The Impact of Ornithogenic Inputs on Phosphorous Transport from Altered Wetland Soils to Waterways in East Mediterranean Ecosystem

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ABSTRACT

Large flocks of Eurasian crane (*Grus grus* > 35,000) have begun wintering in an altered wetland agro-ecosystem located in Northern Israel, a phenomenon that attracts more than 400,000 eco-tourists a year. A 100-ha plot has been used to feed the cranes in order to protect nearby fields. The objective of this study was to evaluate the influence of this birds feeding practice on the P status of the altered wetland soils and waterways. We installed a series of wells at two depths (40 & 90 cm) between two major waterways in the feeding area and monitored the hydraulic heads and collected groundwater samples for elemental analyses. We collected six soil cores and four sediment samples from the waterways and conducted sequential P extraction. We found significant increase in groundwater soluble reactive P (SRP) (> 0.5 mg l^{-1}) compared with much lower concentrations (~0.06 mg l^{-1}) collected in the period prior to the feeding. We found significant decrease in $Fe^{(II)}$, Ca, and SO_4 concentrations in the shallow groundwater (33, 208, and 213 mg l^{-1}, respectively) compared with the period prior to the feeding (47, 460, 370 mg l^{-1} respectively). An increase in the more labile P fraction was observed in soils and sediments compared with the period before the feeding. The P input by bird excrement to the feeding area was estimated around 700 kg P per season, while P removal by plant harvesting was estimated around 640 kg P yr^{-1}. This finding supports the current eco-tourism practices in the middle of intensive farming area, suggesting little impact on waterways.

Table 1. Distribution of P fractions by soil depth after and before the feeding commenced, means ± standard errors of 3-7 (N) replicates.

Depth (cm)	N	WSP	$NaHCO_3$	NaOH	HCl 1M	HCl	residual	Total P
After the feeding								
				mg P kg^{-1}				
0-4	6	2.6±0.6	181±35	233±38	621±44	135±11	49±4	1220±109
4- 15	6	0.8±0.2	112±25	243±41	673±80	106±11	46±4	1180±138
15 - 25	6	0.7±0.2	141±49	332±57	661±66	108±14	42±4	1280±150
25 - 40	6	1.2±0.5	153±48	390±46	425±43	90±13	37±3	1100±87
40 - 60	5	2.8±0.7	138±14	404±69	308±85	68±7	35±4	955±240
60 - 80	7	2.6±0.7	158±40	244±58	176±32	51±6	26±3	660±87
80 – 100+	3	2.6±1.3	90±11	163±23	275±80	44±0.6	18±2	590±64
Before the feeding								
0-20	3	0.3±0.1	90±15	320±53	608±50	120±46	98±26	1236±150
20 - 40	3	0.4±0.2	89±13	405±89	363±87	143±17	71±39	1071±160
40 - 60	3	0.4±0.3	71±17	318±67	414±28	125±15	116±26	1047±39
60 - 80	3	0.8±0.7	45±17	165±78	369±76	88±23	84±32	755±137
80 - 110	4	1.0±1.0	54±11	170±50	424±135	115±36	93±26	858±180

Table 2. Distribution of P fraction in the sediments of the drainage canals after and before the feeding commenced (means ± standard errors of N replicates).

N	WSP	$NaHCO_3$	NaOH	HCl 1M	HCl	residual	Total P
After Feeding				mg kg^{-1}			
4	0.4±0.4	840±92	1780±600	400±75	340±80	870±180	4230±890
Before Feeding							
3	1.1±0.5	180±80	1030±520	960±440	175±44	85±10	2430±1070

Figure 1. **The shallow groundwater and soils sampling locations across the feeding zone between the reconstructed Jordan River and the Crane canal**

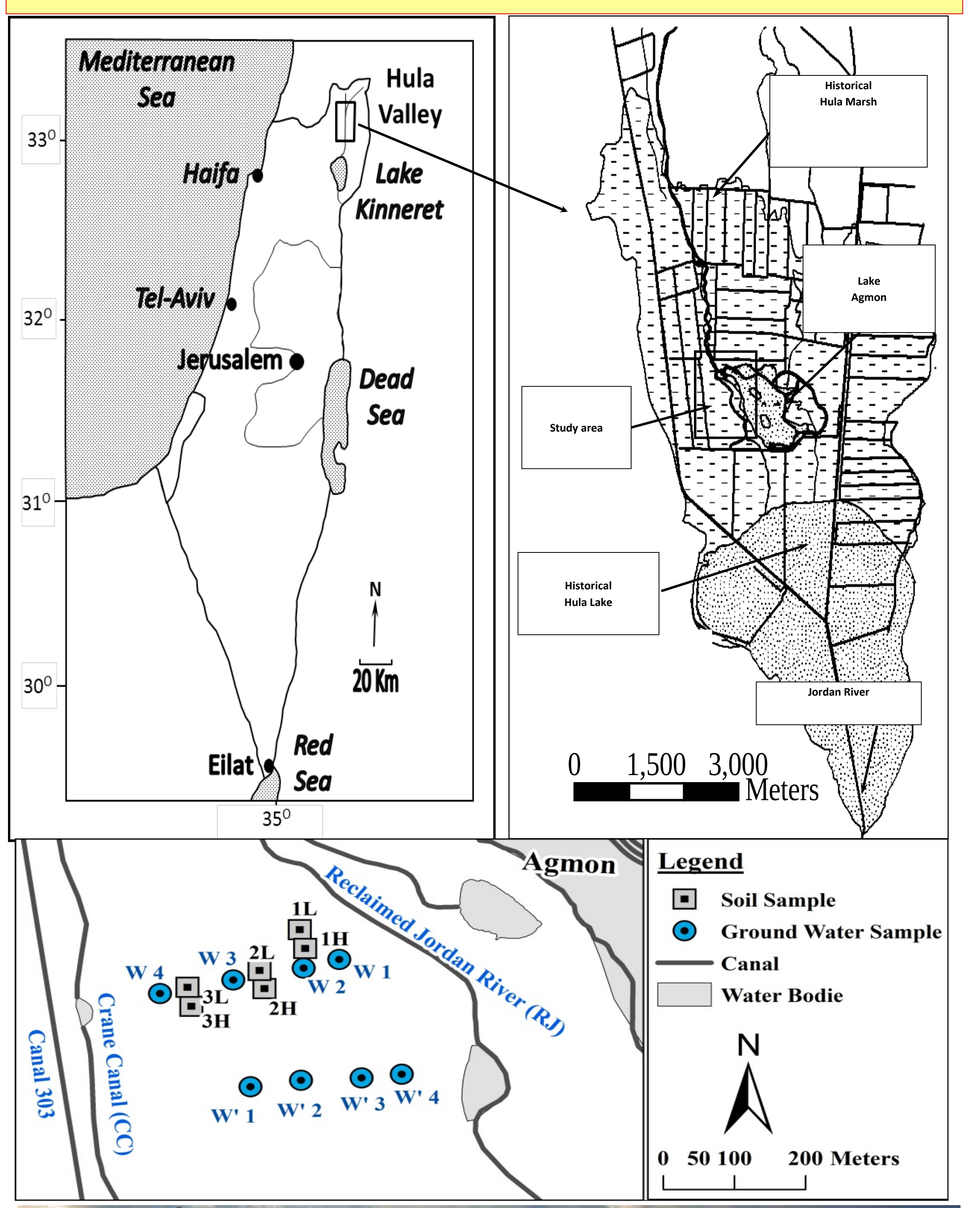

Table 3. Selected hydrochemical parameters of the groundwater across the feeding area before and after the feeding commenced. The data are presented by depth (means ± standard errors, N is number of samples taken weekly or biweekly during the sampling periods before and after the feeding commenced).

Layer	EC (µS cm^{-1})	SO_4 (mg l^{-1})	Ca (mg l^{-1})	SRP (µg l^{-1})	TDP (µg l^{-1})	Total P (mg l^{-1})	$Fe^{(II)}$ (mg l^{-1})	pH
After the feeding commenced (2010) N = 44								
Peat	0.9 ± 0.1	215 ± 58	201 ± 26	437 ± 25	474 ± 25	1.5 ±0.2	37 ± 8.3	6.9 ± 0.03
Marl	1.13 ± 0.1	211 ± 49	215± 19	576 ± 41	611 ± 35	1.2 ± 0.1	30 ± 4.5	6.9 ± 0.03
Before the feeding commenced (1999) N = 22								
Peat	ND	515 ± 170	549 ± 93	26 ± 7	68 ± 16	ND	48 ± 15	6.9±0.1
Marl	ND	223 ± 39	403 ± 57	61 ± 9	134 ± 23	ND	46 ± 8.8	6.5±0.1