Multi-proxy indicators in a Pontocaspian system: a depth transect of surface sediment in the SE Caspian Sea

Supplementary materials

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ABSTRACT. The response of large water-bodies to global change in terms of ecosystem services and economical value is a major concern. The Caspian Sea, the world's largest enclosed water-body, has a poorly-known water-level history, but observed changes are a hundred times faster than recent global sea-level rise. This ancient lake, characterised by brackish waters, is rich in endemic species; some of them have spread to similar environments worldwide. However, the ecology of Pontocaspian species remains poorly understood and must be studied in their original habitat.

This work aims at improving the capacity to reconstruct Quaternary environments of the Pontocaspian region and to provide a benchmark for biodiversity turnover studies. A transect of surface sediment across a wide shelf was subjected to multidisciplinary analyses: stable isotopes, pollen, dinocysts, diatoms, foraminifers, ostracods and molluscs and vertical oceanographic profiles.

Three depositional environments with characteristic communities were found: shore face, shelf and slope. Invasion impact was strongly felt by the molluscs. All biota groups, except diatoms, reflected high endemism. The radiocarbon reservoir effect is highlighted in differential ^{14}C ages for different groups. Understanding such discrepancies require detailed insight into reworking processes. Tephra presence in the sediment shows a potential for tephrochronology. Stable isotope ratios in ostracods appear to reflect temperature depth gradients. Our results provide a baseline for calibrating proxy data to the present Pontocaspian environment.

For the full text, see: https://doi.org/10.20341/gb.2018.008.

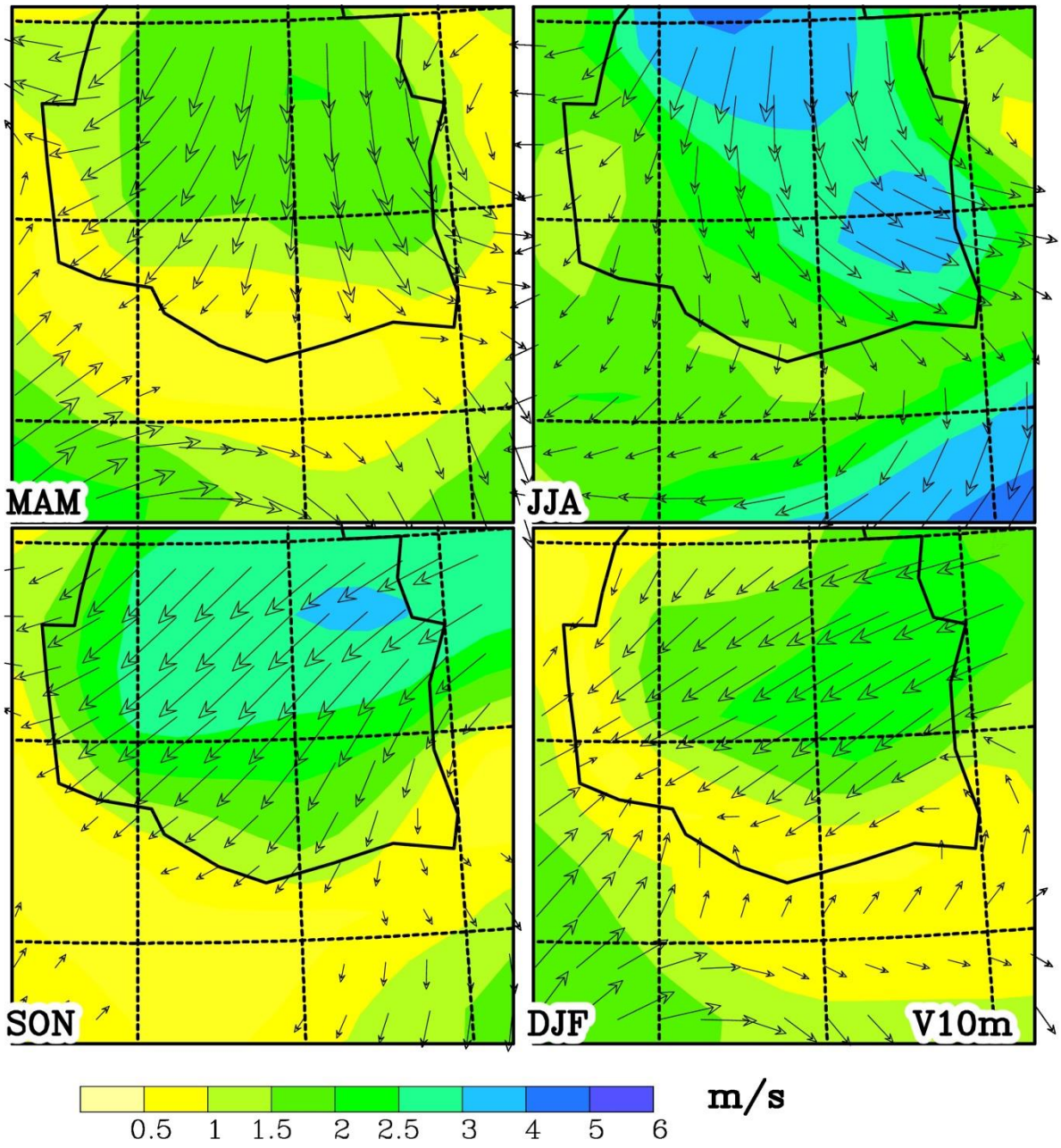

Figure SI 1. Wind for the southern Caspian Sea (thick black line) at 10 m, based on ECMWF interim reanalysis data. Analyses: K. Arpe. Arrows show the direction and arrow length is proportional to the speed; the latter is shown as well by contours. The speed has been calculated by averaging the zonal and meridional components. MAM: March-April-May, JJA: June-July-August, SON: September-October-November, DJF: December, January, February.

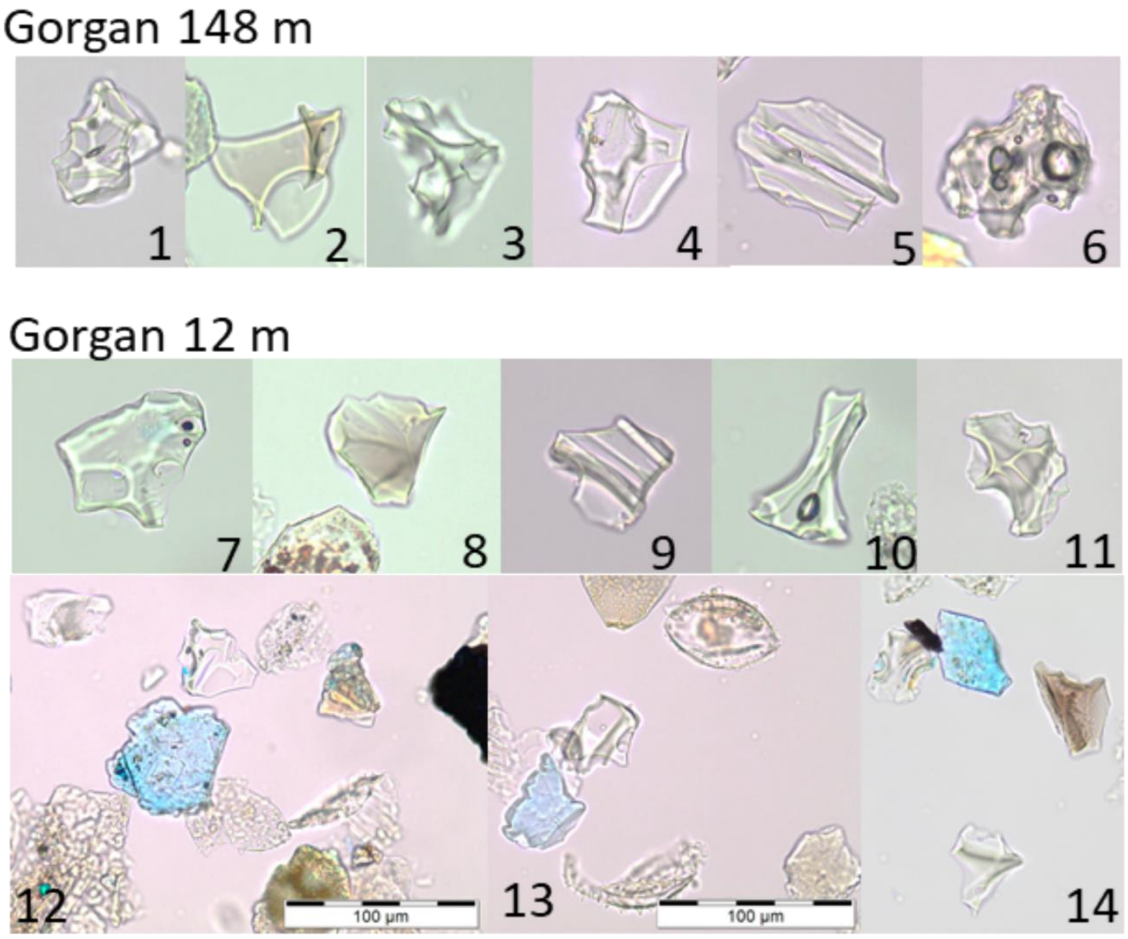

Figure SI 2. Tephra shards from surface sediment samples at 148 m (no 1–6) and 12 m (no 7–14). Colours due the use of a microscope with plane-polarised light.

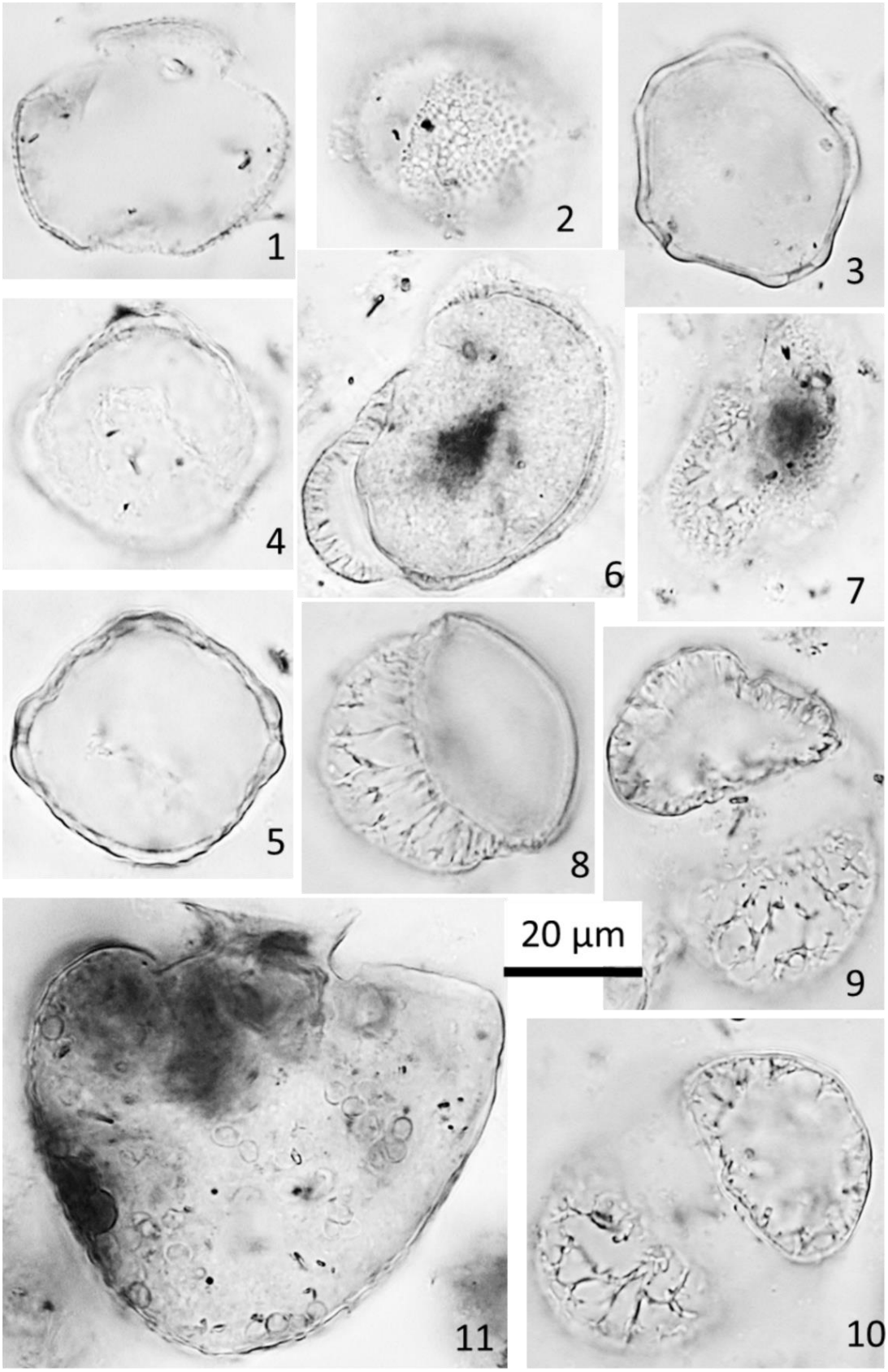

Figure SI 3. Pollen and foraminifer. 1-2: *Parrotia persica* (1: NaharKoran1; 2: Gorgan 2 m); 3: *Pterocarya*, Gorgan 221 m; 4-5: *Ulmus-Zelkova*, *Zelkova* type, Gorgan 2 m; 6-10: *Pinus*, *P. eldarica* type (6-7: core Shirshov 7 at 206 cm; 8-9-10: Gorgan 13 m); 11: inner organic lining of a foraminifer chamber, Gorgan 9 m. Olympus BX50 1000x. Scale bar for 20 µm.

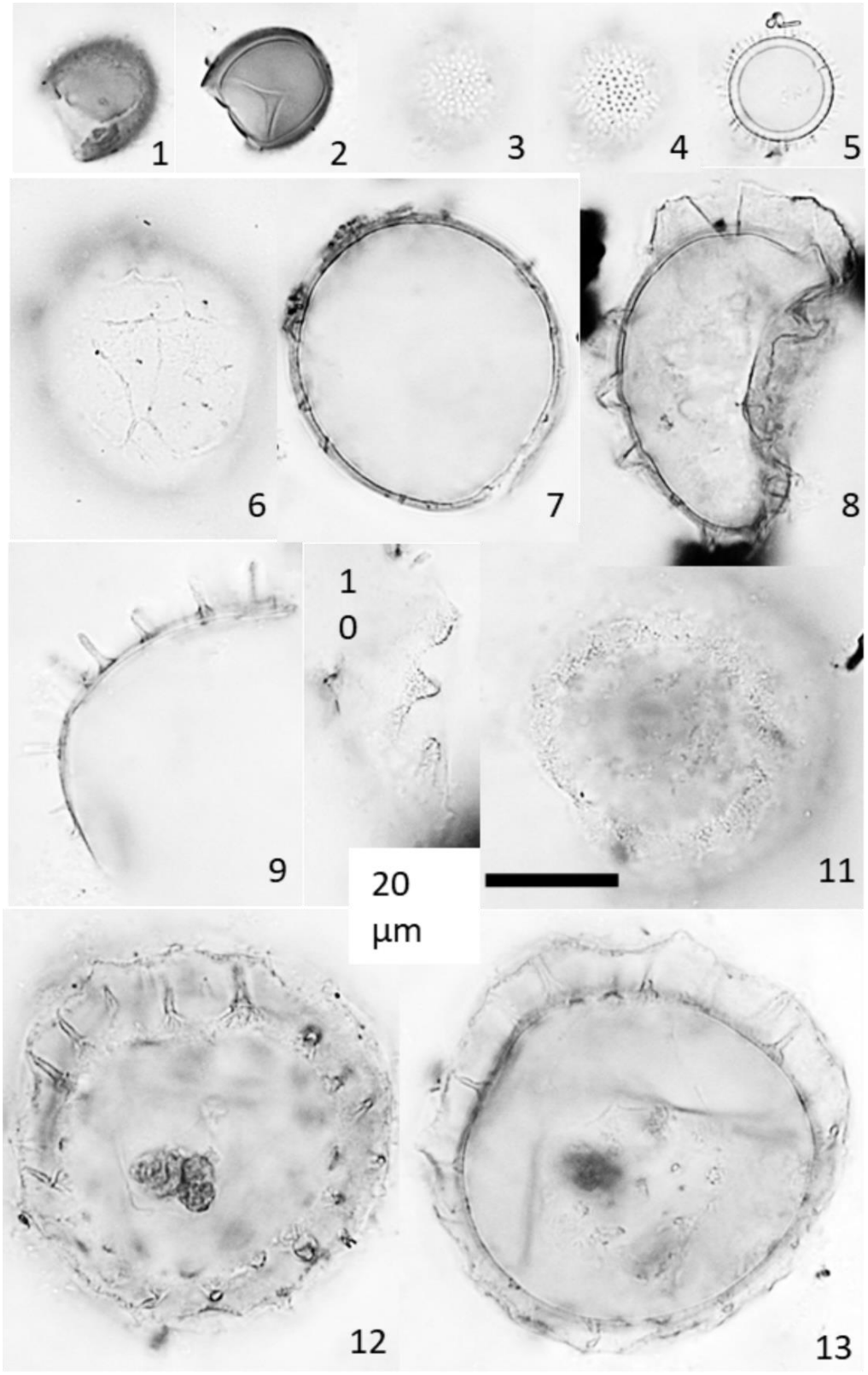

Figure SI 4. Non-pollen palynomorphs and dinocysts. 1-2: *Anabaena* with sheath, Gorgan 221 m; 3-5: Incertae sedis 5b (probably green algae), Gorgan 221 m; 6-8: *Impagidinium caspienense* cyst (6-7: short septa, core NSM3 at 210 cm; 8: large septa, Gorgan 2 m); 9-13: *Lingulodinium machaerophorum* cyst (9: long processes, Gorgan 10 m; 10: acuminate processes, Gorgan 10 m; 11: cerebrate, Gorgan 2 m; 12 and 13: with membrane, Gorgan 9 m). Olympus BX50 1000x. Scale bar for 20 µm.

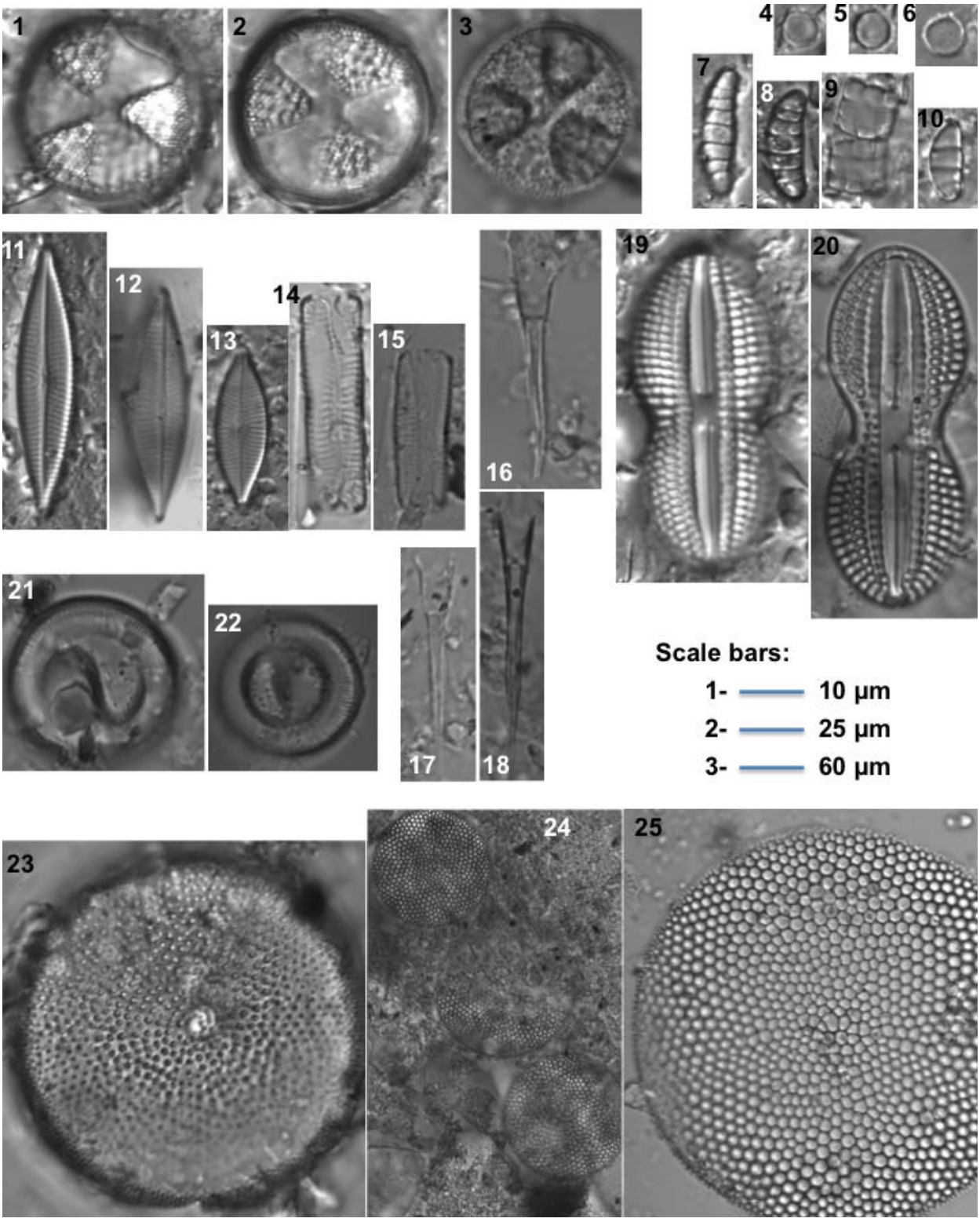

Figure SI 5. Diatoms. Otherwise stated, specimens are shown in valve view, and at the scale indicated by scale bar 1. 1-3: *Actinoptychus senarius* (Ehrenberg) Ehrenberg 1843 – 1 & 2: 2 m; 3: 5 m. 4-6: *Skeletonema* spp. Greville 1865 –2 m. 7-10: *Eunotogramma* spp. J.F.Weisse, 1855 - 2 m – N° 9 in girdle view. 11-15: *Navicula* sp.1 – 5 m. – N° 14-15 in girdle view. 16-18: *Pseudosolenia calcar avis* (Schultze) B.G. Sundström 1986 – 16 and 17: 148 m; 18: 200 m. 19-20: *Diploneis bombus* (Ehrenberg) Ehrenberg 1853 –13 m. 21-22: *Cyclotella caspia* Grunow 1878 - 221 m. 23: *Actinocyclus ehrenbergii* Ralfs in Pritchard 1861 – 200 m. Scale bar 2. 24-25: *Coscinodiscus argus* Ehrenberg 1839 – 24: scale bar 3; 25: scale bar 2 - 200 m.

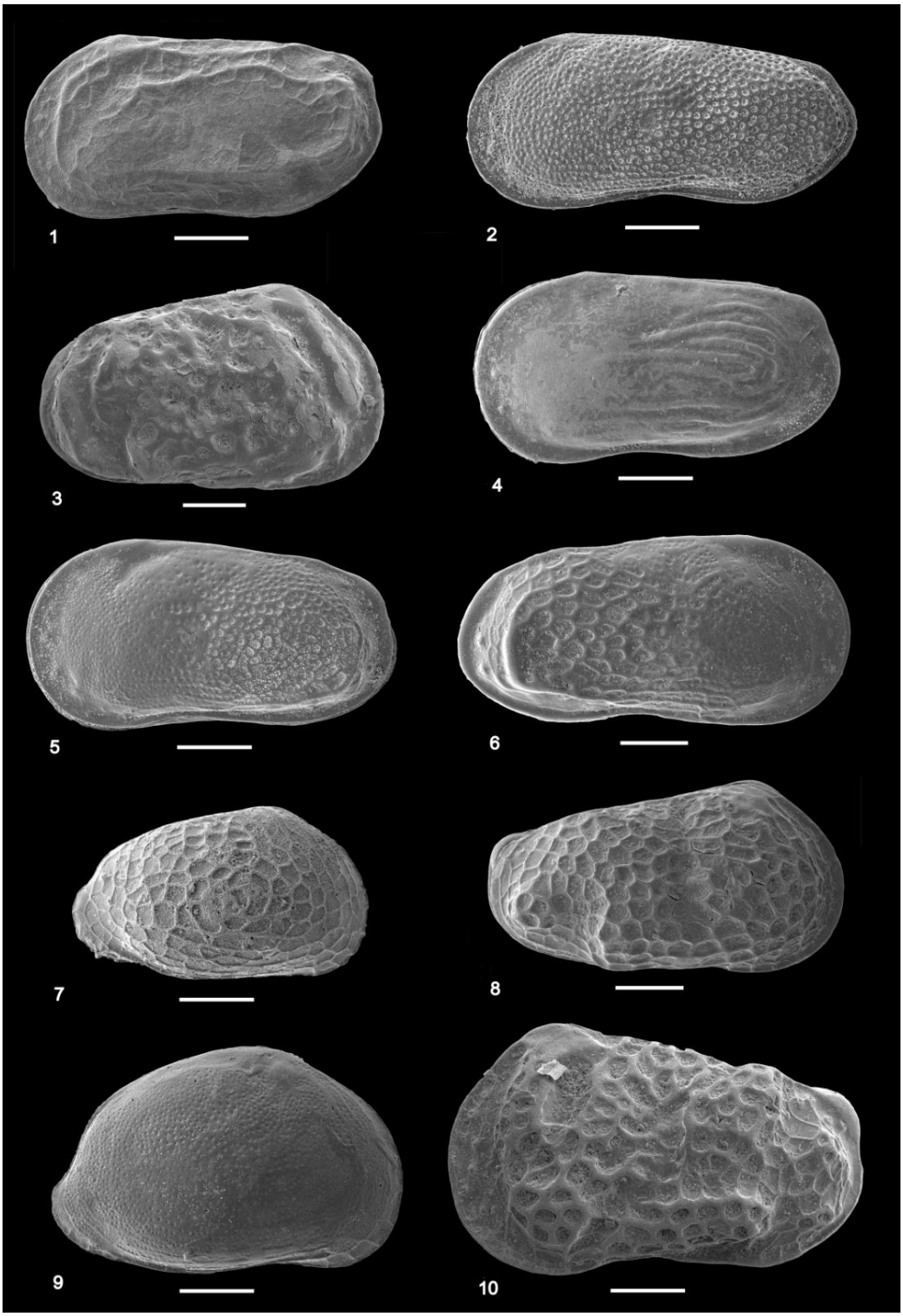

Figure SI 6A. Ostracods. 1 – *Amnicythere caspia* (Livental, 1930) *nomen nudum*. Carapace, left view. 5 m. 2 – *Amnicythere pediformis* (Schornikov, 1966). Carapace, left view. 46 m. 3 – *Callistocythere lopatici (*Schornikov,1964). Right valve. 5 m. 4 – *Amnicythere striatocostata* (Schweyer, 1949). Carapace, left view. 10 m. 5 – *Amnicythere* sp.1 Boomer, 2005 (finely reticulate) Carapace, left view. 46 m. 6 – *Amnicythere* sp.1 Boomer, 2005 (coarsely reticulate). Right valve. 221 m 7 – *Tyrrhenocythere azerbaijanica* (Livental, 1937) *fide* Agalarova *et al.*, 1961. Right valve. 12 m. 8 – *Amnicythere* cf. *olivina* (Livental, 1938). Carapace, right view. 5 m. 9 – *Tyrrhenocythere amnicola* (Sars, 1888). Right valve. 5 m. 10 – *Amnicythere multituberculata* (Livental, 1929). Left valve. 5 m.
Images - Jeol JSM-6480LV Scanning Electron Microscope. All scale bars = 100 μm.

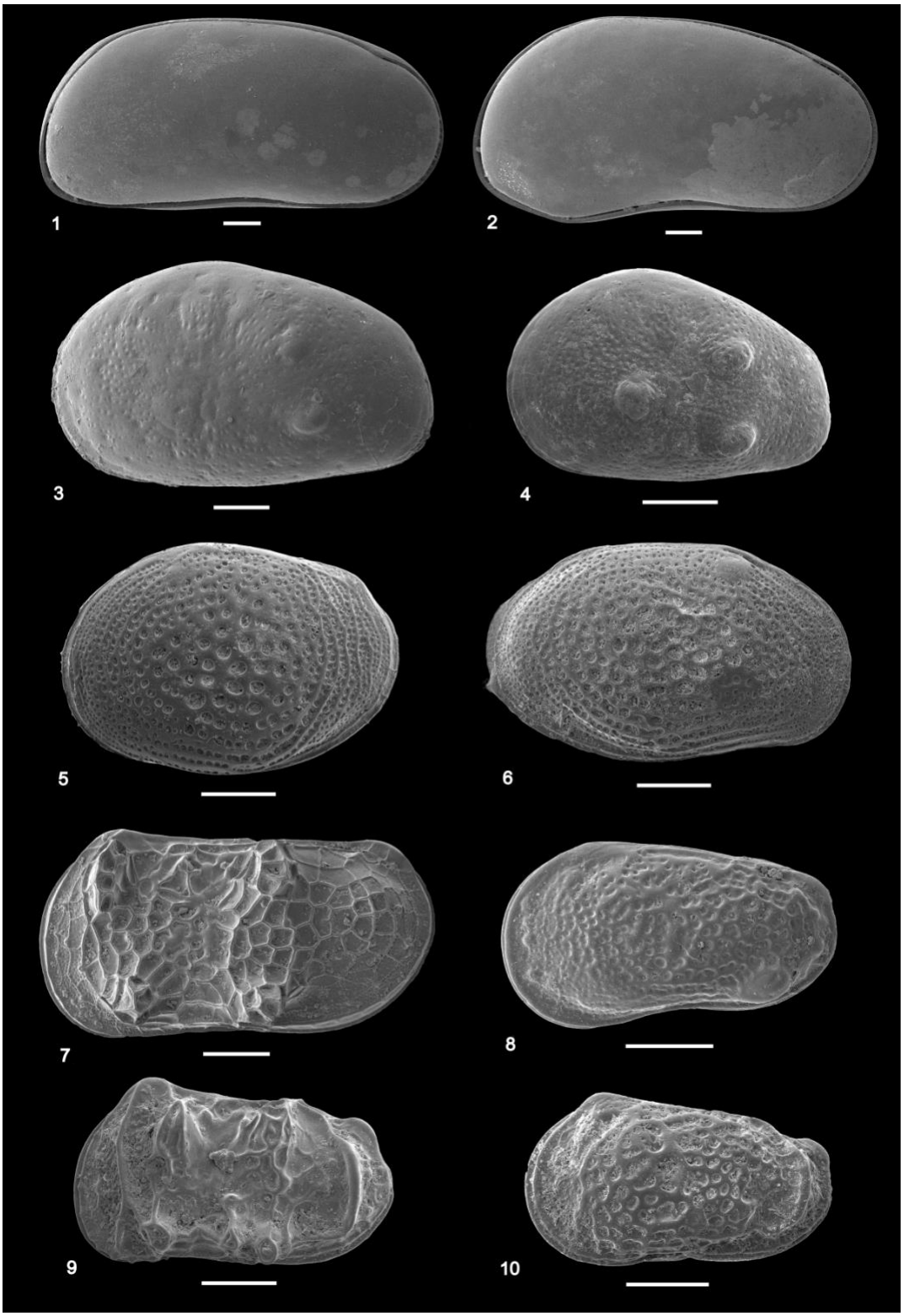

Figure SI 6B. Ostracods. 1 – *Candona* sp. [?= *C. elongata* (Schweyer, 1949)]. Carapace, right view. 221 m. 2 – *Candona* sp. [cf. *C. angulata meridionalis* (Petkovski, 1958)]. Carapace, right view. 221 m. 3 – *Cyprideis torosa* (Jones, 1850). Carapace, left view showing two incipient nodes. 5 m. 4 – *Cyprideis torosa* (Jones, 1850). Left valve juvenile with three nodes. 5 m. 5 – *Loxoconcha* sp. 1 Boomer, 2010. Left valve. 200 m. 6 – *Loxoconcha lepida* Stepanaitys, 1962. Right valve. 92 m. 7 – *Amnicythere quinquetuberculata* (Schweyer, 1949). Left valve. 200 m 8 – *Euxinocythere relicta* (Schornikov, 1964) n.comb. Carapace, left view. 200 m. 9 – *Euxinocythere bacuana* (Livental, 1929). Carapace, left view. 200 m. 10 – *Callistocythere cellula* (Livental, 1929). Carapace, left view. 46 m.
Images - Jeol JSM-6480LV Scanning Electron Microscope. All scale bars = 100 μm.

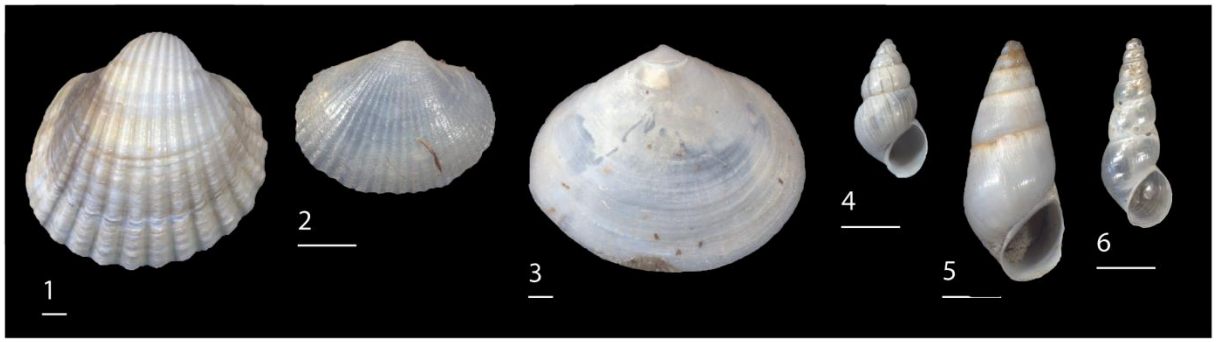

Figure SI 7. Molluscs. 1- *Cerastoderma glaucum* (Bruguière, 1789), an Early Holocene immigrant that became very abundant throughout the Caspian Sea in the 20th century. 10 m. 2- *Monodacna edentula* (Pallas, 18771) s.l., a Caspian endemic. 5 m. 3- *Abra segmentum* (Récluz, 1843), a 20th century immigrant species. 5 m. 4- *Ecrobia grimmi* (Clessin & Dybowski, 1888), an Early Holocene immigrant that became very abundant throughout the Caspian Sea in the 20th century. 5 m. 5- *Turricaspia lincta* (Milaschewitch 1908) s.l., a Caspian endemic. 92 m. 6- *Turricaspia spica* (Eichwald, 1855) s.l., a Pontocaspian endemic. 5 m.

Table SI 1. Sampling locations with latitudes and longitudes, and sampling techniques.

Transect part	St No.	Maximal sampling depth	Date	Time (Local)	Longitude E		Latitude N		CTD	Sediment sampling with	
		m	dd/MM/YYYY	h:min	°	′	°	′		*Grab*	*Core*
A	**1**	2	09/02/2014	12:52	53	59.735	36	57.666	√	√	-
	2	5	09/02/2014	13:02	53	56.441	36	57.799	√	√	-
	3	7	09/02/2014	13:12	53	54.092	36	58.181	√	√	-
	3B	8	09/02/2014	13:20	53	51.636	36	58.564	√	-	-
	4	9	09/02/2014	13:24	53	49.208	36	58.892	√	√	-
	5	10	09/02/2014	13:37	53	46.797	36	59.106	√	√	-
	6	12	09/02/2014	13:59	53	44.414	36	59.377	√	√	-
	7	13	09/02/2014	14:23	53	41.057	36	59.769	√	√	-
B	**13**	25	10/02/2014	16:51	53	15.428	36	57.050	√	√	-
	12	46	10/02/2014	15:54	53	12.446	36	58.285	√	-	√
	11	92	10/02/2014	15:24	53	10.480	36	59.013	√	-	√
	10	148	10/02/2014	14:30	53	8.876	36	59.738	√	-	√
	9	200	10/02/2014	13:43	53	6.011	36	59.480	√	-	√
	8	221	10/02/2014	12:47	53	4.928	37	0.222	√	-	√

Table SI 2. Standard sensor specifications – OCEAN SEVEN 316 plus CTD.

Parameter	Range and unit	Accuracy	Resolution	Time Constant
Pressure	0 … 1000 dbar	0.05 % full scale	0.03 %	50 ms
Chlorophyll-*a*	0 … 150 µg/L	Sensitivity for Gain 30X: 1 V/(µg/L) Accuracy: 0.5 mv	0.076 mv	0.1 s
Temperature	-3 … +50 ºC	0.003 ºC	0.0005 ºC	50 ms
Conductivity	0 … 64 mS/cm	0.003 mS/cm	0.001 mS/cm	50 ms
pH	0 … 14 pH	0.01 pH	0.001 pH	3 s
Dissolved oxygen	0 … 50 ppm	0.1 ppm	0.01 ppm	3 s
Turbidity	0 … > 750 FTU	5 FTU	0.5 FTU	0.1 s
	0 … > 500 FTU	1 FTU	0.1 FTU	0.1 s
	0 … > 125 FTU	0.5 FTU	0.025 FTU	0.1 s
	0 … > 25 FTU	0.1 FTU	0.005 FTU	0.1 s

Table SI 3. Remotely sensed Chl-a data and surface temperatures (MODIS-Aqua, Level-2 products) along the transect parts A and B. The data were obtained from NASA OceanColor website (OceanColor web, no date). n/a: not available. Analyses: K. Kabiri.

Transect part	St No.	Maximal sampling depth	Chl-*a* (mg m^{-3})							
		m	*17/08/2013*	*24/08/2013*	*08/12/2013*	*30/12/2013*	*16/08/2014*	*17/08/2014*	*08/12/2014*	*22/12/2014*
A	*1*	**2**	n/a	4.99	n/a	6.23	5.77	n/a	3.21	6.79
	2	**5**	3.02	4.04	n/a	3.52	4.00	n/a	2.94	3.52
	3	**7**	2.81	3.46	3.58	2.95	3.54	n/a	2.54	2.91
	3B	**8**	2.70	3.18	2.81	3.09	3.18	3.85	2.54	2.76
	4	**9**	2.45	3.03	2.36	2.97	3.07	2.88	2.40	2.96
	5	**10**	2.24	3.05	2.64	2.66	2.87	2.66	2.38	2.76
	6	**12**	1.94	3.00	2.69	2.31	2.79	2.62	2.32	2.84
	7	**13**	1.86	2.41	2.61	2.19	2.11	2.25	2.24	2.65
B	*13*	**25**	1.55	2.10	4.05	1.63	1.49	1.58	2.19	2.85
	12	**46**	1.44	1.32	3.23	1.59	1.67	1.35	1.59	3.05
	11	**92**	1.45	1.34	3.60	1.39	1.31	1.19	1.54	2.89
	10	**148**	1.38	1.32	3.25	1.36	1.27	1.30	1.65	1.88
	9	**200**	1.33	1.25	2.89	1.28	1.29	1.55	1.56	1.97
	8	**221**	1.41	1.31	3.03	1.27	1.06	1.50	1.58	1.37
		Mean:	1.97	2.56	3.06	2.46	2.53	2.07	2.19	2.94

Transect part	St No.	Maximal sampling depth	Sea Surface Temperature in °C							
		m	*17/08/2013*	*24/08/2013*	*08/12/2013*	*30/12/2013*	*16/08/2014*	*17/08/2014*	*08/12/2014*	*22/12/2014*
A	*1*	**2**	29.37	28.65	n/a	10.14	31.64	31.19	11.26	12.39
	2	**5**	28.49	28.34	15.57	11.37	29.97	29.23	10.99	12.17
	3	**7**	28.20	28.28	15.46	11.89	30.04	29.22	11.76	12.31
	3B	**8**	28.01	28.10	16.46	11.68	30.13	29.32	12.68	12.88
	4	**9**	28.11	28.16	16.92	11.61	30.01	29.04	13.30	13.21
	5	**10**	27.83	28.43	17.17	12.33	29.54	28.96	13.83	13.37
	6	**12**	28.09	28.18	17.35	12.68	29.60	28.79	13.38	13.36
	7	**13**	28.04	28.20	17.40	13.05	29.59	28.64	13.59	13.79
B	*13*	**25**	27.89	27.74	18.79	13.99	29.34	28.87	15.14	14.62
	12	**46**	27.53	27.89	18.99	14.29	28.81	28.71	15.53	14.80
	11	**92**	27.76	27.87	18.98	14.38	28.81	28.63	15.39	14.49
	10	**148**	27.68	28.00	19.04	14.30	28.70	28.93	15.58	14.64
	9	**200**	27.76	28.11	18.91	13.80	28.78	28.66	15.42	14.51
	8	**221**	28.06	28.19	18.80	14.38	28.93	28.56	15.42	14.60
		Mean:	28.06	28.15	17.68	12.85	29.56	29.05	13.81	13.65