Depth, bottom - Min	2	2.7	2.7	4.4
Depth, bottom - Max	3.6	4.8	4.6	6.8
Salinity (ppt) - Mean	32.9227 (± 0.0027)	32.0233 (± 0.0087)	32.1369 (± 0.0092)	34.0492 (± 0.0069)
Salinity - Min	33	31	31	33
Salinity - Max	33	33	33	34

Table S5. Mean day and night NEP (mmolO-2 m-2 hr-1) values for each deployment in each season ($\pm$ SE).

Variable	Sham Wan Dry	Sharp Dry	TPC Dry	Sham Wan Wet	Sharp Early Wet	Sharp Late Wet	TPC Wet
Mean NEP	-0.37 ($\pm$ 0.33)	0.12 ($\pm$ 1.28)	-0.22 ($\pm$ 0.91)	-0.37 ($\pm$ 0.56)	-1.39 ($\pm$ 3.03)	0.15 ($\pm$ 9.38)	-0.59 ($\pm$ 2.31)
Mean Day NEP	-0.40 ($\pm$ 0.36)	0.31 ($\pm$ 1.47)	0.15 ($\pm$ 0.87)	-0.53 ($\pm$ 0.80)	-0.63 ($\pm$ 2.85)	2.10 ($\pm$ 9.67)	0.77 ($\pm$ 2.48)
Mean Night NEP	-0.34 ($\pm$ 0.30)	-0.31 ($\pm$ 0.44)	-0.69 ($\pm$ 0.72)	-0.27 ($\pm$ 0.28)	-2.65 ($\pm$ 2.91)	-4.56 ($\pm$ 6.64)	-1.78 ($\pm$ 1.28)