CARBON ISOTOPE FRACTIONATION DURING PHOTOSYNTHESIS IN SUBMERGED MOSS AND AQUATIC PLANTS

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INTRODUCTION

Freshwater mosses and other aquatic (submersed, floating, emersed) plants important fragments in the environment of karstic lakes, such as the Plitvice Lakes, accelerating tufa formation. Understanding the sources and the way they incorporate carbon, gives an insight into the formations of tufa barriers.

Carbon isotopes are a good tool for understanding the sources of carbon (from ^{14}C composition) and mechanisms of carbon incorporation (from ^{13}C composition) into plants' tissue.

We observe plant samples collected in 2011, 2012 and 2015 (2nd period) in the natural habitat of the Plitvice Lakes: terrestrial moss, water submerged moss, marsh and aquatic plants. All collected samples are C3 photosynthetic cycle plants. The $a^{14}C$ and $\delta^{13}C$ values of the plant tissue are compared with values of carbon reservoirs the plants use in photosynthesis: atmospheric CO_2 and/or dissolved inorganic carbon (DIC) as well as with the carbon isotope composition of plants measured 30 years ago (1st period, Marčenko et al, 1989). The fraction of each carbon reservoir in plants is determined and the ^{13}C fractionation factor between DIC and organic tissue of a plant is calculated.

The Crna River, spring, sampling of moss (CR-spr)

Legend for Figures and Tables

white background - 2nd period (2011-2015)
blue background - 1st period (1984 - 1988)

BR-spr	Bijela River- spring
BR	Bijela River
CR-spr	Crna River- spring
Mat	Matica
Pro	Lake Prošćansko
SpV	Špiljski Vrt (beneath a waterfall)
M-V	From Lake Malo to Lake Veliko
Okr	Lake Okrugljak
Vir	Lake Vir
Gra	Lake Gradinsko
Bur	Burgetići, cascades
Koz-K3	Lake Kozjak, K3
Koz-b	Lake Kozjak, bridges
Kal	Lake Kaluđerovac
Rje	Rječica stream, tributary
Kor	The Korana River, bridge
Land	Sampled on land

SAMPLING and METHODS

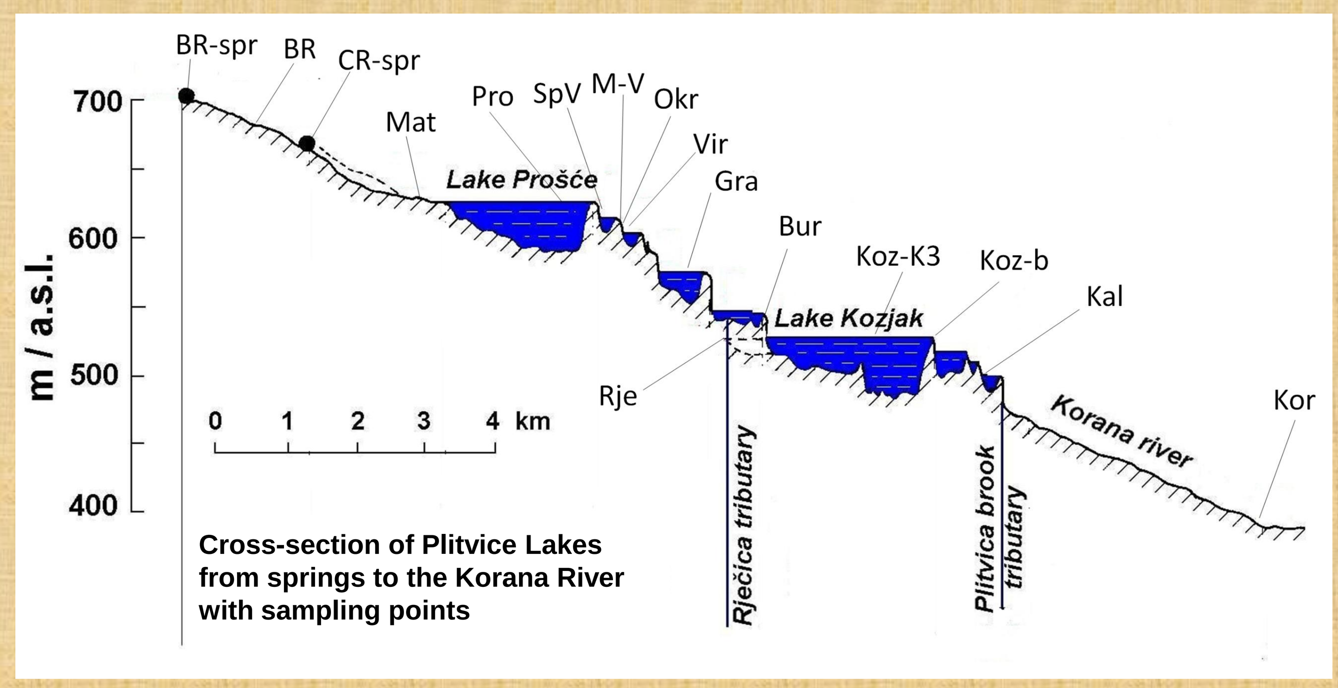
Plitvice Lakes

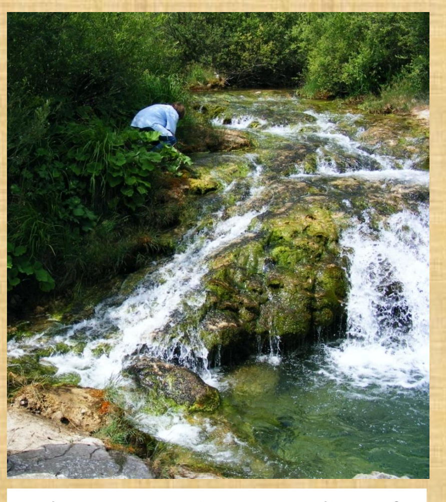
Coinciding sampling of plants and 1 L of water were performed in spring/summer of 2011 and in spring s of 2012 and 2015.

The sampling was performed at the Crna River spring, the River Matica, Lake Prošće, Burgetići cascades, Lake Kozjak, two locations, Rječica stream tributary and the Korana River.

DIC in water was precipitated as $BaCO_3$ and prepared at Ruđer Bošković Institute in the form of CO_2 (for $\delta^{13}C$ - IRMS) and graphite (for ^{14}C AMS) and analyzed at AMS facility of the University of Georgia, Atlanta, GA, USA.

$a^{14}C$ of plant samples was determined by LSC (in form of benzene, Ruđer Bošković Institute) and by AMS.





The Korana River, sampling of moss (Kor)

The Korana River, moss (Kor)

Lake Proščansko, emersed plant (sedge) (Pro)

Rječica tributary, floating plant (Rje)

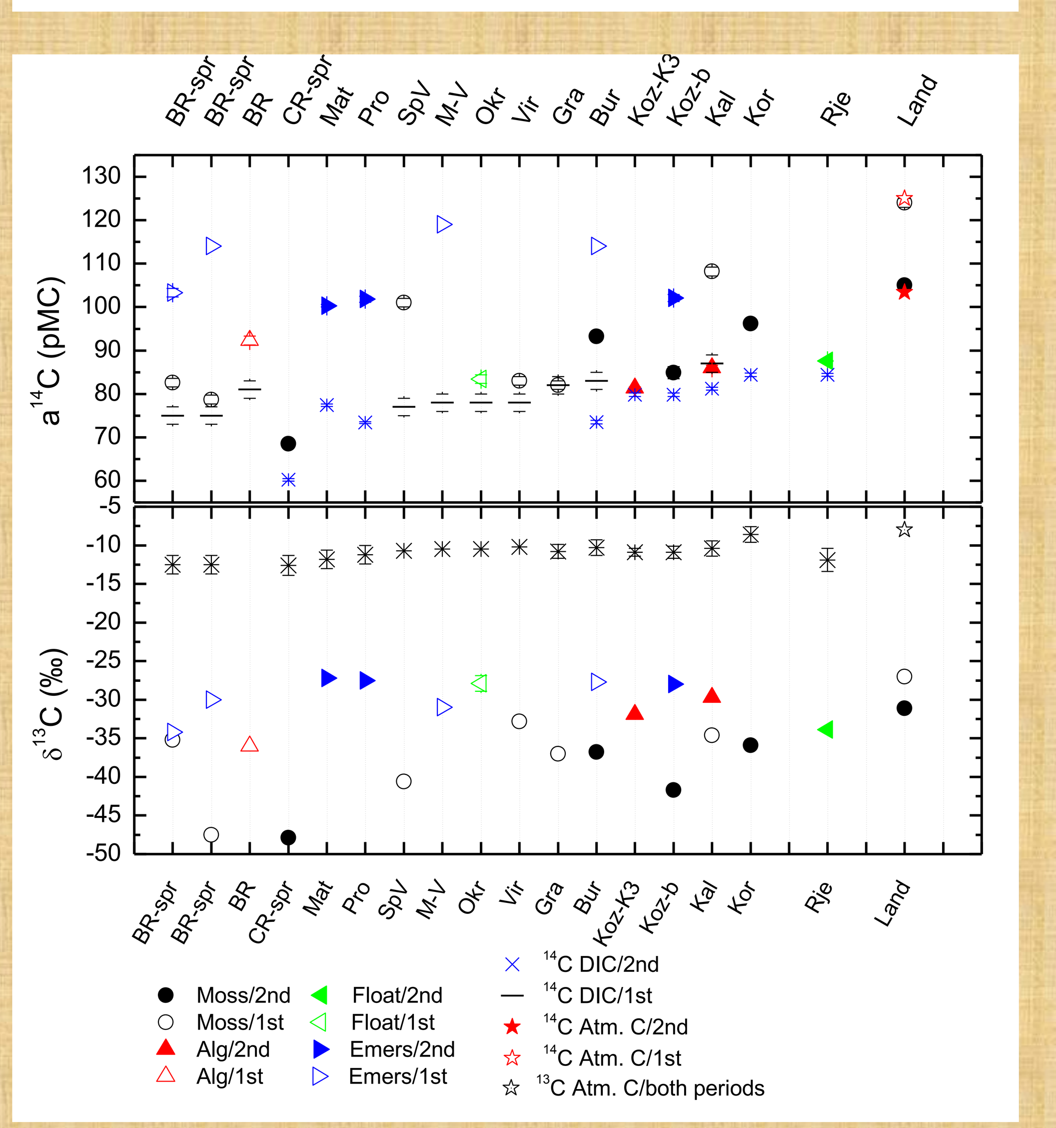
Kozjak Lake, sampling of algea (*Chara sp.*) (Koz-K3)

Kaluđerovac Lake (12 m depth), *Chara sp.* with tufa coating (Kal)

Kozjak Lake, bridges, sedge (Koz-b)

RESULTS and DISCUSSION

$a^{14}C$ and $\delta^{13}C$ of plants and DIC at sampling locations

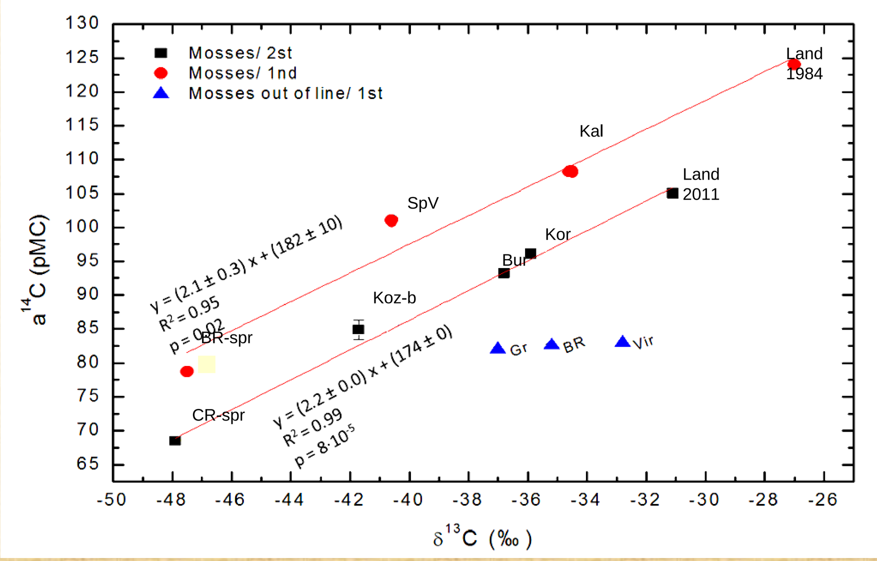


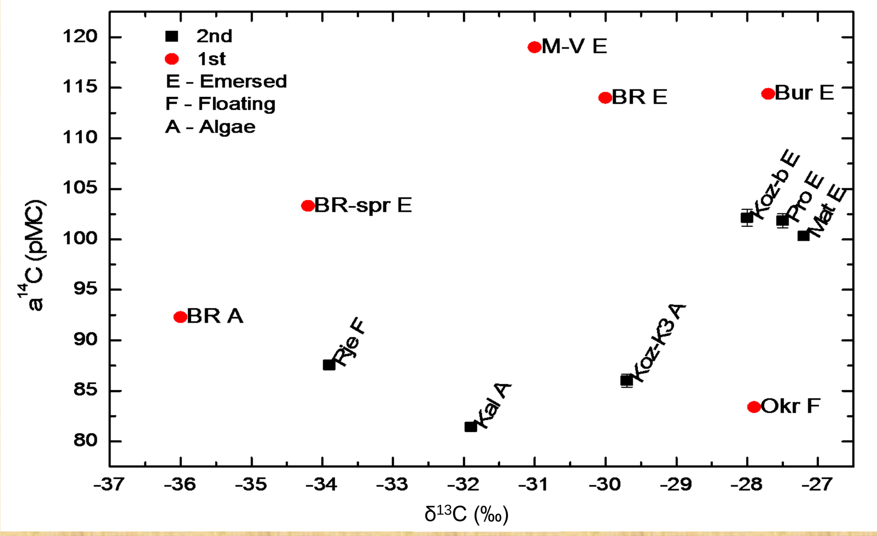
Comparison of $a^{14}C$ and $\delta^{13}C$ data for DIC and plants in two observed periods, 1984 - 1988 (1st, Marčenko et al, 1989) and 2011, 2012 and 2015 (2nd) at each location is presented. $a^{14}C_{DIC}$ for the 1st period is approximated from Srdoč et al (1986).

$a^{14}C$ values of DIC for 1st and 2nd period have changed due to a decrease of $a^{14}C$ of atmospheric CO_2, while $\delta^{13}C$ is the same in both periods.

All plants show higher $a^{14}C$ and lower $\delta^{13}C$ values than that of DIC at the same location. $a^{14}C$ values are a result of mixed carbon sources, from atmosphere and from DIC. $\delta^{13}C$ values are also influenced by ^{13}C fractionation from CO_2 /HCO_3^- from atmosphere and water to plant's tissue during photosynthesis.

Correlations of $a^{14}C$ to $\delta^{13}C$ of plants





A very good correlation between $a^{14}C$ and $\delta^{13}C$ of for mosses in both periods is a result of variation of the ratio of atmospheric and dissolved inorganic carbon in moss. All samples from the 1st period have higher $a^{14}C$ than in 2nd period, with the similar $\delta^{13}C$. Emersed plants have higher $a^{14}C$ and $\delta^{13}C$ values than floating plants or algae (completely submersed).

Calculated fraction of atmospheric carbon in aquatic plant and ^{13}C photosynthesis fractionation between DIC and aquatic plant

	2nd - period			1st - period			
	Location	Fraction of atm. C (%)	Fractionation (‰)	Location	Fraction of atm. C (%)	Fractionation (‰)	Mean (‰)
Mosses	CR	19	-40.1	BR-spr*	15	-24.0	
	Bur	66	-43.9	BR-spr	8	-36.7	
	Koz-b	16	-33.5	SpV	50	-42.5	
	Kor	62	-39.7	Vir**	12	-23.3	
				Gra*	0	-27.0	
				Kal	64	-36.7	**-41 ± 3**
Algae	Koz-K3 (0.3 m)	26	-20.1	BR	18	-25.3	
	Kal (14 m)	1	-22.2				
Floating	Rje	21	-23.1	Okr	12	-17.4	**-22 ± 3**
Emersed	Mat	90	-20.3	BR-spr	57	-29.8	
	Pro	96	-14.8	BR-spr	87	-30.5	
	Koz-B	96	-28.0	M-V	98	-143.8	
				Bur	86	-15.9	

In blue- mosses *out of line*
*carbonates not removed completely?
***Mniobrium albicans;* others are *Cratoneurum commutatum* and *Fontinalis antpyretica*

The fraction of atmospheric carbon in submerged mosses ranges from 8 to 66 %. Calculated ^{13}C fractionation factor between DIC and organic tissue of moss is -41 ± 3 ‰.

Aquatic plants (algae, submersed species) sampled from ~30 cm water depth show higher fraction of atmospheric carbon (~20 %) than a sample from 14 m depth (~0 %). Floating plants have 15 - 20 % of atmospheric carbon, while emersed plants 90 - 100 % of atmospheric carbon (marsh plants, sedge, grasses). Calculated ^{13}C fractionation factor between DIC and plant tissue for submersed and floating plants is -22 ± 3 ‰, which is the same as the ^{13}C fractionation factor between the atmospheric CO_2 and plant tissue for C3 plants. Emersed plants have higher dispersion in ^{13}C fractionation factor values (from -14 to -147 ‰).

CONCLUSION

From these analysis we found the ^{13}C fractionation between DIC and the plant tissue for mosses is -41 ± 3 ‰ and for aquatic plants -22 ± 3 ‰. This difference is probably a result of different plant adjustment to photosynthesis of $HCO_3^-{}_{(aq)}$ and $CO_3^{2-}{}_{(aq)}$ molecules from DIC. Mosses are known to be adjusted to photosynthetic assimilation of CO_2 so there is probably an extra step of transformation of $HCO_3^-{}_{(aq)}$ and $CO_3^{2-}{}_{(aq)}$ to CO_2 resulting in a larger ^{13}C fractionation factor between DIC and plant tissue for mosses than for aquatic plants.

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