RUSSIAN JOURNAL OF ECOSYSTEM ECOLOGY Vol. 7 (1), 2022

Received 05.01.2022 Revised 26.02.2022 Accepted 10.03.2022 RESEARCH ARTICLE Open Access

DOI 10.21685/2500-0578-2022-1-4

SEASONAL VARIATION IN SPECIES RICHNESS AND ABUNDANCE OF WATERBIRDS IN THE SUBURBS OF ASMARA CITY, ERITREA

R. T. Tewelde[1], D. B. Araya[2]

[1] *Eritrea Institute of Technology, P.O.Box 12676, Asmara-Eritrea*

[2] *Private naturalist, P.O.Box 5368, Asmara-Eritrea*

[1] *teweledert@gmail.com,* [2] *dawitray1@gmail.com*

Abstract. Wetlands provide organisms with a diverse range of breeding sites and food, allowing them to survive during the non-breeding season. Despite the hotspot area, the waterbird fauna in the suburbs of Asmara city is poorly described. Information on the seasonal variation in species diversity and abundance is generally patchy. The study described the seasonal change in waterbird species diversity and abundance in different locations with varying physiological and ecological conditions. Waterbirds usually congregate around open wetlands, hence their abundance is more appropriately determined by counting all individuals in the congregate. The direct total area count method was implemented, and data was collected both during the dry (January-March) and wet (July-September) seasons of the year 2020. Species similarity between the study sites was calculated using The Morisita-Horn index (C_{MH}). A total of 5641 waterbirds were counted, representing 12 families and 47 species. The study shows a significant difference ($p<0.05$) in species abundance between the wet and dry seasons, although species richness is not statistically significant. The highest site similarity and low complementarity was seen between Radar and Adi-Nefas areas ($C_{MH} = 0.759$). Despite seasonal species turnover, the total species diversity does not show significant change, while their abundance being notably higher during the dry season. Few waterbird species appear in dominant number, while the majority species are represented by a few individuals. In general, site similarity was high in the dry season, and maximum similarity was seen between Radar and Adi-Nefas sites both in the wet and dry seasons.

Keywords: wetland habitats, waterbirds, species composition, species richness, species abundance

Acknowledgement. The Rufford Small Grant Foundation funded the project, which the authors gratefully acknowledge. IDEA WILD also donated field equipment, which we appreciate. Finally, we thank the Department of Biology, Eritrea Institute of Technology, for their unwavering material and moral support.

For citation: Tewelde R.T., Araya D.B. Seasonal variation in species richness and abundance of waterbirds in the suburbs of Asmara city, Eritrea. *Russian Journal of Ecosystem Ecology*. 2022;7(1). Available from: https://doi.org/10.21685/2500-0578-2022-1-4

УДК 574.22

СЕЗОННЫЕ ИЗМЕНЕНИЯ ВИДОВОГО БОГАТСТВА И ЧИСЛЕННОСТИ ВОДОПЛАВАЮЩИХ ПТИЦ В ПРИГОРОДАХ ГОРОДА АСМЭРА , ЭРИТРЕЯ

Р. Т. Тевельде[1], Д. Б. Арайя[2]

[1] *Технологический институт Эритреи, а/я 12676, Асмэра-Эритрея*

[2] *Частный натуралист, а/я 5368, Асмэра-Эритрея*

[1] *teweledert@gmail.com,* [2] *dawitray1@gmail.com*

Аннотация. Водно-болотные угодья предоставляют организмам разнообразные места для размножения и пищу, что позволяет им выживать в негнездовой сезон. Несмотря на горячую точку, фауна водоплавающих птиц пригородов города Асмэра описана слабо. Информация о сезонных изменениях видового разнообразия и численности, как правило, разрозненна. В данном исследовании описаны сезонные изменения видового разнообразия и численности водоплавающих птиц на различных участках с разными физиологическими и экологическими условиями. Водные птицы обычно собираются вокруг открытых водно-болотных угодий,

поэтому их численность правильнее определять путем подсчета всех особей в скоплении. Был применен метод прямого подсчета общей площади, и данные собирались как в сухой (январь-март), так и во влажный (июль-сентябрь) сезоны 2020 г. Индекс Морисита-Хорна (C_{MH}) использовался для расчета видового сходства между исследуемыми участками. Всего была учтена 5641 водоплавающая птица, представляющая 12 семейств и 47 видов. Исследование показывает значительную разницу ($p<0,05$) в обилии видов между влажным и сухим сезонами, хотя видовое богатство статистически не значимо. Наибольшее сходство участков и низкая комплементарность наблюдалась между районами Радар и Ади-Нефас (СМН = 0,759). Несмотря на сезонный оборот видов, общее видовое разнообразие не показывает значительных изменений, в то время как их обилие заметно выше в сухой сезон. Лишь немногие виды водных птиц преобладают по численности, в то время как большинство видов представлено несколькими особями. В целом сходство участков было высоким в сухой сезон, а максимальное сходство наблюдалось между участками Радар и Ади-Нефас как во влажный, так и в сухой сезон.

Ключевые слова: водно-болотные местообитания, водоплавающие птицы, видовой состав, видовое богатство, видовое изобилие

Благодарности. Авторы выражают признательность Фонду малых грантов Руффорда (Rufford Small Grant Foundation) за финансирование проекта. Авторы также высоко ценят роль организации IDEA WILD в безвозмездной передаче полевого оборудования. Авторы благодарят кафедру «Биология» Технологического института Эритреи за неизменную материальную и моральную поддержку.

Для цитирования: Тевельде Р. Т., Арайя Д. Б. Сезонные изменения видового богатства и численности водоплавающих птиц в пригородах города Асмэра, Эритрея // Russian Journal of Ecosystem Ecology. 2022. Vol. 7 (1). https://doi.org/10.21685/2500-0578-2022-1-4

Understanding the spatial and temporal patterns in species richness and their relative abundance is a fundamental challenge in ecology [1]. Studies show that climate [2, 3] and habitat productivity [4, 5] determine the structure of species assemblages, distribution, and abundance across large spatial scales. Temporal changes in climatic conditions can occur locally, resulting in climatic variability [6] and fluctuations in resource availability [7].

Seasonality affects the availability of food and cover for bird populations, which in turn affects the breeding success and, ultimately, the survival of the bird species [8]. Seasonal variations in the amount of rainfall and temperature as well as spatial and temporal microhabitat conditions are known to influence the availability of various food items for birds [9, 10]. Moreover, the seasonal weather variations can change water quality parameters in an area which in turn will change habitat variables, such as vegetation. Changes in vegetation characteristics affect the availability of important food resources [11, 12] to waterbirds which ultimately affects their diversity and abundance.

Despite the presence of a diverse range of wetland ecosystems across the country, no comprehensive studies have been conducted [3]. In Eritrea, there have been no significant scientific investigations on the ecology, diversity, or abundance of waterbirds. Waterbird diversity, abundance and seasonal dynamics are all poorly understood. This study looked at how waterbird species richness and abundance varied with seasonality in the suburbs of Asmara city.

Generally, dry season (November to April) and wet season (May to October) exist in the ecological zone of Eritrea [13, 14]. According to Behrouzi-Rad [15], species diversity and abundance of waterbirds generally decrease in the dry season, where the level of the water body falls and/or dries up completely, as compared to the wet season. The annual migration of birds in response to seasonal changes is known to affect the species richness, their diversity, and abundance. Rajashekara and Venkatesha [16], however, reported relatively high number of waterbird species during the dry season, owing to the arrival of migratory birds in route to their breeding or wintering grounds.

The ability to prioritize and implement conservation initiatives requires accurate information on their population status, distribution range, annual cycle, and population change over time [17]. Waterbirds require a network of high-quality sites for nesting, refueling during migration, and surviving the non-breeding season [18], where this research emphasizes the importance of the site for waterbirds during their annual cycle.

Material and methods

The research site is located in the central highlands at an elevation of 2325 m above sea level. It includes all the suburbs of the capital city Asmara, characterized by natural and manmade wetland habitats (seasonal natural surface water bodies, small to large-sized dams, and the sewage system of the city), irrigated farmlands, and open grazing areas. Rainfall is generally inadequate and unreliable with annual rainfall 500 mm [14]. Moreover, it includes wetlands proposed important bird areas, which are known to support regionally and globally threatened birds throughout the year.

Based on the water holding capacity and vegetation complexity, the study area has been stratified into three district study units (Sembel, Radar, and Adi-Nefas areas). Sembel is characterized by rich vegetation cover and floating aquatic weeds surrounded by trees and shrubs. Used for small-scale irrigation farms. Radar includes several small dams and the sewage stream of Asmara City along with the irrigation farmlands and open grazing areas. The Adi-Nefas area features an open dam with no floating vegetation used for animal watering and irrigation.

Prior to the actual survey, spots were predefined purposively at intervals. The site was covered systematically traversing on foot giving general thought to the light conditions. Multiple counts were made both during wet and dry seasons. The relative abundance of each species seen or heard was estimated(counted whenever possible) for each study unit, based on the assumption that common birds are more likely to be seen first, using the whole area search technique.

Birds in flight were not counted to reduce the incidence of double counting [19]. Counting was performed using a 10 × 50 binocular. The research was conducted from January to March (dry season) and July to September 2019 (wet season). Each study site was surveyed twice a month for a total of 12 times. Waterbirds were counted during the early morning (6–10) and late afternoon (16–18) hours when they are most active. Birds of Ethiopia and Eritrea: an atlas of distribution [20] and Birds of the Horn of Africa: Ethiopia, Eritrea, Djibouti, Somalia, and Socotra [21] were used to identify birds.

The total bird count was generated for each study site/unite and the relative abundance (R) of each species was calculated. Species similarities between the three sites was estimated using the quantitative Morisita-Horn index (C_{MH}), although it is a little biased on the difference in species richness and sample size [22]. The value of the similarity indices ranges between zero, no species overlap, and one, complete similarity. Generally, $C_{MH} \geq 0.5$ is rated as a high similarity, while $C_{MH} \geq 0.75$ is a very high similarity. Mann–Whitney U test, a non-parametric test, was used to determine the significance of waterbird abundance at the various study sites between the wet and dry seasons; and Kruskal–Wallis to test the significant level abundance among the three study sites.

Results and discussion

Species richness

Overall, 47 species of waterbirds belonging to five orders and 12 families were identified. There were 37 species encountered during the wet season, with 13 species common to all sites, compared to 33 species during the dry season (Table 1 and 2). During the dry season, 15 species were identified across all sites. Thus, there is no statistically significant difference in species richness in the wet and dry seasons. As well during the wet and dry seasons, 23 resident species were recognized. Similarly, 14 species were only found during the rainy season, whereas 10 were discovered exclusively during the dry season.

Table 1

Species diversity and relative abundance of waterbirds during the wet season

Scientific Name	Radar	Adi–Nefas	Sembel	Total	R*
1	2	3	4	5	6
Ciconia abdimii	46	–	23	69	3.1
Mycteria ibis	–	2	–	2	0.1
Ardea melanocephala	21	2	5	28	1.3
Ardea cinerea	12	1	–	13	0.6
Ardeola ralloides	–	–	5	5	0.2
Vanellus tectus	37	8	17	62	2.8
Vanellus spinosus	94	3	25	122	5.5
Charadrius tricollaris	10	7	–	17	0.8
Charadrius hiaticula	1	–	–	1	0.0
Vanellus senegallus	–	–	6	6	0.3
Tringa ochropus	56	2	1	59	2.7
Actitis hypoleucos	36	–	3	39	1.8
Alopochen aegyptiaca	203	271	52	526	23.8
Oxyura maccoa	3	–	6	9	0.4
Spatula querquedula	–	–	5	5	0.2
Anas acuta	19	1	237	257	11.6
Fulica cristata	3	108	92	203	9.2
Fulica atra	47	–	–	47	2.1
Threskiornis aethiopicus	172	1	3	176	8.0
Bostrychia carunculata	39		6	45	2.0
Plegadis falcinellus	–	–	4	4	0.2

End of the Table 1

1	2	3	4	5	6
Bostrychia hagedash	27	–	14	41	1.9
Chlidonias leucopterus	3	–	–	3	0.1
Gelochelidon nilotica	1	–	–	1	0.0
Bubulcus ibis	17	9	3	29	1.3
Ardea intermedia	48	–	5	53	2.4
Egretta garzetta	41	–	–	41	1.9
Spatula clypeata	33	–	–	33	1.5
Limosa limosa	1	–	–	1	0.0
Pelecanus rufescens	–	23	–	23	1.0
Scopus umbretta	23	2	4	29	1.3
Tachybaptus ruficollis	26	30	28	84	3.8
Anas crecca	–	–	6	6	0.3
Himantopus himantopus	22	–	15	37	1.7
Rougetius rougetii	3	7	4	14	0.6
Tringa totanus	–	–	16	16	0.7
Calidris pugnax	75	6	26	107	4.8
Total Individuals	1119	483	611	2213	100
Total Species	29	17	26	37	

R* = Relative Abundance.

Table 2

Species diversity and relative abundance of waterbirds during the dry season

Scientific Name	Radar	Adi–Nefas	Sembel	Total	R
Egretta garzetta	43	35	32	110	3.2
Podiceps cristatus	27	20	17	64	1.9
Pelecanus rufescens	124	87	–	211	6.2
Ardea cinerea	22	18	11	51	1.5
Ardeola ralloides	–	–	15	15	0.4
Ardea goliath	8	–	6	14	0.4
Egretta garzetta	19	7	53	79	2.3
Bubulcus ibis	13	5	9	27	0.8
Ciconia abdimii	23	12	–	35	1.0
Ciconia nigra	6	8	–	14	0.4
Ciconia ciconia	9	–	–	9	0.3
Mycteria ibis	12	2	–	14	0.4
Threskiornis aethiopicus	83	–	26	109	3.2
Plegadis falcinellus	–	–	37	37	1.1
Scopus umbretta	18	7	–	25	0.7
Alopochen aegyptiaca	273	535	147	955	27.9
Spatula clypeata	98	143	139	380	11.1
Fulica cristata	92	59	7	158	4.6
Vanellus spinosus	82	63	49	194	5.7
Charadrius tricollaris	14	6	36	56	1.6
Charadrius dubius	21	39	11	71	2.1
Limosa limosa	–	–	73	73	2.1
Tringa stagnatilis	10	59	18	87	2.5
Actitis hypoleucos	16	26	11	53	1.5
Tringa ochropus	–	–	74	74	2.2
Calidris minuta	4	28	–	32	0.9
Himantopus himantopus	15	7	27	49	1.4
Himantopus mexicanus	–	13	2	15	0.4
Gallinago media	–	1	–	1	0.0
Calidris pugnax	12	184	68	264	7.7
Anas acuta	–	–	125	125	3.6
Anas sparsa	–	–	5	5	0.1
Oxyura maccoa	13	–	9	22	0.6
Total Individuals	1057	1364	1007	3428	100
Total Species	25	23	25	33	

During the wet season, both Radar and Sembel areas scored the highest number of species, 29 and 26 species respectively; while 17 species were encountered in Adi-Nefas. During the dry season, in contrast, all three sites scored a similar number of species, both Radar and Sembel with 25 species followed by Adi-Nefas (23). Both Radar and Sembel exhibit a slight decrease in species richness during the dry season, whereas Adi-Nefas exhibits more than a 35 % increase in the number of species when compared to the wet season.

The highest number of shared species (20) occurred between Radar and Sembel sites, in the wet season, followed by Radar and Adi-Nefas (15); whiles 21 species were common to Radar and Adi-Nefas areas in the dry season. Overall, the quantitative Morisita-Horn index (C_{MH}) shows the highest similarity and low complementarity between Radar and Adi-Nefas areas (C_{MH} = 0.759). In contrast, Adi-Nefas and Sembel scored the lowest index (C_{MH} = 0.484) (Table 3) indicating relatively low similarity between the sites. This is mainly due to the topographic and productivity difference between the sites during the various seasons. Generally, the similarity between the sites is high or very high during the dry season compared to the wet season.

Table 3

Species similarity among the four study sites in Mole National Park, as shown by the quantitative Morisita–Horn index (C_{MH})

	Wet-Season		Dry-Season		Total Similarity	
	Adi-Nefas	Sembel	Adi-Nefas	Sembel	Adi-Nefas	Sembel
Radar	0.468	0.257	0.844	0.632	0.759	0.568
Adi-Nefas		0.308		0.621		0.484

Species abundance

Generally, 2213 waterbirds were counted during the wet season compared to 3428 in the dry season, which shows a significant difference in the abundance of waterbirds between the two seasons (see Table 1 and 2). According to [23], waterbirds gather around the permanent water bodies, and often seen the high numbers of individuals, during the dry season. The mean abundance of waterbirds in the dry season is statistically significant ($P< 0.05$) compared to the wet season recording the highest number of individuals in both Adi-Nefas and Sembel, while there is no significant difference in Radar.

Only 12 species were represented by ≥100 individuals, whereas 23 species occurred in small numbers ((≤50) during the study period, 9 species of which were represented by less than 10 individuals (see Table 1 and 2). Generally, only a few species appeared in dominant number, while the majority species (Fig. 1) represented by a few individuals. The trend with a few common species and many species represented by few individuals seemed not to be strongly influenced by species turnover. Species turnover was observed in all of the study sites over the study period. As a result, some species moved in and others moved out of the site. This might mean that migratory birds, such as waders, are either using the sites as stopover locations, to refuel during the long journey, or wintering ground to overcome drought and avoid competition in their breeding area.

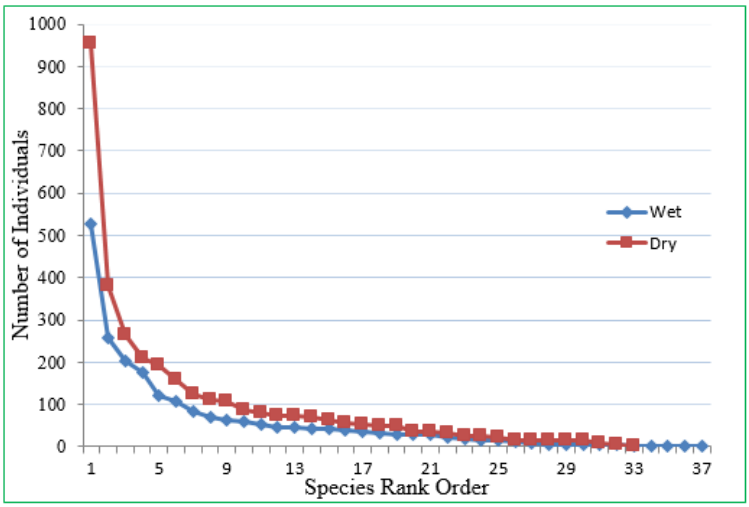
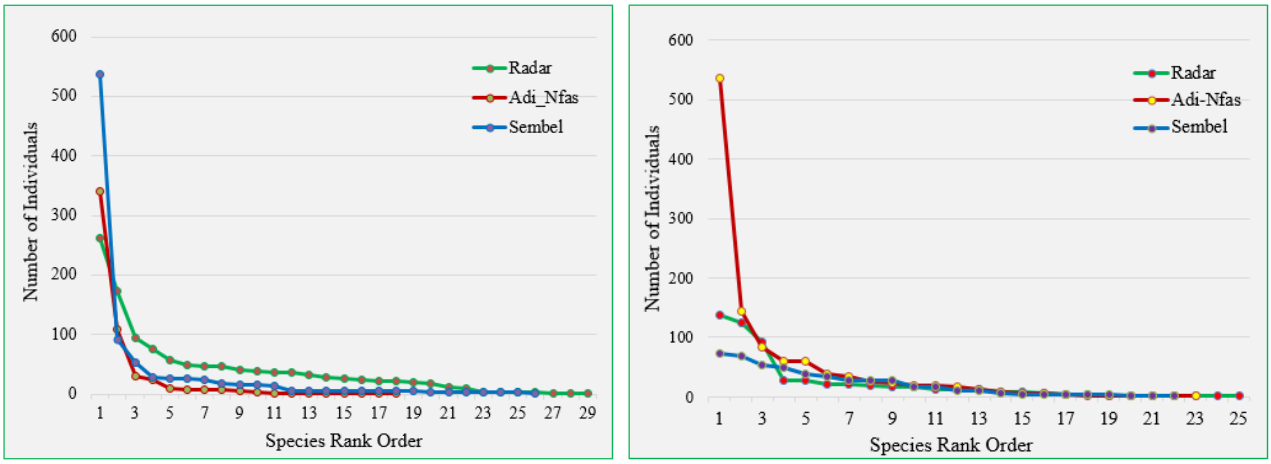


Fig. 1. Total species rank order in the wet and dry seasons

Egyptian Goose *Alopochen aegyptiaca* was the most abundant species during both wet (R = 23.8) and dry (R = 27.9) seasons, followed by the Northern pintail *Anas acuta* (R = 11.6), and Northern Shoveler *Spatula clypeata* (R = 11.1) respectively (Table 1 and 2). Similarly, Egyptian Goose was the most dominant species in Radar and Adi-Nefas areas throughout the year. In the wet season, Northern pintail was found abundantly in Sembel (Fig. 2,*a*), and Egyptian Goose and Northern Shoveler, however, appeared to be equally dominating during the dry season (Fig. 2,*b*), likely due to high food productivity and low human disturbance.



a) *b*)

Fig. 2. Species rank order in the study units relative to the wet (*a*) and dry (*b*) seasons

Conclusion

The study shows the importance of the waterbodies to wetland species, including internationally threatened. In general, there is no discernible difference in species richness across seasons and study sites. High species turnover was observed between the wet and dry seasons, which coincided with bird migration. The abundance of waterbirds shows significant variation between the seasons, with high abundance counted in the dry season. Only a few waterbird species appear in dominant number, while majority species represented by a few individuals. Generally, the site similarity is high during the dry season of the year, and the highest similarity scored between Radar and Adi-Nefas sites both in wet and dry seasons.

References

1. Gaston K.Dzh. Global patterns in biodiversity. *Priroda = Nature*. 2000;405:220–227. (In Russ.)
2. Khokins B.A., Fild R., Kornell Kh.V. [et al.]. Energy, water, and broad-scale geographic patterns of species richness. *Ekologiya = Ecology*. 2003;(84):3105–3117. (In Russ.)
3. Rakhbek K., Gotelli N.Dzh., Kolvell R.K. [et al.]. Predicting continental-scale patterns of bird species richness with spatially explicit models. *Sbornik trudov Korolevskogo obshchestva B: Biologicheskie nauki = Proceedings of the Royal Society B: Biological Sciences*. 2007;(274):165–174. (In Russ.)
4. Vayde R.B., Villig M.R., Shtayner K.F. [et al.]. The relationship between productivity and species richness. *Ezhegodnyy obzor ekologii i sistematiki = Annual Review of Ecology and Systematics*. 1999;(30):257–300. (In Russ.)
5. Khokins B.A., Porter E.E., Felizola Diniz-Fil'o Dzh.A. Productivity and history as predictors of the latitudinal diversity gradient of terrestrial birds. *Ekologiya = Ecology*. 2003;(84):1608–1623. (In Russ.)
6. Uil'yams S.E., Middlton Dzh. Climatic seasonality, resource bottlenecks, and abundance of rainforest birds: implications for global climate change. *Raznoobrazie i raspredelenie = Diversity and Distributions*. 2008;(14):69–77. (In Russ.)
7. Ronal'd K.M., Eyke L.N., Katrin B.G., Mattias S. Seasonal fluctuations of resource abundance and avian feeding guilds across forest–farmland boundaries in tropical Africa. *Oikos*. 2013;(122):524–532. (In Russ.)
8. Mengesha G., Bekele A. Diversity and relative abundance of birds of Alatish National Park, North Gondar, Ethiopia. *Mezhdunarodnyy zhurnal ekologii i nauk ob okruzhayushchey srede = International Journal of Ecology and Environmental Sciences*. 2008;(34):215–222. (In Russ.)
9. Machak A., Yanda M., Dann R.R., Sanders N.Dzh. Elevation gradients in phylogenetic structure of ant communities reveal the interplay of biotic and abiotic constraints on diversity. *Ekografiya = Ecography*. 2011;34:364–371. (In Russ.)

10. Linkol'n K., Fredrik K., Peterson S.R., Tsimmerman Dzh.L. *Migratsiya ptits. Vashington, okrug Kolumbiya : Obshchestvo okhrany ryb i dikoy prirody SShA = Migration of birds. Washington, DC : United States Fish and Wildlife Society*. 1998. (In Russ.)
11. Naugl D.E., Dzhonson R.R., Esti M.E., Khiggins K.F. A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota. *Vodno-bolotnye ugod'ya = Wetlands*. 2000;(20):588–604. (In Russ.)
12. Riffell S.K., Keas B.E., Berton T.M. Area and habitat relationships of birds in Great Lakes coastal wet meadows. *Vodno-bolotnye ugod'ya = Wetlands*. 2001;(21):492–507. (In Russ.)
13. *Natsional'nyy plan ratsional'nogo prirodopol'zovaniya Eritrei = National Environmental Management Plan for Eritrea.* Department of Environment, Ministry of Land, Water & Environment. 1995:274. (In Russ.)
14. Gebru K., Redkliff D., Berkhe G., Yosef D. *Karta agroekologicheskikh zon Eritrei. Tablitsa uslovnykh oboznacheniy = Map of agroecological zones of Eritrea. Table of symbols*. Asmera: Ministerstvo zemel'nykh, vodnykh i ekologicheskikh resursov, 1997:256. (In Russ.)
15. Bekhruzi R.B. Waterbird populations during dry and wet years in the Hamoun Wetlands Complex, Iran/Afghanistan Border. *Podoces*. 2009;(4):88–99. (In Russ.)
16. Radzhashekara S., Venkatesha M.G. Eco-spatial and temporal variation in waterbirds composition and their relationship with habitat characteristics of Urban Lakes of Bengaluru city, India . *Mezhdunarodnyy zhurnal perspektivnykh issledovaniy = International Journal of Advanced Research*. 2014;(2):60–80. (In Russ.)
17. Russom T.T., Kunduru S.R. Diversity and Abundance of Waterbirds in Maekel Zone, Eritrea, North East Africa. *Mezhdunarodnyy zhurnal perspektivnykh issledovaniy = International Journal of Advanced Research*. 2016;(4): 773–787. (In Russ.)
18. *Rukovodstvo v ramkakh Afrikansko-Evraziyskogo soglasheniya po sokhraneniyu vodoplavayushchikh ptits. Mezhdunarodnaya organizatsiya vodno-bolotnykh ugodiy – Vageningen = African Eurasian Waterbird Agreement Conservation guidelines. Wetland International – Wageningen*. 2005:117. (In Russ.)
19. Bibbi K.Dzh., Berdzhess N.D., Khill D.A., Masto S.Kh. *Metody perepisi ptits = Bird census techniques*. London: Academic Press, 2000:302. (In Russ.)
20. Esh K., Atkins Dzh. (eds.). *Ptitsy Efiopii i Eritrei: Atlas rasprostraneniya = Birds of Ethiopia and Eritrea: An Atlas of Distribution*. London: Christopher Helm, 2009:463. (In Russ.)
21. Naydzhel R., Terri S., Dzhon F. (eds.). *Ptitsy Afrikanskogo Roga: Efiopiya, Eritreya, Dzhibuti, Somali i Sokotra = Birds of the Horn of Africa: Ethiopia, Eritrea, Djibouti, Somalia and Socotra*. 2nd ed. London: Christopher Helm, 2009:512. (In Russ.)
22. Magurran A. (ed.). *Ekologicheskoe raznoobrazie i ego izmerenie = Ecological diversity and its measurement* . London: Izdatel'stvo Prinstonskogo universiteta, 1988:181. (In Russ.)
23. Mundava Dzh., Aleksandre K., Nikolas G. [et al.]. Factors influencing long-term and seasonal waterbird abundance and composition at two adjacent lakes in Zimbabwe. *Ostrich: Zhurnal afrikan-skoy ornitologii = Ostrich: Journal of African Ornithology*. 2012;(83):69–77. (In Russ.)

Библиографический список

1. Гастон К. Дж. Глобальные закономерности в биоразнообразии // Природа. 2000. Т. 405. С. 220–227.
2. Хокинс Б. А., Филд Р., Корнелл Х. В. [и др.]. Энергетические, водные и широкомасштабные географические закономерности богатства видов // Экология. 2003. № 84. С. 3105–3117.
3. Рахбек К., Готелли Н. Дж., Колвелл Р. К. [и др.]. Прогнозирование богатства видов птиц в масштабе континента с помощью четких территориальных моделей // Сборник трудов Королевского общества В: Биологические науки. 2007. № 274. С. 165–174.
4. Вайде Р. Б., Виллиг М. Р., Штайнер К. Ф. [и др.]. Взаимосвязь между продуктивностью и богатством видов // Ежегодный обзор экологии и систематики. 1999. № 30. С. 257–300.
5. Хокинс Б. А., Портер Э. Э., Фелизола Диниз-Фильо Дж. А. Продуктивность и история как прогностические параметры широтного градиента разнообразия наземных птиц // Экология. 2003. № 84. С. 1608–1623.
6. Уильямс С. Э., Миддлтон Дж. Климатическая сезонность, недостаток ресурсов и видовое разнообразие птиц тропических лесов: последствия глобального изменения климата // Разнообразие и распределение. 2008. № 14. С. 69–77.
7. Рональд К. М., Эйке Л. Н., Катрин Б. Г., Маттиас С. Сезонные колебания изобилия ресурсов и кормовых баз птиц на границах лесов и сельскохозяйственных угодий в тропической Африке // Oikos. 2013. № 122. С. 524–532.
8. Менгеша Г., Бекеле А. Разнообразие и относительная численность птиц Национального парка Алатиш, Северный Гондэр, Эфиопия // Международный журнал экологии и наук об окружающей среде. 2008. № 34. С. 215–222.
9. Мачак А., Янда М., Данн Р. Р., Сандерс Н. Дж. Градиенты высот в филогенетической структуре муравьиных сообществ, отражающие взаимодействие биотических и абиотических ограничений на разнообразие // Экография. 2011. Т. 34. С. 364–371.
10. Линкольн К., Фредрик К., Петерсон С. Р., Циммерман Дж. Л. Миграция птиц. Вашингтон, округ Колумбия : Общество охраны рыб и дикой природы США, 1998.

11. Наугл Д. Э., Джонсон Р. Р., Эсти М. Э., Хиггинс К. Ф. Ландшафтный подход к сохранению среды обитания птиц на водно-болотных угодьях в районе карстовых углублений в прериях восточной части Южной Дакоты // Водно-болотные угодья. 2000. № 20. С. 588–604.
12. Риффелл С. К., Кеас Б. Э., Бертон Т. М. Соотношение ареала и среды обитания птиц на прибрежных влажных лугах Великих озер // Водно-болотные угодья. 2001. № 21. С. 492–507.
13. Национальный план рационального природопользования Эритреи. Департамент окружающей среды Министерства земельных, водных и экологических ресурсов, 1995. С. 274.
14. Гебру К., Рэдклифф Д., Берхе Г., Йосеф Д. Карта агроэкологических зон Эритреи. Таблица условных обозначений. Асмэра : Министерство земельных, водных и экологических ресурсов, 1997. 256 с.
15. Бехрузи Р. Б. Популяции водоплавающих птиц в засушливые и влажные годы в комплексе водно-болотных угодий Хамун, граница Ирана и Афганистана // Podoces. 2009. № 4. С. 88–99.
16. Раджашекара С., Венкатеша М. Г. Эколого-пространственные и временные различия в составе водоплавающих птиц и их взаимосвязь с характеристиками среды обитания городских озер города Бангалор, Индия // Международный журнал перспективных исследований. 2014. № 2. С. 60–80.
17. Руссом Т. Т., Кундуру С. Р. Разнообразие и численность водоплавающих птиц в зоне Маекел, Эритрея, Северо-Восточная Африка // Международный журнал перспективных исследований. 2016. № 4. С. 773–787.
18. Руководство в рамках Африканско-Евразийского соглашения по сохранению водоплавающих птиц. Международная организация водно-болотных угодий – Вагенинген, 2005. 117 с.
19. Бибби К. Дж., Берджесс Н. Д., Хилл Д. А., Масто С. Х. Методы переписи птиц. Лондон : Academic Press, 2000. С. 302.
20. Птицы Эфиопии и Эритреи: Атлас распространения / под ред. К. Эш, Дж. Аткинса. Лондон : Christopher Helm, 2009. 463 с.
21. Птицы Африканского Рога: Эфиопия, Эритрея, Джибути, Сомали и Сокотра / под ред. Р. Найджела, С. Терри, Ф. Джона. 2-е изд. Лондон : Christopher Helm, 2009. 512 с.
22. Экологическое разнообразие и его измерение / под ред. А. Магуррана. Лондон : Издательство Принстонского университета, 1988. 181 с.
23. Мундава Дж., Александре К., Николас Г. [и др.]. Факторы, влияющие на долгосрочную и сезонную численность и состав водоплавающих птиц на двух соседних озерах в Зимбабве // Ostrich: Журнал африканской орнитологии. 2012. № 83. С. 69–77.