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Method Article

Classification method for quantification of waterbird nutrient cycling guilds

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ABSTRACT

This classification method for quantification of waterbird nutrient cycling guilds focuses on the location of feeding habitats and the quantitative role of waterbirds in the nutrient and energy flow for inland aquatic ecosystems. The classification is a complex integration of the taxonomic, trophic, feeding and daily habitat use patterns based on most relevant previous studies and reference data in relation with the ecology and nutrient cycling of waterbirds: A) Net-importer guild: includes species which feed mostly outside inland waters in the terrestrial ecosystems and wetlands, but use water bodies as gathering and roosting sites (geese, cranes). B) Importer-exporter guild: includes species which feed both outside and in of inland waters and wetlands (dabbling ducks and gulls). C) Net-exporter guild: includes species which feed mostly on inland waters and wetlands (diving ducks, grebes, cormorants, small herons, most shorebirds). Conclusion of main findings that method can significantly contribute to the better understanding how waterbirds can effect the environment and the guilds as ecological indicators quantify their ecosystem functions, services.

- Net-importer guild includes species which feed mostly outside the inland waters
- Importer-exporter guild includes species which feed both in- and outside inland waters
- Net-exporter guild includes species which feed mostly inside the inland waters

ARTICLE INFO

Method name: Boros's guild methods
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Specifications table

Subject area:	Environmental Science
More specific subject area:	*aquatic ecology, bird ecology*
Method name:	*Boros's guild methods*
Name and reference of original method:	*This is my original Boros's method used*
Resource availability:	*All the complete datasets are presented in the supplementary tables (Table S1 and S2)*

**Method details* [Methodological protocols should be in sufficient detail to be replicated. There is no word limit! You can include figures, tables, videos – anything that you feel will help others to reproduce the method. The main focus of the paper should be on the technical steps required for this method, more than results; where appropriate, guide the reader through the procedure and provide all extra observations or "tricks" alongside the protocol. Results and Discussion are not sections included in the MethodsX format. However, providing data that validate the method is valuable and required. This section could become a "method validation" paragraph within the Method Details section.]

Waterbirds can exert significant impacts on biochemical cycles, energy flow and production in aquatic ecosystems (inland waters) by production-decomposition processes through various trophic relationships [10]. For example, the guanotrophication by waterbirds can have a significant impact on nutrient cycling, food web structure, productivity and energy flow of waters [4–7,15]. Estimating the contribution of waterbirds to the nutrient cycling of aquatic ecosystems is complicated because it is fundamentally dependent on several biological, environmental and methodological factors.

A guild is defined as a functional group of species that exploit the same class of environmental resources in a similar way [14]. Most authors identify the foraging functional and trophic guilds for waterbirds based on the physical characteristic of the feeding habitat (e.g. shallow or deep water, mudflat) and feeding techniques of the species (e.g. grazing, probing, filtering, picking) describing their trophic relations in the aquatic ecosystems. A further approach [12] combines the physical characteristics, feeding techniques and taxonomic groups (e.g. herbivorous ducks, visual and tactile surface-foraging waders, pelagic-foraging waders, wading herons, fishing pelicans and terns). Recently even the most simplified taxonomic groups classification (Anatidae, Cormorants, Cranes, Gulls, Herons, Shorebirds, Spoonbills, Storks) is also used for functional waterbird guilds as ecological indicators [16].

Besides, Oláh et al. [13] defined qualitative functional groups of waterbird for the Hungarian wetland ecosystems, which explains both the feeding and the nutrient cycling function of the birds. This concept contains three main waterbird guilds: (1) the material transporters group (e.g. grazer geese), which take organic materials from the outside of wetlands; the decomposition accelerating group which accelerates the organic breakdown inside the water bodies (e.g. ducks), and the bioturbing group which accelerates the recycling directly through mechanical effects on the bottom during feeding (e.g. waders). These three main qualitative nutrient cycling guild groups are also divided into nine subgroups based on feeding characteristics of the waterbirds species.

The aim of this study to detail a classification method for waterbird nutrient cycling guilds quantification, based on the previous related methods and studies, in order to better quantify the nutrient cycle function of waterbirds in the aquatic ecosystems.

This classification waterbird nutrient cycling guild method focuses on the location of feeding habitats daily lifecycle patterns by habitat use and the quantitative role of waterbirds in the nutrient and energy flow for inland aquatic ecosystems. This method for guilds classification and quantification was elaborated based on most relevant previous studies and reference data (habitat selection and use, feeding techniques, gathering and roosting behaviour) in relation with the ecology and nutrient cycling of waterbirds in the region [2–7,11,13,15]. Thus this is a modified adaptation of Oláh et al. [13] single nutrient transporting guild category, based on a former first version, which was applied focused on the intermittent soda pan ecosystems in Hungary [5].

The classification factors of the species into the quantitative guilds are based on the feeding habitats (aquatic, wetlands, terrestrial), feeding type (trophic relationships) and habitat use with residence time (daily pattern of habitat use) on the target site for guild classification, which are

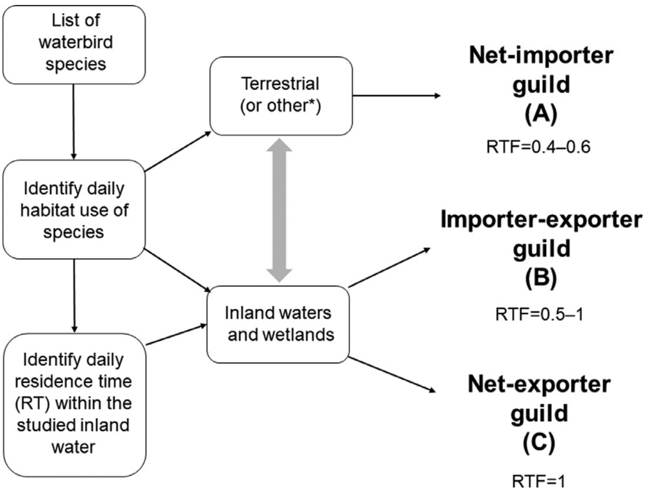

Fig. 1. The workflow of the classification method steps, with the specified daily residence time for the nutrient cycling guilds (RTF: *residence time factor*=hours spent on the target inland water/24 hours)

summarized in the Table 1. According to the aim and previous studies, the technical steps of classification method for quantification of waterbird nutrient cycling guilds categories (A, B, C) are summarized in the 1–5 points, and the workflow of the classification method steps is presented in the Fig. 1, with the specified daily residence time for the guilds, which is a complex integration of the taxonomic, trophic, feeding and habitat use factors:

(1) Identify the waterbird species list: the waterbird species list can be done by simple representative birdwatching observation, which has to cover minimum one year and all climate seasons.
(2) Identify the characteristic habitat use (feeding, assembling, roosting etc.) by each species for the studied aquatic ecosystems (inland water, wetlands, terrestrial or other aquatic habitats outside the studied inland water) or region. This step requires thematic observations from sunrise to sunset to distinguish the characteristic habitat use (feeding, assembling, roosting etc.) for each species.
(3) Identify the daily residence time factor (RTF=hours spent on the target inland water/24 h) for each species within the studied inland waters (lakes, intermittent pans, wetlands, etc.). It can be recorded during the observation of habitat use mapping.
(4) Classification of each waterbird species based on the 1–3 points as above into the three identified nutrient cycling guild categories;
(5) Quantification of the nutrient cycling guilds (A, B, C) by species number and/or density, biomass. Composition of guilds= Σ N_A species + Σ N_B species + Σ N_C species. It can be quantified by the sum of number (N) and/or density (D), biomass (B) of the waterbird species within each guilds.

The resulting waterbird nutrient cycling guilds:

A) Net-importer guild: includes species which feed mostly outside inland waters in the terrestrial ecosystems and wetlands, but use water bodies as gathering and roosting sites. Primarily they are typical large-bodied herbivorous species (e.g. geese) and secondary omnivorous species (e.g. cranes),
B) Importer-exporter guild: includes species which feed both outside and in of inland waters and wetlands. Primarily they are medium-bodied omnivorous species (e.g. dabbling ducks and gulls),

Table 1
The classification factors of the waterbirds used for quantification of specified nutrient cycling guilds in a target site or territory. Groups and species names after [9] (RTF: *residence time factor*=hours spent on the target inland water/24 hours)

Guilds	Waterbird groups or species	Scientific name	Feeding habitats	Feeding type	RTF
A	Geese	*Anser, Branta spp.*	terrestrial, wetland	herbivorous	0.4–0.6
A	Eurasian Stone-curlew, Dotterel	*Burhinus oedicnemus, Charadrius morinellus*	terrestrial, wetland	invertebrates	<0.5
A	Pratincoles	*Glareola spp.*	terrestrial, wetland	invertebrates	<0.6
A	Cranes	*Grus, Leucogeranus spp.*	terrestrial, wetland	omnivorous	0.4–0.6
A	Eurasian Woodcock	*Scolopax rusticola*	aquatic, wetland, terrestrial	invertebrates	<0.6
B	Dabbling ducks	*Anas, Mareca, Spatula spp.*	aquatic, wetland, terrestrial	omnivorous	0.8–1
B	Herons	*Ardea spp., Botaurus stellaris, Bubulcus ibis*	aquatic, wetland, terrestrial	carnivorous	0.5–1
B	Ruff	*Calidris pugnax*	aquatic, wetland, terrestrial	invertebrates	0.5–1
B	Gulls	*Chroicocephalus, Hydrocoloeus, Ichthyaetus, Larus, spp.*	aquatic, wetland, terrestrial	omnivorous	0.5–1
B	Storks	*Ciconia spp.*	aquatic, wetland, terrestrial	carnivorous	0.5–1
B	Corn Crake	*Crex crex*	aquatic, wetland, terrestrial	omnivorous	0.5–1
B	Curlews	*Numenius spp.*	aquatic, wetland, terrestrial	invertebrates	0.5–1
B	Glossy Ibis	*Plegadis falcinellus*	aquatic, wetland	carnivorous	0.5–1
B	Big Plovers, Lapwings	*Pluvialis spp., Vanellus vanellus*	aquatic, wetland, terrestrial	invertebrates	0.5–1
C	Small sandpipers	*Actitis, Calidris spp.*	aquatic, wetland	invertebrates	1
C	Small Herons	*Ardeola, Ixobrychus, Nycticorax spp., Egretta alba*	aquatic, wetland	carnivorous	1
C	Diving ducks	*Aythya, Bucephala, Clangula, Melanitta, Mergus, Mergellus, Somateria spp.*	aquatic	omnivorous	1
C	Small Plovers	*Charadrius spp.*	aquatic, wetland	invertebrates	1
C	Skuas, Terns	*Chlidonias, Hydroprogne, Stercorarius, Sterna spp.*	aquatic, wetland, terrestrial	carnivorous	1
C	Swans	*Cygnus spp.*	aquatic, wetland	omnivorous	1
C	Coots, Crakes, Moorhen, Rails	*Fulica, Gallinula, Porzana, Rallus, Zaporina spp.*	aquatic, wetland	omnivorous	1
C	Snipes	*Gallinago, Lymnocryptes spp.*	aquatic, wetland	invertebrates	1
C	Black-winged Stilt, Pied Avocet	*Himantopus himantopus, Recurvirostra avosetta*	aquatic, wetland	invertebrates	1
C	Godwits, Dowitchers	*Limosa, Limnodromus spp.*	aquatic, wetland	invertebrates	1
C	Cormorants	*Phalacrocorax, Microcarbo spp.*	aquatic	piscivorous	1
C	Phalarops	*Phalaropus spp.*	aquatic, wetland	invertebrates	1
C	Eurasian Spoonbill	*Platalea leucorodia*	aquatic	carnivorous	1
C	Grey Plover, Eurasian Oystercatcher, Ruddy Turnstone	*Pluvialis squatarola, Haematopus ostralegus, Arenaria interpres*	aquatic, wetland	invertebrates	1
C	Grebes, Loons	*Podiceps, Tachybaptus, Gavia spp. spp.*	aquatic	piscivorous	1
C	Shelducks	*Tadorna spp.*	aquatic, wetland	omnivorous	1
C	Big sandpipers	*Tringa, Xenus spp.*	aquatic, wetland	invertebrates	1

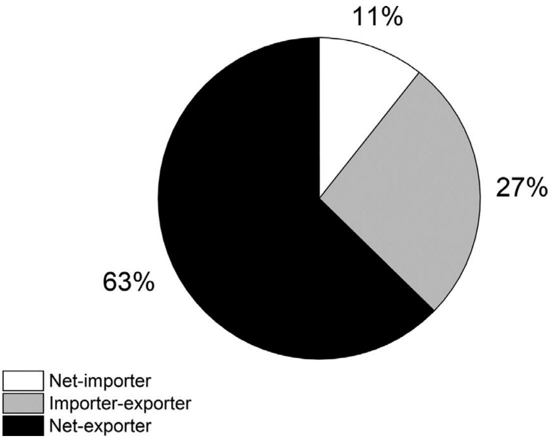

Fig. 2. Percentage distribution of species number by classification method for quantification of specified waterbird nutrient cycling guilds (Central Europe, Hungary)

C) Net-exporter guild: includes species which feed mostly on inland waters and wetlands. These are medium-bodied piscivorous (e.g. grebes, cormorants, small herons), omnivorous (e.g. diving ducks) and/or typical small-bodied species feeding on invertebrates (e.g. most shorebirds species).

According to the classification factors, if the investigated species use different aquatic habitats for feeding, roosting or spending the night within an area in the same time, thus it belongs to the net-exporter guild in the feeding site and to the net-importer guild in the roosting site. Furthermore, the classification also depends on breeding, migrating and wintering seasons, though classification method can be extended for a complete region, by consideration of the guild classification of most characteristic habitats, behaviour and lifecycle of the waterbird species within the analysed territory. As an example for application, a regional classification of the waterbird community is developed for quantification of nutrient cycling guilds in the Central European (Carpathian Basin) Pannon Biogeographical region. The complete species ($N_{species}$ = 150) list of classification for quantification of nutrient cycling guilds of waterbirds is presented in Table S1. According to the species composition of the guilds, the net-importer guild is dominated by large-bodied herbivorous geese species ($N_{species}$ = 9; 56%), the importer-exporter guild by medium-bodied omnivorous gull ($N_{species}$ = 14; 35%) and duck ($N_{species}$ = 7; 18%) species, while the net-exporter guild by small-bodied (Charadriidae, Haematopodidae, Recurvirostridae, Scolopacidae) shorebird species feeding on invertebrates ($N_{species}$ = 37; 43%) and medium-bodied omnivorous diving ducks ($N_{species}$ = 20; 21%). Overall the number of waterbird species in the guilds is increasing with the residence time in the aquatic and wetland ecosystem as in order: net-importer guild (16; 11%), importer-exporter guild (40; 27%), net-exporter guild (94; 63%), which percentage distribution (%) is presented in Fig. 2. Another regional example of classification and quantification is also presented in the Eurasian steppe zone from Central Asia (Kazakhstan) in Alakol National Nature Reserve based on a local ornithological survey [1] and own observations (Table S2). In contrast with the relatively long distance (~4600 km) between the presented territories, the composition of the Central Asian waterbird species list and their percentage distribution in nutrient cycling guilds are very similar to Central European: net-importer guild (14; 11%), importer-exporter guild (31;25%), net-exporter guild (79; 64%).

The classification method and quantification of waterbird nutrient cycling guilds can significantly contribute to the better understanding how waterbirds can effect ecosystems, quantify their ecosystem functions and services, that is a fundamental requirement for more effective environmental monitoring and management. The classification method was developed based on and tested by Boros's generalized method [8], which is a referred reliable estimation to the carbon (C), nitrogen

(N) and phosphorus (P) loading of waterbirds on aquatic ecosystems, thus rationale why this formula presented is valid can be proven with detailed nutrient loading calculation by related studies [5–7,15]. Besides, this classification method can be easy used for quick quantitative nutrient cycling surveys of waterbirds population in the inland aquatic ecosystems, without time consuming constant bird population monitoring efforts and detailed nutrient or energy balance calculation, only the classification factors must be followed by simple periodical observations and modified the classification scheme if any of the species factors change. Furthermore, the classification of waterbird nutrient cycling guilds can be completed with the seasonal number, density or biomass data of the bird species or even detailed nutrient loading estimation, which allows different levels of multivariate guild analyses and getting qualitative information about trophic linkages.

The accuracy of classification can be increased by taking into account the regional, local and seasonal ecology of the waterbirds populations, thus development of innovative regional classifications are encouraged, which can be different structured guilds with same species (as in Tables S1 and S2). The implementation both of the former qualitative concepts and current quantitative guild classification method for waterbirds can also be regarded as ecological indicators for productivity and trophic relations as a useful practical approach in the applied aquatic ecology and management including its terrestrial environment land use as well.

Acknowledgments

[OPTIONAL. This is where you can acknowledge colleagues who have helped you that are not listed as co-authors, and funding. MethodsX is a community effort, by researchers for researchers. We highly appreciate the work not only of authors submitting, but also of the reviewers who provide valuable input to each submission. We therefore publish a standard "thank you" note in each of the articles to acknowledge the efforts made by the respective reviewers.]

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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.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mex.2021.101597.

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