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SUPPLEMENTARY MATERIAL TO

Bioaccumulation and translocation of heavy metals by *Ceratophyllum demersum* from the Skadar Lake, Montenegro

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Study area

Lake Skadar (42°03′–42°21′ N; 19°03′–19°30′ E), picturesque and in many ways unique within the surrounding environment, is one of the most interesting biotopes in the wider area. It is the largest lake on the Balkan Peninsula and is located on the border between Montenegro and Albania. Two-thirds of the lake is situated in Montenegro. During the summer, Lake Skadar has a surface of 370 km^2, while its surface is 540 km^2 in the winter. The lake is 44 km long with a width of 13 km. The average depth of the lake in its low water level is approximately 5 m, with the bottom part featuring cryptodepression. The maximum depth of the lake is about 60 m. The Skadar Lake exhibits a large change of the water level: on a rainy day, lake level can be raised to one meter. The size of the catchment area is 5500 km^2.

Skadar Lake is a flow type. The greatest amount of water along with a large amount of sediment enters *via* the River Morača and its tributaries the Zeta and Cijevna. The River Bojana is the primary outflow and can cause tumefaction of the Lake. The water in the Lake is completely exchanged two or more times a year.

Samples of sediment, water, and *C. demersum* plants from the Skadar Lake were collected from six locations (Fig. S-1): 1 – Raduš (42° 13′ 26.85″ N, 19° 09′ 54.44″ E); 2 – right estuary of the Morača River (42° 16′ 50.18″ N, 19° 07′ 38.92″ E); 3 – left estuary of the Morača River (42° 15′ 55.80″ N, 19° 08′ 31.49″ E); 4 – Plavnica (42° 16′ 17.48″ N, 19° 12′ 1.01″ E); 5 – Crni Žar (42° 17′ 49.30″ N, 19° 22′ 23.75″ E); 6 – Crnojevića River (42° 21′ 6.03″ N, 19° 02′ 23.05″ E).

Raduš is the deepest underwater source lake with a depth of 60 m. Plavnica is a tributary of the lake, a tourist complex with a large number of tourists and visitors, with an interflow of ground and surface waters gravitating towards it from the surrounding farming land. On the left and right banks of the mouth of the Morača into the Lake, its water quality is affected by numerous impurities in the river collected throughout its course. Probably the most noticeable

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impact on the changing quality of the Skadar Lake ecosystem refers to the technological processes in the Aluminum Plant in Podgorica. Crni Žar with its lush waterway and wetland vegetation indicates to accelerated eutrophication, resulting in more water logging of the lake, which inevitably leads to changes in its ecosystem. Crnojevića River, a small town that lies on the eponymous river, possesses a number of factors that suggest caution when it comes to protecting that part of the lake: a fish processing plant, the development of a local fleet, and the waste water systems in the nearby villages and farms. All the above-mentioned measures of precaution are planned because of the large number of tourists to be taken into consideration.

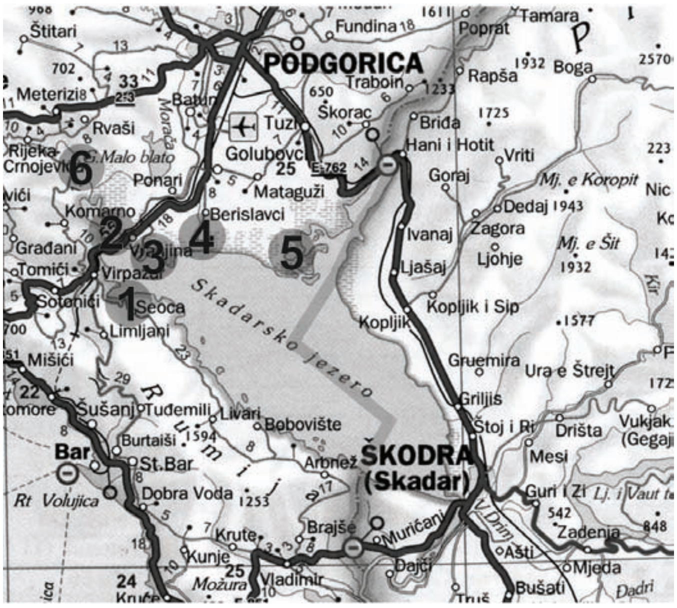

Fig. S-1. Location of the sampling station in Lake Skadar.

TABLE S-I. Seasonal minimum and maximum concentrations (ppm) of the studied metals in the water of the Skadar Lake and the average concentrations ± standard deviation (*SD*); *LOD* – limit of detection. *LOD*(Cd) = 0.001 ppm; *LOD*(Cu) = 0.001 ppm; *LOD*(Co) = 0.001 ppm; *LOD*(Cr) = 0.002 ppm; *LOD*(Mn) = 0.001 ppm; *LOD*(Ni) = 0.001 ppm; *LOD*(Pb) = 0.005 ppm; *LOD*(Zn) = 0.001 ppm; *LOD*(V) = 0.001 ppm; *LOD*(Sr) = 0.001 ppm

Metal		Season			
		April	June	August	October
Cd	Min.–max.	< *LOD**	< *LOD*	< *LOD*	< *LOD*
	Average±*SD*				
Cu	Min.–max.	0.003–0.012	0.002–0.012	0.002–0.013	0.002–0.014
	Average±*SD*	0.007±0.004	0.007±0.004	0.007±0.004	0.007±0.004
Co	Min.–max.	< *LOD*	< *LOD*	< *LOD*	< *LOD*
	Average±*SD*				

TABLE S-I. Continued

Metal		Season			
		April	June	August	October
Cr	Min.–max.	0.002–0.003	0.002–0.003	< *LOQ*	< *LOQ*
	Average±*SD*	0.0022±0.0004	0.0023±0.0005		
Mn	Min.–max.	0.006–0.013	0.005–0.013	0.007–0.014	0.006–0.014
	Average±*SD*	0.009±0.003	0.010±0.003	0.011±0.003	0.010±0.003
Ni	Min.–max.	0.001–0.003	0.001–0.003	0.001–0.004	0.001–0.004
	Average±*SD*	0.0013±0.0008	0.0015±0.0008	0.0018±0.0012	0.0015±0.0012
Pb	Min.–max.	< *LOD*	< *LOD*	< *LOD*	< *LOD*
	Average±*SD*				
Zn	Min.–max.	0.002–0.008	0.002–0.007	0.003–0.008	0.003–0.008
	Average±*SD*	0.005±0.002	0.005±0.002	0.005±0.002	0.005±0.002
V	Min.–max.	0.002–0.007	0.002–0.007	0.002–0.006	0.002–0.005
	Average±*SD*	0.004±0.002	0.004±0.002	0.004±0.002	0.004±0.001
Sr	Min.–max.	0.023–0.047	0.019–0.046	0.020–0.052	0.020–0.051
	Average±*SD*	0.035±0.009	0.034±0.010	0.035±0.011	0.037±0.012

TABLE S-II. Seasonal minimum and maximum concentrations of metals in sediment (ppm) and average concentrations ± standard deviation (*SD*)

Metal		Season			
		April	June	August	October
Cd	Min.–max.	0.27–0.66	0.29–0.63	0.28–0.65	0.28–0.65
	Average±*SD*	0.40±0.15	0.41±0.14	0.41±0.14	0.40±0.15
Cu	Min.–max.	27.2–50.4	25.5–46.9	25.5–52.1	23.9–54.4
	Average±*SD*	34.5±8.84	33.1±7.81	33.3±10.2	34.0±11.1
Co	Min.–max.	6.31–10.1	5.73–12.9	5.28–13.2	5.12–12.6
	Average±*SD*	8.96±2.52	9.02±2.94	8.76±3.13	9.18±3.08
Cr	Min.–max.	42.4–127	42.3–117	39.8–122	35.6–126
	Average±*SD*	69.7±31.4	67.0±27.6	68.7±30.2	68.2±32.0
Mn	Min.–max.	99.0–424	120–357	118–379	95.4–419
	Average±*SD*	232±122	221±91.4	223±101	239±128
Ni	Min.–max.	29.3–131	34.8–110	30.1–113	34.6–125
	Average±*SD*	79.0±44.3	73.1±36.3	74.5±40.6	83.4±47.6
Pb	Min.–max.	19.1–43.2	16.6–37.6	19.4–43.5	17.6–46.2
	Average±*SD*	29.0±10.2	25.7±9.39	27.6±9.85	30.2±12.1
Zn	Min.–max.	47.6–117	56.1–135	59.1–128	53.2–108
	Average±*SD*	75.4±24.0	79.1±29.7	76.2±26.1	73.8±19.7
V	Min.–max.	20.4–46.7	20.1–45.3	18.8–49.5	18.1–45.5
	Average±*SD*	29.4±9.93	28.9±10.6	27.9±11.7	26.9±9.92
Sr	Min.–max.	17.7–101	20.4–101	18.2–113	16.8–105
	Average±*SD*	55.1±30.6	55.8±30.7	56.2±34.2	57.6±32.3

TABLE S-III. Temporal and spatial changes in metal concentrations (ppm d.w.) in parts of *C. demersum*

Location	Season	Specimen	Cd	Cu	Co	Cr	Mn	Ni	Pb	Zn	V	Sr
Raduš	April	Stem	0.20	15.2	3.57	6.15	606	11.1	8.75	48.4	3.36	34.4
		Leaf	0.30	13.5	7.60	7.65	1404	26.2	6.43	62.9	3.82	22.1
	June	Stem	0.15	9.58	1.28	1.49	491	5.75	9.95	29.4	1.12	15.4
		Leaf	0.35	15.3	3.86	4.55	1343	11.4	8.61	58.9	3.36	20.3
	August	Stem	0.05	8.92	2.48	2.86	468	7.31	4.38	24.1	0.69	31.8
		Leaf	0.22	14.7	4.90	3.36	1676	18.8	3.45	25.6	2.67	27.8
	October	Stem	0.03	15.6	1.79	0.89	391	5.87	4.48	16.7	0.84	15.9
		Leaf	0.19	15.7	5.24	2.88	1336	13.4	4.91	37.1	1.88	23.8
Right estuary of Morača	April	Stem	0.14	12.7	5.78	8.81	1189	12.6	12.7	61.5	3.49	27.5
		Leaf	0.15	14.7	7.63	13.6	1745	24.1	14.6	69.1	6.03	29.9
	June	Stem	0.11	12.0	2.75	4.43	1014	11.2	10.8	75.6	1.97	29.7
		Leaf	0.15	17.4	3.77	7.07	1632	14.5	16.8	104	2.48	23.1
	August	Stem	0.03	16.5	3.29	2.76	991	14.9	6.43	49.0	2.15	31.1
		Leaf	0.21	33.6	5.18	3.57	1709	21.8	8.02	85.4	2.98	24.2
	October	Stem	0.05	19.3	0.69	1.79	876	7.81	8.23	46.9	0.34	29.6
		Leaf	0.19	34.0	2.19	2.79	1984	11.7	10.8	88.5	0.70	23.2
Left estuary of Morača	April	Stem	0.12	24.5	3.05	5.74	733	10.7	10.6	38.7	2.25	35.1
		Leaf	0.28	29.4	6.18	4.27	539	11.7	8.97	47.1	7.32	25.3
	June	Stem	0.09	19.8	0.99	4.34	849	12.8	8.31	49.1	1.37	25.8
		Leaf	0.15	12.1	2.96	4.89	567	22.0	8.88	84.8	2.12	33.2
	August	Stem	0.06	22.6	1.38	2.38	357	10.3	7.57	26.9	1.28	25.1
		Leaf	0.08	34.5	3.28	5.62	659	26.1	3.18	62.8	2.69	37.4
	October	Stem	0.10	24.3	1.48	1.58	488	11.8	5.26	32.4	0.93	17.2
		Leaf	0.05	31.2	4.42	4.70	1655	28.5	7.76	107	2.36	29.2
Plavnica	April	Stem	0.16	13.1	1.78	7.91	584	5.04	11.4	61.3	4.05	24.3
		Leaf	0.20	9.85	5.24	18.6	1479	16.5	12.3	70.6	4.08	25.5
	June	Stem	0.14	7.93	1.47	2.86	382	3.95	9.59	43.6	0.69	18.3
		Leaf	0.12	13.2	4.20	6.06	809	10.1	4.75	72.1	1.71	30.1
	August	Stem	0.15	8.11	1.09	2.46	415	5.41	6.56	27.3	0.89	29.6
		Leaf	0.28	13.6	3.09	8.19	1149	16.8	3.99	45.1	1.48	22.4
	October	Stem	0.18	12.4	0.89	2.98	496	4.47	6.43	31.1	0.44	18.5
		Leaf	0.15	18.9	2.59	7.28	1770	18.8	3.96	70.4	0.85	24.8
Crni Žar	April	Stem	0.15	17.8	1.91	5.79	472	4.32	3.15	47.4	6.87	22.7
		Leaf	0.29	16.3	6.19	12.7	627	9.04	9.84	38.7	8.81	12.1
	June	Stem	0.09	13.8	0.69	4.26	427	5.91	3.94	38.3	2.28	14.9
		Leaf	0.17	10.7	1.48	9.00	722	16.9	6.46	61.3	3.95	20.4
	August	Stem	0.05	10.3	2.13	1.29	351	4.38	2.98	26.2	1.79	17.4
		Leaf	0.07	19.5	1.68	4.67	1291	8.73	4.57	48.7	4.95	17.6
	October	Stem	0.11	16.8	0.95	1.20	275	4.20	2.74	26.6	1.20	15.5
		Leaf	0.08	22.3	1.59	3.78	1525	9.35	4.54	52.2	2.29	15.0

TABLE S-III. Continued

Location	Season	Specimen	Cd	Cu	Co	Cr	Mn	Ni	Pb	Zn	V	Sr
Crnoje-	April	Stem	0.35	10.1	2.09	3.55	356	3.68	8.92	48.2	1.89	19.8
vića River		Leaf	0.42	17.5	2.06	11.7	722	9.21	11.9	103	2.49	23.4
	June	Stem	0.29	6.48	1.41	1.88	372	3.77	5.56	26.7	0.81	10.8
		Leaf	0.28	16.4	2.58	3.14	647	6.48	12.7	85.4	0.79	18.3
	August	Stem	0.20	8.64	1.68	1.00	424	4.08	4.56	21.1	0.70	12.9
		Leaf	0.30	21.2	3.76	2.29	1118	10.2	7.60	66.4	2.36	14.9
	October	Stem	0.17	15.4	1.32	1.23	356	4.97	2.87	31.4	0.45	11.0
		Leaf	0.32	21.7	1.48	2.08	1112	10.4	8.05	114	1.28	19.6

TABLE S-IV. Seasonal changes in the metal concentrations (ppm d.w.) in the parts of *C. demersum*; minimum and maximum concentrations and average concentrations ± standard deviation (*SD*); the values of individual metals with the same letter(s) are not significantly different at $p \leq 0.05$

Metal	Part	Season			
		April	June	August	October
Cd	Stem	0.12–0.35	0.09–0.29	0.03–0.20	0.03–0.18
		0.19±0.08 **ab**	0.14±0.07 **ab**	0.09±0.07 **b**	0.11±0.06 **b**
	Leaf	0.15–0.42	0.12–0.35	0.07–0.30	0.05–0.32
		0.27±0.09 **a**	0.20±0.09 **ab**	0.19±0.10 **ab**	0.16±0.10 **ab**
Cu	Stem	10.1–24.5	6.48–19.8	8.11–22.6	12.4–24.3
		15.6±5.08 **b**	11.6±4.82 **b**	12.5±5.83 **b**	17.3±4.09 **ab**
	Leaf	9.85–29.4	10.7–17.4	13.6–34.5	15.7–34.0
		16.9±6.68 **b**	14.2±2.60 **b**	22.8±9.13 **a**	24.0±7.14 **a**
Co	Stem	1.78–5.78	0.69–2.75	1.09–3.29	0.69–1.79
		3.03±1.52 **b**	1.43±0.71 **b**	2.01±0.80 **b**	1.19±0.41 **b**
	Leaf	2.06–7.63	1.48–3.86	1.68–5.18	1.48–5.24
		5.82±2.06 **a**	3.14±1.01 **b**	3.65±1.28 **ab**	2.92±1.56 **b**
Cr	Stem	3.55–8.81	1.49–4.43	1.00–2.86	0.89–2.98
		6.32±1.85 **b**	3.21±1.32 **bcd**	2.12±0.78 **cd**	1.61±0.74 **d**
	Leaf	4.27–18.6	3.14–9.00	2.29–8.19	2.08–7.28
		11.4±4.97 **a**	5.78±2.07 **bc**	4.62±2.09 **bcd**	3.92±1.88 **bcd**
Mn	Stem	356–1189	372–1014	351–991	275–876
		657±290 **cd**	589±273 **cd**	501±244 **cd**	480±211 **d**
	Leaf	539–1745	567–1632	659–1709	1112–1984
		1086±516 **abc**	953±431 **bcd**	1267±392 **ab**	1564±311 **a**
Ni	Stem	3.68–12.6	3.77–12.8	4.08–14.9	4.20–11.8
		7.91±3.97 **bc**	7.23±3.83 **bc**	7.73±4.20 **bc**	6.52±2.90 **c**
	Leaf	9.04–26.2	6.48–22.0	8.73–26.1	9.35–28.5
		16.1±7.52 **a**	13.6±5.48 **abc**	17.1±6.69 **a**	15.4±7.24 **ab**
Pb	Stem	3.15–12.7	3.94–10.8	2.98–7.57	2.74–8.23
		9.25±3.34 **a**	8.02±2.71 **ab**	5.41±1.72 **b**	5.00±2.12 **b**
	Leaf	6.43–14.6	4.75–16.8	3.18–8.02	4.54–10.8
		10.7±2.87 **a**	9.70±4.39 **a**	5.14±2.13 **b**	6.67±2.65 **ab**

TABLE S-IV. Continued

Metal	Part	Season			
		April	June	August	October
Zn	Stem	38.7–61.5	26.7–75.6	21.1–49.0	16.7–46.9
		50.9±8.89 **abc**	43.8±17.7 **bc**	29.1±10.0 **c**	30.8±9.78 **c**
	Leaf	38.7–103	58.9–104	25.6–85.4	37.1–114
		65.2±22.4 **ab**	77.8±17.1 **a**	55.7±20.6 **abc**	78.2±30.5 **a**
V	Stem	1.89–6.87	0.69–2.28	0.69–2.15	0.34–1.20
		3.65±1.77 **ab**	1.37±0.64 **cd**	1.25±0.61 **cd**	0.70±0.34 **d**
	Leaf	2.49–8.81	0.79–3.95	1.48–4.95	0.70–2.36
		5.42±2.38 **a**	2.40±1.14 **bcd**	2.86±1.15 **bc**	1.56±0.72 **cd**
Sr	Stem	19.8–35.1	10.8–29.4	12.9–31.8	11.0–29.4
		27.3±6.29 **a**	19.2±7.18 **a**	24.6±7.85 **a**	17.9±6.25 **a**
	Leaf	12.1–29.9	18.3–33.2	14.9–37.4	15.0–29.2
		23.0±5.98 **a**	24.2±6.02 **a**	24.0±8.00 **a**	22.6±4.84 **a**