water

Coupling between Hydrodynamics and Chlorophyll *a* and Bacteria in a Temperate Estuary: A Box Model Approach

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Additional Water Column Characterization

Additional physical-chemical analyses were performed for the water samples collected in the Lima estuary. For the determination of total suspended solids (TSS), the water samples were filtered through pre-combusted glass fiber filters (GF/F Whatman), and dried at 105 °C [1]. The dissolved orthophosphate, nitrite, ammonium and silicate determinations were performed according the methods described by Koroleff [2]. Orthophosphate ions react with an acid solution containing molybdate and antimony ions to form a phosphomolybdate antimony complex, followed by reduction of the latter with ascorbic acid to form a blue molybdenum complex. For dissolved silica quantification, an acidic solution of ammonium molybdate was added to the sample to produce silicomolybdic acid which is then reduced to silicomolybdous acid (a blue compound) using ascorbic acid. Ammonia, in moderately alkaline solutions, reacts with the hypochlorite to form monochloramine, which in the presence of a catalyst (nitroprusside), phenol, and excess hypochlorite gives rise to an intense blue complex (indophenol blue). The nitrite was determined by diazotizing nitrite with sulfanilamide and coupling it with N-(1-napthyl)-ethylenediamine hydrochloride to form a highly coloured azo dye. The concentration of nitrate was obtained by the method described by Jones [3], and adapted by Joye and Chambers [4], which consists of the nitrite determination procedure, after the reduction of nitrate to nitrite using spongy cadmium (total concentration of NO_x). The nitrate concentration was obtained subtracting the nitrite from the total concentration of NO_x obtained. After color development, all nutrients were determined by molecular absorption spectrophotometry. Determination of total dissolved carbon (TDC), dissolved organic carbon (DOC), and total dissolved nitrogen (TDN) was performed by high-temperature catalytic oxidation with a TOC-VCSN analyzer (Shimadzu Instruments), according to Magalhães et al. [5]. Briefly, TDC was measured by high temperature catalytic oxidation followed by nondispersive infrared detection of CO_2. For DIC determination, samples were automatically acidified (1.5% HCl 2 M), and sparged with carrier gas (purified air) to convert only the inorganic carbon to CO_2. DOC was determined by the difference between TDC and DIC. TDN was thermally decomposed in a combustion tube and the resulting nitric oxide detected by chemiluminescence. All analyzes were performed in triplicate.

Table S1. Mean concentrations ± SE for key environmental parameters measured at the surface of the sampling sites: Secchi disc (SD)—m (in bold-bottom depth); temperature—°C; salinity; dissolved oxygen (DO)—mg O_2 L^{-1}; pH; NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, N:P, and Si—μM; chlorophyll *a* (CHL *a*)—mg m^{-3}; total cell counts (TCC)—log_{10} cells mL^{-1}. In brackets—minimum and maximum values.

Site	SD	T	Salinity	DO	pH	NO_3^-	NO_2^-	NH_4^+	PO_4^{3-}	N:P	Si	CHL *a*	TCC
1	2.48 ± 0.33 (1.30–3.30)	15.47 ± 1.58 (11.06–20.56)	18.29 ± 5.89 (1.99–30.30)	8.80 ± 0.60 (7.69–10.89)	7.75 ± 0.09 (7.51–7.96)	19.97 ± 7.09 (9.12–46.75)	0.189 ± 0.043 (0.108–0.295)	1.517 ± 0.355 (0.818–2.800)	0.384 ± 0.065 (0.211–0.562)	60 ± 17 (25–107)	47.01 ± 16.59 (15.29–95.67)	1.04 ± 0.16 (0.57–1.50)	5.72 ± 0.12 (5.38–6.08)
2	2.46 ± 0.39 (1.3–3.30)	15.65 ± 1.57 (11.06–20.64)	17.32 ± 5.53 (1.99–29.70)	8.87 ± 0.58 (7.61–10.89)	7.81 ± 0.07 (7.57–7.96)	22.42 ± 6.31 (13.00–46.75)	0.202 ± 0.046 (0.110–0.319)	2.000 ± 0.557 (0.850–3.877)	0.409 ± 0.076 (0.226–0.639)	66 ± 15 (27–107)	50.49 ± 15.19 (20.41–95.67)	1.08 ± 0.18 (0.57–1.69)	5.71 ± 0.15 (5.38–6.17)
3	2.32 ± 0.46 (1.10–3.80)	16.13 ± 1.74 (10.93–21.09)	12.49 ± 4.44 (1.59–23.30)	9.14 ± 0.63 (8.14–11.26)	7.84 ± 0.11 (7.44–8.12)	25.91 ± 5.15 (16.75–45.71)	0.162 ± 0.036 (0.062–0.245)	1.576 ± 0.335 (0.839–2.554)	0.355 ± 0.049 (0.243–0.477)	81 ± 13 (48–103)	64.19 ± 11.75 (35.71–97.58)	1.29 ± 0.17 (0.81–1.86)	5.80 ± 0.14 (5.56–6.23)
4	2.12 ± 0.40 (1.10–3.10)	16.41 ± 1.88 (10.76–21.28)	10.05 ± 4.00 (0.40–20.70)	9.37 ± 0.57 (8.25–11.18)	7.85 ± 0.12 (7.45–8.21)	26.56 ± 5.82 (9.46–45.78)	0.146 ± 0.032 (0.038 –0.222)	1.746 ± 0.854 (0.472–5.115)	0.320 ± 0.049 (0.205–0.455)	96 ± 17 (32–128)	69.79 ± 10.52 (41.35–100.22)	1.63 ± 0.23 (0.92–2.38)	5.82 ± 0.15 (5.53–6.27)
5	1.58 ± 0.34 (**1.00**–2.90)	16.63 ± 2.00 (10.52–21.33)	7.08 ± 3.09 (0.05–15.90)	9.38 ± 0.60 (8.15–11.31)	7.79 ± 0.12 (7.46–8.12)	25.81 ± 3.56 (15.71 − 35.61)	0.118 ± 0.024 (0.046–0.182)	1.176 ± 0.614 (0.248–3.563)	0.287 ± 0.048 (0.138–0.425)	117 ± 38 (60–262)	78.01 ± 7.84 (53.31–100.59)	2.52 ± 0.52 (0.66–3.54)	5.96 ± 0.14 (5.63–6.33)
6	1.60 ± 0.39 (**0.80**–3.10)	16.79 ± 2.05 (10.50–21.42)	5.60 ± 2.53 (0.03–13.40)	9.39 ± 0.58 (8.23–11.23)	7.52 ± 0.14 (7.09–7.90)	35.72 ± 4.16 (27.63–51.37)	0.139 ± 0.024 (0.046–0.174)	0.565 ± 0.167 (0.141–0.968)	0.238 ± 0.062 (0.074–0.439)	208 ± 70 (102–483)	82.90 ± 6.91 (59.60–101.79)	3.39 ± 0.77 (0.75–5.06)	6.06 ± 0.12 (5.61–6.26)
7	1.30 ± 0.08 (**1.10–1.50**)	16.99 ± 2.11 (10.54–21.41)	4.56 ± 2.01 (0.02–10.30)	9.58 ± 0.57 (8.19–11.34)	7.30 ± 0.14 (6.97–7.67)	30.98 ± 4.55 (19.93–47.56)	0.108 ± 0.021 (0.038–0.158)	0.536 ± 0.206 (0.018–1.243)	0.249 ± 0.060 (0.106–0.462)	152 ± 36 (71–283)	83.76 ± 5.23 (66.80–99.55)	3.79 ± 1.19 (0.74–6.67)	6.04 ± 0.14 (5.50–6.26)
8	1.18 ± 0.17 (**0.60–1.60**)	17.08 ± 2.15 (10.50–21.10)	2.50 ± 1.10 (0.00–5.60)	9.76 ± 0.59 (8.35–11.63)	7.39 ± 0.15 (6.90–7.71)	33.98 ± 4.64 (24.87–49.91)	0.126 ± 0.012 (0.094 − 0.157)	0.916 ± 0.355 (0.077–2.047)	0.253 ± 0.058 (0.150–0.477)	154 ± 29 (108–265)	91.67 ± 4.48 (80.57–105.41)	5.13 ± 2.63 (0.59–15.24)	5.97 ± 0.10 (5.59–6.14)
9	2.02 ± 0.25 (**1.30**–2.70)	17.13 ± 2.19 (10.58–22.20)	0.30 ± 0.16 (0.00–0.70)	9.72 ± 0.52 (8.65–11.63)	7.29 ± 0.24 (6.68–8.05)	41.05 ± 4.11 (26.51–50.60)	0.116 ± 0.020 (0.038–0.149)	0.867 ± 0.343 (0.306–2.068)	0.234 ± 0.055 (0.106–0.431)	227 ± 70 (105–499)	97.89 ± 5.73 (79.68 − 115.55)	8.53 ± 3.25 (0.66–16.50	5.93 ± 0.08 (5.63–6.12)
10	1.11 ± 0.348 (**0.35–2.50**)	19.60 ± 2.11 (13.74–23.30)	0.46 ± 0.38 (0.00–1.60)	9.27 ± 0.43 (8.21–10.07)	7.17 ± 0.21 (6.66–7.51)	41.61 ± 6.01 (24.35–51.83)	0.122 ± 0.031 (0.046–0.189)	1.912 ± 0.462 (0.940–3.164)	0.212 ± 0.031 (0.138–0.286)	227 ± 59 (114–391)	99.36 ± 6.63 (87.64–118.35)	7.11 ± 3.43 (1.22–17.04)	5.99 ± 0.04 (5.90–6.09)
11	0.38 ± 0.02 (**0.35–0.40)**	21.44 ± 0.89 (20.02–23.08)	0.04 ± 0.03 (0.00–0.10)	9.32 ± 0.53 (8.72–10.38)	7.24 ± 0.14 (6.98–7.45)	46.44 ± 2.97 (41.54–51.81)	0.139 ± 0.030 (0.108–0.198)	2.225 ± 0.786 (1.160–3.758)	0.160 ± 0.035 (0.106–0.224)	339 ± 87 (222–508)	105.35 ± 8.23 (95.45v 121.69)	6.80 ± 1.70 (3.88–9.78)	6.07 ± 0.01 (6.06–6.08)

Table S2. Mean concentrations ± SE for key environmental parameters measured at middle depth of the sampling sites: temperature—°C; salinity; dissolved oxygen (DO)—mg O_2 L^{-1}; pH; NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, N:P, and Si—µM; chlorophyll *a* (CHL *a*)—mg m^{-3}; total cell counts (TCC)—log_{10} cells mL^{-1}. In brackets—minimum and maximum values.

Site	T	Salinity	DO	pH	NO_3^-	NO_2^-	NH_4^+	PO_4^{3-}	N:P	Si	CHL *a*	TCC
1	15.48 ± 1.47 (11.24–20.32)	23.43 ± 4.36 (8.99–33.20)	8.44 ± 0.52 (7.65–10.51)	7.59 ± 0.22 (6.73–7.90)	17.62 ± 7.54 (6.32–47.02)	0.224 ± 0.047 (0.084–0.333)	1.768 ± 0.587 (0.425–3.639)	0.438 ± 0.079 (0.180–0.593)	47 ± 15 (18–98)	38.21–16.74 (10.35 –97.65)	1.56 ± 0.35 (0.66–2.75)	5.72 ± 0.12 (5.40–6.12)
2	15.45–1.49 (11.24 - 20.28)	23.29 ± 4.34 (8.99–32.60)	8.35 ± 0.55 (7.52–10.51)	7.59 ± 0.22 (6.73–7.89)	18.84 ± 7.16 (9.44–47.02)	0.234 ± 0.043 (0.124–0.340)	1.842 ± 0.369 (0.979–2.758)	0.452 ± 0.052 (0.336–0.624)	47 ± 14 (20–98)	39.99 ± 16.14 (12.69–97.65)	1.75 ± 0.49 (0.66–3.54)	5.74 ± 0.14 (5.40–6.14)
3	15.30 ± 1.53 (11.00–20.35)	16.37 ± 5.66 (1.91–28.40)	8.80 ± 0.71 (7.31–11.11)	7.68 ± 0.12 (7.21–7.89)	22.37 ± 5.87 (11.75–43.98)	0.192 ± 0.047 (0.086–0.319)	1.609 ± 0.357 (0.944–2.975)	0.410 ± 0.073 (0.228–0.587)	70 ± 20 (23–116)	52.54 ± 15.62 (15.97–96.75)	1.97 ± 0.38 (0.83–3.09)	5.86 ± 0.14 (5.56–6.26)
4	15.62 ± 1.67 (10.83–20.70)	13.65 ± 5.55 (0.90–26.20)	9.00 ± 0.68 (7.66–11.13)	7.65 ± 0.10 (7.26–7.87)	24.63 ± 5.71 (7.57–43.32)	0.167 ± 0.037 (0.054–0.269)	2.024 ± 1.139 (0.551–6.533)	0.338 ± 0.073 (0.202–0.593)	94 ± 19 (24–132)	65.37 ± 13.10 (28.21–100.15)	2.64 ± 0.52 (0.91–3.95)	5.87 ± 0.16 (5.56–6.29)
5	16.57 ± 1.97 (10.54–21.33)	7.22 ± 3.16 (0.05–16.40)	9.32 ± 0.60 (8.02–11.22)	7.61 ± 0.14 (7.18–7.87)	34.09 ± 4.23 (23.11–49.13)	0.146 ± 0.029 (0.038–0.206)	1.220 ± 0.560 (0.321–3.390)	0.293 ± 0.055 (0.154–0.477)	136 ± 26 (77–230)	76.98 ± 7.93 (52.27–100.25)	2.73 ± 0.59 (0.74–3.90)	6.02 ± 0.15 (5.66–6.35)
6	16.81 ± 2.05 (10.50–21.41)	5.89 ± 2.63 (0.04–13.85)	9.44 ± 0.57 (8.19–11.23)	7.43 ± 0.12 (7.06–7.73)	34.71 ± 4.19 (28.71–51.24)	0.134 ± 0.022 (0.054–0.182)	0.639 ± 0.168 (0.139–1.198)	0.253 ± 0.064 (0.106–0.473)	171 ± 38 (98–314)	83.02 ± 7.40 (58.04–103.23)	3.55 ± 0.81 (0.75–4.79)	6.05 ± 0.12 (5.61–6.27)
7	16.98 ± 2.11 (10.54–21.41)	4.59 ± 2.02 (0.02–10.40)	9.56 ± 0.58 (8.18–11.33)	7.27 ± 0.15 (6.91–7.64)	32.64 ± 3.96 (26.05–47.92)	0.116 ± 0.020 (0.038–0.149)	0.535 ± 0.182 (0.156–1.161)	0.244 ± 0.064 (0.106–0.477)	166 ± 38 (99–306)	83.61 ± 5.36 (66.18–99.87)	3.93 ± 1.15 (0.70–6.85)	6.05 ± 0.12 (5.56–6.26)
8	17.00 ± 2.12 (10.50–21.11)	2.88 ± 1.39 (0.00–7.45)	9.75 ± 0.60 (8.30–11.58)	7.30 ± 0.15 (6.84–7.64)	34.89 ± 4.22 (26.67–49.85)	0.130 ± 0.018 (0.066–0.162)	0.915 ± 0.350 (0.048–2.137)	0.245 ± 0.067 (0.142–0.507)	187 ± 43 (101–311)	91.36 ± 5.54 (75.67–108.11)	5.76 ± 2.64 (0.62–15.47)	5.99 ± 0.10 (5.62–6.15)
9	16.98 ± 2.11 (13.74–23.30)	0.70 ± 0.41 (0.00–2.20)	9.58 ± 0.58 (8.10–11.41)	7.07 ± 0.16 (6.58–7.52)	36.39 ± 4.63 (25.25–50.16)	0.092 ± 0.016 (0.054–0.133)	1.066 ± 0.358 (0.105–1.937)	0.186 ± 0.021 (0.135–0.235)	207 ± 23 (146–289)	97.51 ± 5.23 (80.80–113.07)	8.57 ± 3.23 (0.57–15.07)	5.91 ± 0.09 (5.65–6.13)
10	19.60 ± 2.11 (13.74–23.30)	0.436 ± 0.39 (0.00–1.60)	9.22 ± 0.44 (8.21–10.07)	7.15 ± 0.20 (6.66–7.51)	36.60 ± 6.62 (24.35–51.83)	0.112 ± 0.034 (0.046–0.189)	1.933 ± 0.482 (0.940–3.249)	0.223 ± 0.041 (0.138–0.332)	206 ± 68 (91–391)	99.54 ± 6.61 (87.64–118.35)	7.11 ± 3.43 (1.22–17.04)	6.01 ± 0.04 (5.90–6.09)
11	21.44 ± 0.89 (20.02–23.08)	0.04 ± 0.03 (0.00–0.10)	9.32 ± 0.53 (8.72–10.38)	7.24 ± 0.14 (6.98–7.45)	46.44 ± 2.97 (41.54–51.81)	0.139 ± 0.030 (0.108–0.198)	2.225 ± 0.786 (1.160–3.758)	0.160 ± 0.035 (0.106–0.224)	339 ± 87 (222–508)	105.35 ± 8.23 (95.45–121.69)	6.80 ± 1.70 (3.88–9.78)	6.07 ± 0.01 (6.06.08)

Table S3. Mean concentrations ± SE for key environmental parameters measured near bottom of the sampling sites: temperature—°C; salinity; dissolved oxygen (DO)—mg O_2 L^{-1}; pH; NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, N:P, and Si—μM; chlorophyll *a* (CHL *a*)—mg m^{-3}; total cell counts (TCC)—log_{10} cells mL^{-1}. In brackets—minimum and maximum values.

Site	T	Salinity	DO	pH	NO_3^-	NO_2^-	NH_4^+	PO_4^{3-}	N:P	Si	CHL *a*	TCC
1	15.48 ± 1.19 (12.56–19.13)	30.32 ± 1.69 (26.00–30.90)	8.02 ± 0.37 (7.28–9.24)	7.76 ± 0.16 (7.20–8.14)	9.37 ± 3.27 (1.10–21.07)	0.233–0.045 (0.060–0.317)	1.613 ± 0.629 (0.000–3.428)	0.394 ± 0.073 (0.165–0.593)	28 ± 9 (7–55)	17.57 ± 7.38 (2.25–41.33)	2.33 ± 0.66 (1.14–4.87)	5.79 ± 0.10 (5.55–6.13)
2	15.61 ± 1.33 (12.56–19.87)	30.06 ± 1.56 (26.00–33.70)	7.95 ± 0.35 (7.25–9.24)	7.76 ± 0.16 (7.20–8.14)	9.86 ± 3.09 (2.23–21.07)	0.240 ± 0.048 (0.060–0.343)	1.881 ± 0.528 (0.830–3.536)	0.466 ± 0.087 (0.272–0.731)	28 ± 8 (12–55)	18.18 ± 7.12 (4.82–41.33)	2.05 ± 0.34 (1.47–3.37)	5.79 ± 0.11 (5.55–6.07)
3	14.89 ± 1.49 (11.20–20.06)	23.83 ± 4.21 (11.66–32.20)	8.49 ± 0.61 (7.18–10.36)	7.61 ± 0.20 (6.88–7.93)	16.14 ± 5.38 (5.96–36.39)	0.226 ± 0.050 (0.076–0.340)	2.005 ± 0.446 (1.124–3.652)	0.457 ± 0.064 (0.257–0.639)	40 ± 10 (22–75)	37.91 ± 14.90 (12.61–89.83)	2.22 ± 0.54 (0.91–4.16)	5.84 ± 0.14 (5.52–6.21)
4	15.02 ± 1.58 (10.89–20.48)	19.61 ± 5.39 (1.45–31.10)	8.69 ± 0.74 (7.32–11.08)	7.57 ± 0.15 (7.17–7.88)	19.81 ± 7.94 (4.70–50.22)	0.205 ± 0.035 (0.132–0.287)	2.592 ± 0.834 (1.368–5.895)	0.426 ± 0.068 (0.272–0.654)	58 ± 18 (17–116)	46.35 ± 15.02 (16.63–99.82)	3.04 ± 0.53 (1.00–3.83)	5.91 ± 0.14 (5.63–6.30)
5	16.44 ± 1.93 (10.54–21.33)	7.33 ± 3.20 (0.056–16.70)	9.35 ± 0.59 (8.154–11.19)	7.55 ± 0.14 (7.10–7.81)	31.12 ± 4.16 (21.86–45.60)	0.133 ± 0.023 (0.046–0.174)	0.655 ± 0.122 (0.321–1.042)	0.298 ± 0.073 (0.122–0.552)	126 ± 24 (65–203)	76.32 ± 7.75 (52.31–97.73)	3.14 ± 0.79 (0.75–4.86)	6.01 ± 0.15 (5.63–6.35)
6	16.77 ± 2.04 (10.50–21.40)	6.11 ± 2.73 (0.04–14.30)	9.43 ± 0.58 (8.15–11.22)	7.37 ± 0.13 (7.03–7.72)	34.77 ± 4.24 (28.74–51.11)	0.145 ± 0.022 (0.062–0.190)	0.558 ± 0.236 (0.080–1.427)	0.258 ± 0.073 (0.090–0.507)	185 ± 56 (93–394)	82.64 ± 7.91 (56.49–104.67)	3.92 ± 0.95 (0.74–5.57)	6.04 ± 0.12 (5.62–6.28)
7	16.97 ± 2.11 (10.54–21.40)	4.62 ± 2.04 (0.02–10.50)	9.54 ± 0.58 (8.16–11.31)	7.23 ± 0.15 (6.85–7.61)	34.30 ± 3.69 (27.60–48.27)	0.124 ± 0.022 (0.038–0.158)	0.534 ± 0.163 (0.139–1.078)	0.240 ± 0.068 (0.106–0.492)	180 ± 41 (101–330)	83.46 ± 5.50 (65.57–100.19)	4.08 ± 1.15 (0.66–7.02)	6.05 ± 0.12 (5.62–6.28)
8	16.93 ± 2.09 (10.50–21.12)	3.25 ± 1.70 (0.00–9.30)	9.74 ± 0.61 (8.24–11.52)	7.21 ± 0.15 (6.77–7.56)	35.80 ± 4.18 (26.71–49.79)	0.134 ± 0.026 (0.038–0.198)	0.915 ± 0.407 (0.018–2.227)	0.236 ± 0.079 (0.090–0.537)	219 ± 69 (94–469)	91.04 ± 6.66 (70.77–110.81)	6.40 ± 2.68 (0.66–15.69)	6.00 ± 0.09 (5.65–6.16)
9	16.09 ± 1.80 (10.54–20.68)	6.79 ± 3.90 (0.00–16.70)	9.13 ± 0.72 (7.33–11.40)	7.07 ± 0.21 (6.50–7.65)	33.28 ± 5.12 (22.53–48.03)	0.138 ± 0.026 (0.038–0.174)	1.065 ± 0.375 (0.141–2.161)	0.223 ± 0.051 (0.090–0.348)	192 ± 47 (70–312)	80.00 ± 9.07 (53.43–102.31)	8.28 ± 3.54 (0.74–17.24)	5.98 ± 0.09 (5.63 – 6.14)
10	19.62 ± 2.11 (13.74–23.30)	0.43 ± 0.39 (0.00–1.60)	9.20 ± 0.435 (8.21–10.07)	7.12 ± 0.19 (6.66–7.51)	40.99 ± 5.86 (24.35–51.83)	0.126 ± 0.030 (0.046–0.189)	1.895 ± 0.448 (0.940–3.098)	0.196 ± 0.021 (0.138–0.228)	236 ± 57 (114–391)	99.31 ± 6.63 (87.64–118.35)	6.81 ± 3.50 (1.22–17.04)	6.01 ± 0.04 (5.90–6.09)
11	21.44 ± 0.89 (20.02–23.08)	0.04 ± 0.03 (0.00 –0.10)	9.32 ± 0.53 (8.72–10.38)	7.24 ± 0.14 (6.98–7.45)	46.44 ± 2.97 (41.54–51.81)	0.139 ± 0.030 (0.108–0.198)	2.225 ± 0.786 (1.160–3.758)	0.160 ± 0.035 (0.106–0.224)	339 ± 87 (222–508)	105.35 ± 8.23 (95.45–121.69)	6.80 ± 1.70 (3.88–9.78)	6.07 ± 0.01 (6.06–6.08)

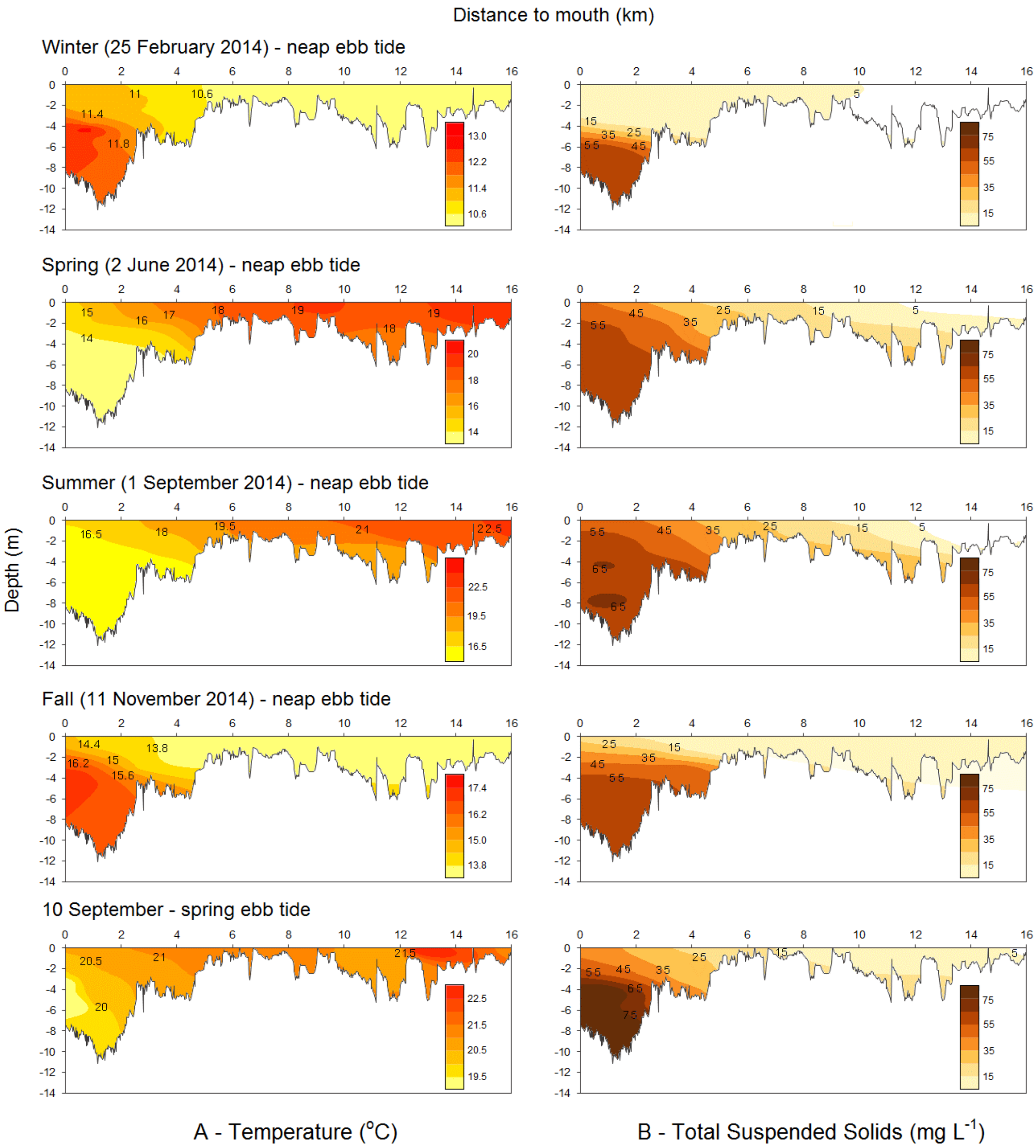

Figure S1. Longitudinal profiles of temperature and total suspended solids in the temperate Lima estuary.

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