Method Article

Generalized estimation of nutrient loading of waterbirds on inland aquatic ecosystems

Emil Boros, PhD

Institute of Aquatic Ecology, Centre for Ecological Research, Karolina str. 29., Budapest H-1113, Hungary

A B S T R A C T

Estimating the nutrient loading of aquatic bird is complicated because it is fundamentally dependent on several biological, environmental and methodological factors. The new Boros's generalized method is relatively easy to use based on the conventional bird counting and implemented excrement (faecal) analyses by integrated daily net rates data (g/day/ind.). According to the Boros's generalized method, the carbon (C), nitrogen (N) and phosphorus (P) loading of waterbirds on aquatic ecosystems can be estimated by determining the abundance of waterbird populations and the nutrient content (C, N, P) of their excrement. Weekly total loading of waterbirds = Σ species (A × E × RTF × D), where: A (ind./m^2): the daily mean of abundance of waterbird species for each month, E (g/day/ind.): the daily net rate of C, N, P in the excrement of each species, RTF: the daily residency time factor (hours spent on soda pans/24 h) of each species in the target habitat, *D* (*n* days): the number of days of each month.

- Waterbirds can cause extreme guanotrophication (max. 2500 mg P/m^2/y) in waters.
- The nutrient loading of waterbirds can be estimated by abundance of waterbirds.
- Boros's method estimates the carbon, nitrogen and phosphorus loading of waterbirds.

Specifications Table

Subject Area:	Environmental Science
More specific subject area:	aquatic ecology, bird ecology
Method name:	Boros's generalized method
Name and reference of original method:	This is my original Boros's method used
Resource availability:	All the complete dataset used by Boros et al. [5] as an example can be found in Dryad depository at the following location for this dataset that is currently private for peer review: https://datadryad.org/stash/share/ctkhxkSdrb5aNcqsMa2CoRnlzQ6Qm_GMSqXk_MCx0RY

Waterbirds can have a significant impact on biochemical cycles, energy flow and production in aquatic ecosystems by several supporting or regulatory ecosystem services [8], moreover the guanotrophication by waterbirds can have a positive impact on productivity and energy flow ([3–5]. However, estimating the nutrient loading of aquatic bird is complicated because it is fundamentally dependent on several biological, environmental and methodological factors. Although there are different methods for estimation of the nutrient loading of the waterbirds, the Boros's generalized method is relatively easy to general use based on the conventional bird counting and integrated data of implemented excrement (faecal) analyses, which can be significantly contribute to the better understanding of how waterbirds can effect ecosystems, and quantify their ecosystem services, which is a fundamental requirement for more effective monitoring and management of the ecosystems. According to a number of uncertainties, Adhurya et al. [1] reviewed several direct and indirect estimation methods and results for guanotrophication by waterbirds. As the direct models are based on excrement matter analysis, while the bioenergetics models use estimation of daily energy requirements of waterbirds. The Boros's generalized method is a direct model, which based on *in situ* bird counting data in the aquatic habitats and excrement matter analysis data, using own and cited data from references, which are summarised in the Table 1. The detailed backgrounds of previous methodologies can be found in the original published references cited in Table 1. All the excrement analyses data of waterbirds by different authors and methods were transformed into a same unit as integrated daily net rates data of nutrient excretion of each waterbird species (g/day/ind.). The most of previous studies use the own nutrient analyses of excrement and some of them also takes data from the limited literature. The Boros's method integrates the combination of own and wide range of accessible references data from different kind of inland water environment, and it uses an extended implementation for several waterbird species within the taxonomic genus of similar species respectively [3–5]. Thus this is a new generalized method for estimation of nutrient loading of waterbirds, which can be generally used for quick surveys. Because of generalization by several methods and ecosystems, the accuracy of estimation can be increased by modification of the parameters with the regional or local peculiarities and with other species in the further studies.

The rationale why the formula presented is valid, are based on Boros et al.'s [3–5] publications in several repetitions by different sites and years in aquatic inland ecosystems, where significant correlation were found between the annual mean carbon and phosphorus loading of aquatic bird estimated by Boros's generalized method, as well as the total organic carbon and total phosphorus (TP) concentration of the investigated inland aquatic ecosystems. Moreover, not only the annual data correlated between the estimated bird loading by Boros's method and the *in situ* concentration of the nutrient in the lake-water, even a significant time shift was indicated by cross-correlation with two-week time lags implementation for the P loading of waterbirds by this model between and the P-forms of soda pans in the latest study [5]. The nutrient and microbial dynamics of Fuente de Piedra saline lake (Málaga, Spain) showed a same two weeks time-lag with the abundance of flamingos [2], which also confirms the validity of Boros's generalized nutrient loading model for waterbirds by significant time shift relation with the bird derived nutrient (C, N, P) concentration of the lake-water. Because these results indicate a delay in dissolution of certain *P*-forms (e.g. particulate fractions) after *P* loading of waterbirds respectively, thus it must be taken into account in the seasonal assessment of nutrient loading of waterbird populations.

Table 1

Daily standard net Carbon (C), Nitrogen (N), Phosphorus (P) excrement data (g P/day/individual) and residency time factors (RTF: hours spent on pans/24 h) of waterbird species used for estimation of P loading (after [3–5]). Species names after [6].

Waterbird species	Scientific name	RTF	C	N	P	References
Swans	*Cygnus spp.*	0.6	9.76	0.49	0.11	Oláh [12], Boros et al. [3–5]
Taiga Bean Goose	*Anser fabalis*	0.6	9.76	0.49	0.11	Oláh [12]
Greylag Goose	*Anser anser*	0.6	9.76	0.49	0.11	Oláh [12]
Greater White-fronted Goose	*Anser albifrons*	0.6	8.60	0.69	0.08	Kear [9]
Small geese and shelducks	*Branta, Tadorna spp.*	0.6	8.60	0.69	0.08	Boros et al. [3–5]
Dabbling ducks	*Anas, Mareca, Spatula spp.*	0.8	9.12	0.58	0.18	Manny et al. [10], Oláh [12]
Diving ducks	*Aythya, Bucephala, Mergus spp.*	1.0	9.69	0.61	0.19	Manny et al. [10], Oláh [12]
Eurasian Coot	*Fulica atra*	1.0	9.69	0.61	0.19	Boros et al. [3–5]
Cormorants	*Phalacrocorax, Microcarbo spp.*	1.0	19.60	1.04	4.58	Marion et al. [11], Boros et al. [3–5]
Herons	*Ardea, Egretta, Botaurus spp.*	1.0	14.50	1.38	3.78	Marion et al. [11]
Storks and Ibises	*Ciconia, Platalea, Plegadis spp.*	1.0	14.50	1.38	3.78	Marion et al. [[11]; Boros et al. [3–5]
Grebes	*Podiceps, Tachybaptus spp.*	1.0	9.69	0.61	0.19	Manny et al. [10], Oláh [12]
Common Crane	*Grus grus*	0.6	8.40	3.48	0.58	Oláh [12]
Pied Avocet	*Recurvirostra avosetta*	1.0	5.00	2.16	0.36	Oláh [12]
Black-tailed Godwit	*Limosa limosa*	1.0	5.00	2.16	0.36	Oláh [12]
Black-winged Stilt	*Himantopus himantopus*	1.0	5.00	2.16	0.36	Oláh [12]
Curlews	*Numenius spp.*	0.6	3.00	1.30	0.22	Oláh [12]
Northern Lapwing	*Vanellus vanellus*	0.6	2.52	0.65	0.12	Oláh [12]
Plovers 1	*Pluvialis spp.*	0.6	2.52	0.65	0.12	Oláh [12]
Plovers 2	*Charadrius spp.*	1.0	3.00	0.93	0.11	Oláh [12]
Ruff	*Calidris pugnax*	0.6	2.52	0.65	0.12	Oláh [12]
Sandpipers 1	*Actitis, Calidris, Phalaropus spp.*	1.0	3.00	0.93	0.11	Oláh [12]
Sandpipers 2	*Tringa spp.*	1.0	4.20	1.08	0.20	Oláh [12]
Snipes	*Gallinago spp.*	1.0	4.20	1.08	0.20	Oláh [12]
Black-headed Gull	*Chroicocephalus ridibundus*	0.6	3.48	0.36	0.23	Gould and Fletcher [7]
Mediterranean and Little Gull	*Ichthyaetus melanocephalus, Hydrocoloeus minutus*	0.6	3.48	0.36	0.23	Boros et al. [3–5]
Caspian Gull	*Larus cachinnans*	0.6	7.68	0.66	0.62	Gould and Fletcher [7]
Mew Gull	*Larus canus*	0.6	4.32	0.48	0.30	Gould and Fletcher [7]
Yellow-legged Gull	*Larus michahellis*	0.6	7.68	0.66	0.62	Gould and Fletcher [7]
Terns	*Chlidonias, Hydroprogne, Sterna spp.*	1.0	4.50	0.60	0.38	Boros et al. [3–5]

According to the Boros's generalized method the carbon (C), nitrogen (N) and phosphorus (P) loading of waterbirds on aquatic habitats can be estimated by determining the abundance of waterbird populations and the nutrient content (C, N, P) of their excrement.

The abundance of waterbirds in the clearly visible open aquatic habitats can be counted with binoculars (8×42 and 10×42) and spotting scopes (zoom 20–60×78) in daylight, at a maximum 14-day intervals (biweekly) or a minimum 7-day intervals (obviously shorter interval gives a better estimation). The species on the small number individuals can be exactly counted, while bigger number in group of birds by a small unit counting of scope view and then extrapolated it to the total scope view. Daily waterbird abundance (individuals/m^2) is calculated from the mean of the weekly or biweekly counts for each month. The contribution of waterbird populations to the daily nutrient loading is estimated by using daily net rates data of nutrient excretion, which are listed in Table 1 with references. It is used a linear time defecation rate assumption in our estimation. Each daily total C, N, P excretion data (g/day/individual) is modified by a species-residency time correction factor (RTF: residence time in hours on the soda pans during 24 h) on the water surface (m^2) based on observed diurnal and nocturnal activity of the involved waterbird species within the used aquatic habitat. Daily net nutrient excrement data and used waterbird species RTFs are also listed in Table 1.

The (bi)weekly total loading of waterbirds = Σ species (A $\times$ E $\times$ RTF $\times$ D), where A (ind./m^2): the daily mean of abundance of waterbird species for each month, E (g/day/ind.): the daily net rate of C, N, P in the excrement of each species,

RTF: the daily residency time factor (hours spent on soda pans/24 h) of each species in the target habitat, *D* (*n* days): the number of days of each month.

The annual cumulative net C, N, P loading can be determined by summing the weekly or two-week mean loadings. Surface-related data (mg C, N, P/m^2/year) can be calculated as the sum of loading quantities, measured every two weeks divided by the actual size of the target habitat. The volume-related unit (mg P/L/year) can be calculated based on the sum of surface-related data (mg C, N, P/m^2/year) and yearly average of water depth (m) of the investigated aquatic habitat.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] S. Adhurya, S. Das, S. Ray, P.K. Roy, et al., Guanotrophication by waterbirds in freshwater lakes: a review on ecosystem perspective, in: Mathematical Analysis and Applications in Modeling, 302, Springer Proceedings in Mathematics & Statistics, 2018, pp. 253–269, doi:10.1007/978-981-15-0422-8_22.

[2] G.L. Batanero, E. León-Palmero, L. Li, A.J. Green, M. Rendón-Martos, C.A. Suttle, I. Reche, Flamingos and drought as drivers of nutrients and microbial dynamics in a saline lake, Sci. Rep. 7 (2017) 12173, doi:10.1038/s41598-017-12462-9.

[3] E. Boros, T. Nagy, Cs. Pigniczki, L. Kotymán, K. V.-Balogh, L. Vörös, The effect of aquatic birds on the nutrient loading and water quality of soda pans in Hungary, Acta Zool. Acad. Sci. Hung. 54 (Suppl. 1) (2008) 207–224 http://actazool.nhmus.hu/54/Suppl1/azh54_S1_Boros2.pdf.

[4] E. Boros, C. Pigniczki, T. Sápi, K. V.-Balogh, L. Vörös, B. Somogyi, Waterbird-mediated productivity of two soda pans in the carpathian basin in central europe, Waterbirds 39 (2016) 388–401, doi:10.1675/063.039.0408.

[5] E. Boros, A. Takács, P. Dobosy, L. Vörös, Extreme guanotrophication by phosphorus in contradiction with the productivity of alkaline soda pan ecosystems, Sci. Total Environ. (2021) Article reference: STOTEN_148300.

[6] F. Gill, D. Donsker, P. Rasmussen (Eds.), IOC World Bird List (v10.2), 2020 www.worldbirdnames.org, doi:10.14344/IOC.ML.10.2.

[7] D.J. Gould, M.R. Fletcher, Gull droppings and their effects on water quality, Water Res. 12 (1978) 665–762.

[8] A.J. Green, J. Elmberg, Ecosystem services provided by waterbirds, Biol. Rev. 89 (2013) 105–122.

[9] J. Kear, The agricultural importance of wild goose droppings, Wildfowl Trust 14 Ann. Rep. 1961–1962 (1963) 72–77.

[10] B.A. Manny, W.C. Johnson, R.G. Wetzel, Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality, Hydrobiologia 279 (1994) 121–132, doi:10.1007/978-94-011-1128-7_12.

[11] L. Marion, P. Clergeau, L. Brient, G. Bertru, The importance of avian-contributed nitrogen (N) and phosphorus (P) to Lake Grand-Lieu. France, Hydrobiologia 279–280 (1994) 133–147, doi:10.1007/BF00027848.

[12] J. Oláh, in: Vízimadár Anyagforgalmi Guildek. [Waterbird Trophic Guilds.], 10, Hungarian Waterfowl Publication, 2003, pp. 381–423. (In Hungarian with English summary).