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SEASONAL DYNAMICS AND RESOURCES OF AQUATIC INVERTEBRATES OF SIVASH AS A FORAGE BASE AND KEY AREA FOR TUNDRA WADERS, MIGRATING ALONG THE AFRO-EURASIAN FLYWAYS

Results of nine years of the research (1994-2002) dedicated to the role of aquatic invertebrates in the distribution of long-distance migrating species of tundra waders. The stocks of forage resources and their seasonal dynamics were assessed for the first time. Forage resources of Sivash exceeded the tundra waders intake as follows: in Eastern Sivash during the spring migration – 21.5-28.7 times, during the autumn migration – 6.2-10.9 times; in Central Sivash – 2.4 times in spring, and 5.7 times in autumn, respectively. A total of 22 species of aquatic invertebrates were recorded in the diet. They included 2 species of Polychaeta, 7 species of Crustacea (Anostraca – 1, Isopoda – 3, Amphipoda – 3 species), 11 species of Gastropoda and insect larvae – 2 species. Among the taxonomic groups, the greatest number of species was represented by mollusks and crustaceans. Research shows that Sivash can be referred to the most valuable wetland in Eastern Europe for long-distance migrants due to the consistently high indices of forage macrozoobenthos and extensive shallows suitable for bird feeding during their migratory stopovers.

Key words: waders; aquatic invertebrates; macrozoobenthos; Sivash.

A general assessment of the macrozoobenthos resources, determining feeding capacity of the Black Sea wetlands for tundra species of waders, deserves special attention due to the role of coastal water areas for the conservation of Western Palearctic migrants. A majority of publications on macrozoobenthos are dedicated to detailed analysis of species composition, its seasonal variations, and local productivity of macrozoobenthos communities in the areas of limans and lagoons not accessible for the studied group of birds [1, 3, 4]. In this regard, the assessment of resources in a narrow intertidal zone, accessible for waders and ultimately determining the value of the territory and its total feeding capacity, remains to be an urgent task. Sivash is well studied in terms of estimating migrations for this group of long-distance migrants [5, 8–11, 13, 14, 17–19, 23], and results of these studies show that the territory is one of the most important places for the waders using the Mediterranean continental flyway. Tundra waders were selected as an object for the research due to the features of their migration, ability to long non-stop flights between the stopover areas most convenient for their feeding and fatting along the flyway and the location of a major part of their breeding range in the Arctic tundra zone. This peculiarity of their migration strategy determines a special demand of waders for the quality of stopovers since this determines the success of their further reproduction and the general state of the populations.

Several of our publications are devoted to the study of species composition and abundance of the most valuable objects of forage macrozoobenthos [12, 20–22] using by tundra species of waders, but the general forage resources and their dynamics have not yet been evaluated.

The aim of investigation was determine of tundra waders food stock in Sivash area and their seasonal dynamics.

Material and methods

The survey of feeding areas and seasonal distribution of 13 species of tundra waders at stopovers in the Sivash lagoons was carried out from 1994 to 2002.

The studied group of waders belongs to two families (*Charadriidae* and *Scolopacidae*) suborder *Charadrii*, order *Charadriiformes*:

Order *Charadriiformes*
Suborder *Charadrii*
Family *Charadriidae*
Grey Plover – *Pluvialis squatarola* (Linnaeus, 1758)
Ringed Plover – *Charadrius hiaticula* (Linnaeus, 1758)
Turnstone – *Arenaria interpres* (Linnaeus, 1758)
Family *Scolopacidae*
Red-necked Phalarope – *Phalaropus lobatus* (Linnaeus, 1758)
Ruff – *Philomachus pugn*ax (Linnaeus, 1758)
Little Stint – *Calidris minuta* (Leisler, 1812)
Temminck's Stint – *Calidris temminckii* (Leisler, 1812)
Curlew Sandpiper– *Calidris ferruginea* (Pontoppidan, 1763)
Dunlin – *Calidris alpina* (Linnaeus, 1758)
Red Knot – *Calidris canutus* (Linnaeus, 1758)
Sanderling – *Calidris alba* (Pallas, 1764)
Broad-billed Sandpiper – *Limicola falcinellus* (Pontoppidan, 1763)
Bar-tailed Godwi t– *Limosa lapponica* (Linnaeus, 1758)

The taxonomic order of wader species and their Latin names are given according to L. S. Stepanyan [26].

A total of 375 hydrobiological samples were selected to assess resources of aquatic invertebrates, including 70 samples at 18 stations on Central Sivash, and 305 samples at 33 stations in Eastern Sivash. Benthic samples were taken according to a standard method [29], using a benthic sample bucket with a capture area of 0.015 m^2 at depths up to 10 cm, available for the feeding of waders. The sample material was washed through a set of soil sieves with a minimum mesh size of 1.0 mm. Preservation and laboratory processing of the collected material was conducted according to a standard procedure [27].

Species composition of hydrobionts was determined according to the identification guide of Black and Azov Seas fauna [6, 7, 16, 24, 25, 24], also using the reference collection of hydrobionts collected by the author at Sivash and identified by I. A. Sinegub, an expert from the Institute of Marine Biology (Odessa). The weight of hydrobionts was determined in the laboratory by weighting on a torsion balance with an accuracy of 0.001 mg, using design equations of B. G. Aleksandrov [3].

Biomass energy equivalent (kJ/m^2) was calculated basing on the mean biomass (g/m^2) of each species of water invertebrates [3].

To analyze the long-term biomass dynamics of the forage macrozoobenthos, the data obtained earlier at Sivash in 1992–1993 [28], expressed as ash free dry weight (g AFDW/m^2), were transformed into the biomass energy equivalent (kJ/m^2) [2].

The daily energy intake of waders (DEB – Daily Energy Budget, kJ/day) was calculated by the formula:

$$DEB = 12.06 \cdot m^{0,63},$$

where *m* is the average bird weight [15]:

The total energy intake of waders in different seasons of the year was calculated basing on the daily energy intake of waders [15], their number and duration of migratory stopovers.

The forage resources were calculated basing on the total values of available and required biomass of prey species and the size of feeding areas.

Results

Over the period from 1994 to 2002 were recorded 62 species of aquatic invertebrates in Sivash [21]. 40 macrozoobenthos species were found in coastal shallows (feeding areas of waders), 22 species of them could be prey items of waders. They included polychaete worms (Polychaeta) – 2 species, crustaceans (Crustacea) – 7 species (Anostraca – 1, Isopoda – 3, Amphipoda – 3 species), gastropods (Gastropoda) – 11 species and insect larvae (Insecta) – 2 species. Among the taxonomic groups, the greatest number of species was represented by mollusks and crustaceans.

The number of forage macrozoobenthos in Eastern Sivash was more stable showing an increasing trend by the period of wader autumn migration (Fig. 1).

The major part of biomass of forage macrozoobenthos in shallow waters of Eastern Sivash was composed of polychaete worms, being a valuable food for waders. Their percentage in autumn biomass was usually higher than that in spring. The percentage of polychaetes in spring biomass ranged from 28.4 to 88.7% (57.0% on average), and in autumn – 48.8 to 92.0 (72.0% on average). The greatest contribution in the formation of energy value of forage macrozoobenthos of Eastern Sivash in spring were made by gastropods, and in autumn – by polychaete worms.

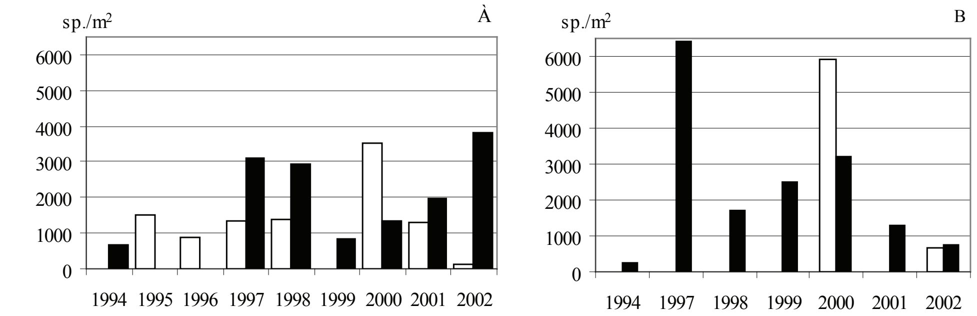

Fig. 1. Long-term dynamics of the average seasonal abundance of forage macrozoobenthos of Eastern (A) and Central (B) Sivash in 1994–2002.

Note: white columns indicate spring; black bars – autumn; omissions of the columns in some seasons mean the absence of research

The average seasonal biomass of forage macrozoobenthos of Eastern Sivash was higher than that in Central Sivash. In Eastern Sivash, in the spring seasons of 1994–2002 it was equal to 12.14 ± 1.7 g/m^2 (n = 92), ranging from 0.17 to 15.99 g/m^2 [21]. In autumn, it was higher and amounted to 14.57 ± 1.07 g/m^2 (n = 179), ranging from 5.30 to 22.82 g/m^2 (Fig. 2).

The long-term average seasonal biomass of forage macrozoobenthos of Central Sivash in the spring seasons of 2000 and 2002 amounted to 6.03 ± 1.07 (n = 18), ranging from 1.25 to 18.22 g/m^2, and in autumn of 1994–2002 it constituted 5.30 ± 1.47 (n = 179), respectively, ranging from 0.79 to 21.53 g/m^2 (Fig. 2).

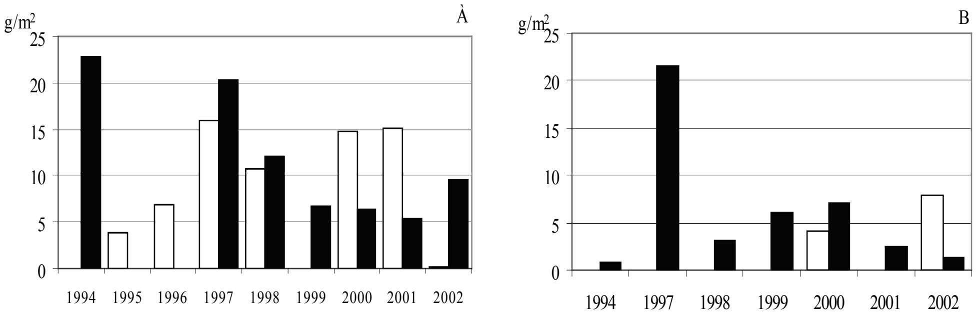

Fig. 2. Dynamics of the average seasonal biomass of forage macrozoobenthos of Eastern (A) and Central (B) Sivash in 1994–2002.

Note: white columns indicate spring; black bars – autumn; omissions of the columns in some seasons mean the absence of research.

Retrospective studies [28] have shown that the energy equivalent of benthos biomass in Eastern Sivash over the period from 1995 to 2002 was significantly lower than in the spring seasons of 1992–1993 (Table 1).

Table 1

Seasonal dynamics of biomass of forage macrozoobenthos and energy equivalent of biomass (EEB) at Sivash

Parts of Sivash	Date	Biomass, g/ m²		EEB, kJ/m²	
		spring	autumn	spring	autumn
Eastern Sivash[1]	8-15.04.1992	12.6	-	290.3	-
	16-30.04.1992	5.6	-	129.9	-
	1-15.05.1992	9.1	-	209.5	-
	16-25.05.1992	6.7	-	155.1	-
	21-22.05.1993	11.6	-	147.7	-
	3-4.06.1993	21.4	-	295.1	-
Eastern Sivash [2]	1994	-	22.8±2.32	-	52.4±6.02
	1995	3.9±0.69	-	26.9±5.21	-
	1996	6.9±0.63	-	32.6±6.43	-
	1997	16.0±5.8	20.3±3.28	34.0±11.62	50.2±10.77
	1998	10.7±3.36	12.1±1.51	32.0±9.54	41.0±6.39
	1999	-	6.7±1.14	-	19.5±3.0
	2000	14.7±3.43	6.4±1.49	54.5±9.6	20.9±4.1
	2001	15.2±4.22	5.3±1.86	48.9±12.37	21.7±3.32
	2002	0.2±0	9.6±1.52	0.5±0	26.6±4.1
Central Sivash	1994	-	0.8±0.13	-	2.3±0.39
	1997	-	21.5±7.36	-	62.4±21.38
	1998	-	3.1±0.83	-	17.4±4.52
	1999	-	6.1±0.44	-	17.5±1.3
	2000	4.2±0.37	7.0±1.34	10.5±0.8	20.3±3.9
	2001	-	2.4±0.53	-	7.0±1.54
	2002	7.9±1.96	1.4±0.12	13.3±2.94	4.0±0.36

Note: [1] – data from [28]; [2] – our data; biomass is expressed in units of raw weight (g/m²); EEB – energy equivalent of biomass (kJ/m²).

During the period of research in Eastern Sivash, a decreasing trend in the proportion of polychaetes in biomass and in the calorific value of the forage macrozoobenthos was recorded along with the increasing proportion of chironomid larvae (Fig. 3).

The results of studies of the average seasonal biomass of forage macrozoobenthos showed that in spring, among the most used by waders feeding areas of Eastern Sivash, biomass ranged from 0.17 to 22.12 g/m^2, and in autumn – from 3.19 to 41.76 g/m^2 [21].

The energy equivalent of long-term values of average annual biomass of forage macrozoobenthos in spring in Eastern Sivash was equal to 41.48 ± 4.63 kJ/m^2 (n = 92), in autumn – 36.66 ± 2.58 kJ/m^2 (n = 179); at Central Sivash – 11.88 ± 1.52 kJ/m^2 (n = 18) in spring, and 16.97 ± 4.30 kJ/m^2 (n = 47) in autumn. Fluctuations in the energy equivalent of biomass at Eastern Sivash in spring ranged from 0.45 to 54.47 kJ / m2, and in autumn – from 19.49 to 52.38 kJ/m^2.

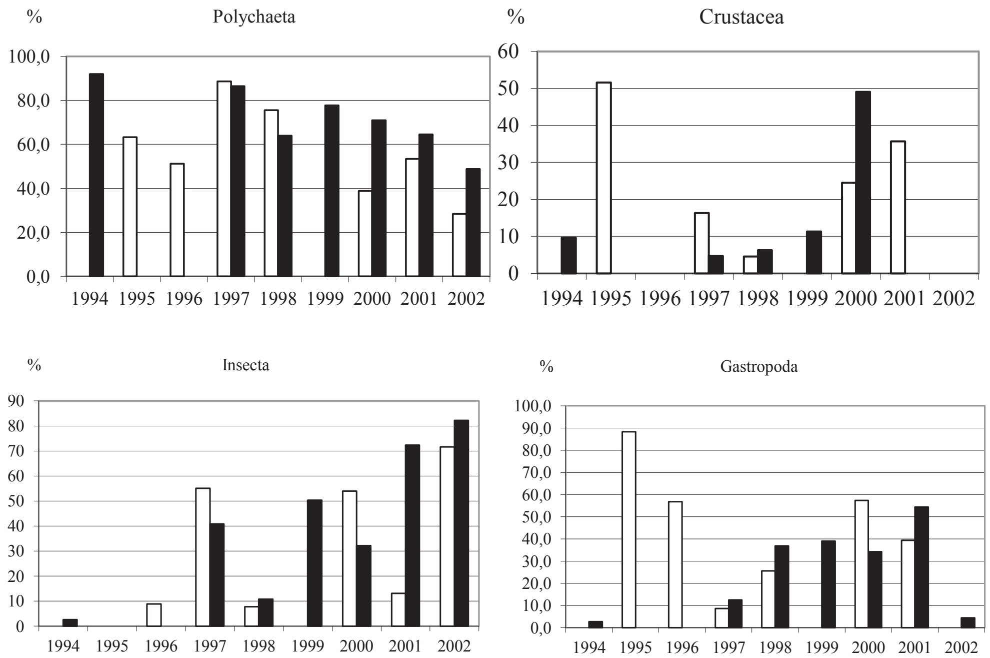

Fig. 3. The percentage of different taxonomic groups in the formation of biomass of forage macrozoobenthos in shallows of Eastern Sivash.

Note: white columns indicate spring; black bars – autumn; omissions of the columns in some seasons mean the absence of research.

At Central Sivash, long-term values of biomass and its energy equivalent were lower (except for 1997), but more stable than those at Eastern Sivash.

Between seasons, biomass and its energy equivalent also significantly varied. The average seasonal values of the energy equivalent correlated with the macrozoobenthos biomass, and at Eastern Sivash ranged in spring from 0.45 to 67.09 kJ/m^2, and in autumn – from 8.84 to 148.27 kJ/m^2. At Central Sivash, the average seasonal biomass varied from 0.79 to 24.26 g/m^2, and its energy equivalent ranged from 2.30 to 70.36 kJ/m^2.

Discussion

As for the resources of aquatic invertebrates, available for feeding of tundra species of waders, it is necessary to clarify which resources are studied and the procedure of their evaluation. We estimate the forage resources of the narrowest littoral strip with a water depth ranging from 0 to 10 cm. Resources of this part of shallows are unstable, since they are affected by two key factors – dynamics of the wind regime, and vertical and horizontal migration of benthos dwellers.

These calculations were based on the assessment of the size of coastal shallows (with a depth up to 10 cm), within which waders can feed on aquatic invertebrates. This is one of the variables used in the calculations, because, depending on the wind-driven effects, the size and configuration of the feeding areas, as well as the water depth within them, may change. The second variable in the calculations was determined by the average value of biomass (its energy equivalent) in different seasons of the year. Finally, the third variable was based on the concept of waders provision with food that formed from the total energy requirements of all individuals of all species of waders making a stopover on feeding areas and consuming macrozoobenthos during seasonal migrations. The waders provision with food we understand as the relationship between the hydrobiont resources, which the birds are able to harvest within the potential feeding area on the temporarily exposed bottom areas and shallows up to 10 cm deep, and the total requirements of the birds in these resources.

The uniqueness of the Sivash shallows is determined by the fact that, even with lower average values of the aquatic invertebrates biomass than in the Black Sea limans [22], extensive feeding areas of Sivash contribute to the formation of significant forage resources. The total area of wader feeding area in the studied parts of Central and Eastern Sivash in spring reached 2.1–91.6 km^2 at the maximum water level and 28.7–145.7 km^2 at the minimum water level, thus comprising 0.09–5.95% of the total area of Sivash. In autumn, due to the shallowing of the lagoon, the size of feeding areas in the studied territory increased and ranged from 1.2 to 87.4 km^2 at the maximum water level and from 50.6 to 151.3 km^2 at the minimum water level, or 0.05 to 6.17% of the total area of Central and Eastern Sivash [21].

The average annual resources of aquatic invertebrates (available forage resource) calculated for these Sivash areas were as follows: at the maximum water level – 460.5 tons of wet weight (1590.6 GJ) in spring, and up to 408.2 tons (1343.3 GJ) in autumn; at the minimum water level – from 756.5 tons (2409 GJ) in spring to 949.8

tons (2846 GJ) in autumn (Table 2). The forage resources of the Azov and Black Sea limans, expressed in terms of the wet weight of benthos (in tons), were significantly lower than the resources of the Sivash lagoons, despite the higher values of biomass and its energy equivalent [22].

Table 2

Average long-term resources of forage macrozoobenthos, used by waders at various water levels in Sivash

Area	Season	max		Min	
		tons	GJ	tons	GJ
Central Sivash	spring	6.2±1.9 n=3	12.2±1.4 n=3	146.2±45.6 n=3	288.5±34.1 n=3
	autumn	7.8±5.9 n=7	24.0±16.9 n=7	172.7±137.5 n=7	530.8±397.2 n=7
Eastern Sivash	spring	454.3±208.2 n=7	1578.4±719.9 n=7	610.3±273.3 n=7	2120.3±947.8 n=7
	autumn	400.4±123.50 n=7	1319.3±383.1 n=7	777.1±86.8 n=7	2315.20±377.9 n=7

Note. Max – at the maximum water level; min – at the minimum water level

The largest resources were in the lagoons of the Eastern Sivash (Table 2). The largest feeding areas were also found there: on average, in Eastern Sivash they reached 45.2 km^2 during the spring migration and 78.9 km^2 during the autumn migration.

Conclusions

Due to the exceptional shallowness and the large area of these shallows, the available for tundra waders resources of forage macrozoobenthos make it possible to classify Sivash as the most valuable wetland in Eastern Europe for the long-distance migrants using the Mediterranean continental flyway, owing to consistently high resource indices and areas suitable for bird stopovers.

In Eastern Sivash, during the spring migration forage resources 21.5–28.7 times exceed the waders intake, during the autumn migration – by 6.2–10.9 times; in Central Sivash – by 2.4 times in spring and 5.7 times in autumn, correspondingly.

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СЕЗОННАЯ ДИНАМИКА И ЗАПАСЫ ВОДНЫХ БЕСПОЗВОНОЧНЫХ СИВАША, КАК КОРМОВОЙ БАЗЫ И КЛЮЧЕВОЙ ТЕРРИТОРИИ ДЛЯ ТУНДРОВЫХ ВИДОВ КУЛИКОВ, МИГРИРУЮЩИХ АФРО-ЕВРАЗИЙСКИМИ ПРОЛЕТНЫМИ ПУТЯМИ

Резюме
Изложены результаты девяти лет исследований (1994–2002 гг.), посвященных изучению роли водных беспозвоночных в размещении тундровых видов куликов, мигрирующих на дальние расстояния. Впервые дана оценка запасам кормовых ресурсов, а также их сезонной динамики. Кормовые запасы Сиваша перекрывали потребности тундровых видов куликов: на Восточном Сиваше в период весенней миграции – в 21,5–28,7 раза, в период осенней миграции – в 6,2–10,9 раза; на Центральном Сиваше – весной – в 2,4 раза, осенью – в 5,7 раз. В кормовом рационе были отмечены 22 вида водных беспозвоночных. Среди них – Polychaeta – 2 вида, Crustacea – 7 видов (Anostraca – 1, Isopoda – 3, Amphipoda – 3 вида), Gastropoda – 11 видов и личинки насекомых – 2 вида. Среди таксономических групп наибольшим числом видов были представлены моллюски и ракообразные. Исследования позволяют отнести Сиваш к наиболее ценным водно-болотным угодьям Восточной Европы для дальних мигрантов за счет стабильно высоких показателей кормового макрозообентоса и значительных площадей мелководий, удобных для кормления птиц во время их миграционных остановок.

Ключевые слова: кулики, водные беспозвоночные, макрозообентос, Сиваш.

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СЕЗОННА ДИНАМІКА І ЗАПАСИ ВОДНИХ БЕЗХРЕБЕТНИХ СИВАШУ, ЯК КОРМОВОЇ БАЗИ ТА КЛЮЧОВОЇ ТЕРИТОРІЇ ДЛЯ ТУНДРОВИХ КУЛИКІВ, МІГРУЮЧИХ АФРО-ЄВРАЗІЙСЬКИМИ ПРОЛІТНИМИ ШЛЯХАМИ

Резюме
Викладені результати дев'яти років досліджень (1994–2002 рр.), присвячених вивченню ролі водних безхребетних у розміщенні тундрових куликів, що

мігрують на далекі відстані. Вперше дана оцінка запасів кормових ресурсів, а також їх сезонної динаміки. Кормові запаси Сивашу перекривали потреби тундрових куликів: на Східному Сиваші в період весняної міграції – в 21,5–28,7 разів, в період осінньої міграції – в 6,2–10,9 разів; на Центральному Сиваші – навесні – в 2,4 рази, восени – в 5,7 разів. У кормовому раціоні були відзначені 22 види водних безхребетних. Серед них – Polychaeta – 2 види, Crustacea – 7 видів (Anostraca – 1, Isopoda –3, Amphipoda – 3 види), Gastropoda – 11 видів та личинки комах – 2 види. Серед таксономічних груп найбільшим числом видів були представлені молюски та ракоподібні. Дослідження дозволяють віднести Сиваш до числа найцінніших водно-болотних угідь Східної Європи для далеких мігрантів за рахунок стабільно високих запасів водних безхребетних та значних площ мілководь, зручних для годування птахів під час їх міграційних зупинок.

Ключові слова: кулікі, водні безхребетні, макрозообентос, Сиваш.

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