Some Data on the Adventive Component of Flora in Communities of Aquatic and Coastal-Aquatic Vegetation in Saline Ecotopes of Southeastern Europe

N A Yuritsyna

Samara Federal Research Center RAS, Institute of the Ecology of the Volga Basin RAS, Togliatti, Russia

E-mail: natyur@mail.ru

Abstract. In the article, the author analyzes the features of the invasions of alien plant species in the European Southeast into communities of two classes of aquatic and coastal aquatic vegetation - Crypsidetea aculeatae Vicherek 1973 and Phragmito-Magno-Caricetea Klika in Klika et Novák 1941. In the saline habitats of this mega-region in the above communities the alien species turned out to be represented in very limited quantities [2 species - Atriplex tatarica L. (Chenopodiaceae Vent.) and Echinochloa crus-galli (L.) P. Beauv. (Poaceae Barnhart)], in terms of syntaxonomy (only in 4 lower units of the “association-community” rank), and geographically (only in the Lower Volga region, the lower reaches of the Volga River - Astrakhan oblast). The total share of alien species in the cenoflora of the lower syntaxa of the classes under consideration is insignificant and varies from 2 to 5.5%. Echinochloa crus-galli is most successfully adapted to local conditions. It invades communities of both of these classes, which are found on soils of the entire range of salinity (from weak to strong). But at the same time, the level of soil salinity, obviously, is a certain limiting factor for it. Since this species is more massively present in communities growing on weakly and moderately saline soils than in highly saline soils.

1. Introduction

The scientific community for more than a decade has claimed the problem of biological invasions to be one of the most important on our planet [1-4, etc.]. Water bodies (including large rivers), along with the fact that they can be natural barriers, contribute to the active penetration of alien plant species into the territory. Vegetation in contact with water bodies or located on the banks, in the first place, can be affected by adventive flora.

A number of publications have already been devoted to the invasions of alien plant species into saline soils of the South-East of Europe [5-8]. The purpose of this study is to assess how relevant it is here for aquatic and coastal aquatic vegetation, namely for the communities of classes Crypsidetea aculeatae Vicherek 1973 and Phragmito-Magno-Caricetea Klika in Klika et Novák 1941 found in saline ecotopes. The first class consists of pioneer communities with a predominance of annuals in periodically inundated habitats with a very variable moisture regime and salinity of the upper soil layer; the second class are the communities of swampy meadows and herbaceous bogs, as well as rooted plants rising above water along the shores and coastal zone of water bodies [9].
2. Materials and Methods
By the European South-East, the author understands the previously adopted concept of mega-region, its geographical and vegetative component [10, 11]:
1) territory: Russia - Republic of Kalmykia, Astrakhan, Volgograd, Saratov, Samara and Orenburg (only its southwestern part) oblasts, Kazakhstan - European parts of West Kazakhstan and Atyrau regions;
2) vegetation of saline ecotopes of this mega-region (its classification is ecological-floristic).

Taxa names are given in accordance with [12], names and nomenclature of syntaxa - [13], soil characteristics - [14]. The abundance of the species in the community corresponds to [15, 16]: “+” - the projective cover of the species is less than 1%, 1 point - 1–5%, 2 - 6–15%, 3 - 16–25%, 4 - 26–50%, 5 - more than 50%; and constancy: I point - less than 20%, II - 21-40%, III - 41-60%, IV - 61-80%, V - 81-100%.

We found the lower syntaxa of the classes Crypsidetae aculeatae Vicherek 1973 and Phragmito-Magno-Cariceteta Klika in Klika et Novák 1941 described in saline ecotopes of the European South-East, where alien species were recorded. Then we assessed the role of invasive species in their formation (based on the indicators of abundance, constancy, and proportion in coenoflora); we studied the geography of the introduction of species in the class range as well as ecological conditions of their habitats. We included in the analysis the lower syntaxa of the classes of the “association-community” rank. But only in ass. Phalarido-Scirpetum Golub et Mirkin 1986 we considered one subass. Ph.-S. bolboschoenetosum Golub et Mirkin 1986, since only it is found on saline soils.

The article uses abbreviations: ass. - association, WSI - Western steppe ilmen (area to the west of the main central system of the Volga River branches in its delta); C - constancy, class - cl., subass. - subassociation.

3. Results and Discussion
In coenoses of the classes Crypsidetae aculeatae and Phragmito-Magno-Cariceteta in the European South-East, we recorded only one alien species from 2 families - Atriplex tatarica L. (Chenopodiaceae Vent.) and Echinochloa crus-galli (L.) P. Beauv. (Poaceae Barnhart). We found the first species only in the first class, and the second one - in both. Both of them are annuals, archaeophytes, xenophytes, epeophytes; Atriplex tatarica is of Iranian-Turanian origin, and Echinochloa crus-galli is of South Asian origin [17-19].

Alien plant species are found in coenoses of 4 lowest units of the “association-community” rank: Crypsidetae aculeatae - Alismato-Salicornietum Golub 1985 and Argusio-Phragmitetum Golub et Mirkin 1986, Phragmito-Magno-Cariceteta - Phalarido-Scirpetum Golub et Mirkin 1986 (Ph.-S. bolboschoenetosum Golub et Mirkin 1986) and Typha laxmanii-community [20].

Both species are seldom found in communities of each class (C = 1). Atriplex tatarica is present there with a low (1 point) abundance, while Echinochloa crus-galli is generally more abundant: with a variable abundance index (1-3), the cereal is more abundant in cl. Phragmito-Magno-Cariceteta (table 1).

Floristic composition of almost all of the lower syntaxa of both classes found in the European South-East is rather poor: the total number of species is about 10–20, the average is 5–10 [10, 11]. This, in general, is accurate for those classes where we find alien species (table 2). The total share of alien species in the coenoflora of lower syntaxa is small - no more than 5.5% (table 2), but in specific coenoses where invasive species have been present for some time, it can increase to 10-20% - due to their species depletion in comparison with the lowest unit.
Table 1. Alien species in communities of classes *Phragmito-Magno-Caricetea* and *Crypsidetea aculeatae* in Southeastern Europe

| Syntaxa                                      | *Echinochloa crus-galli* | *Atriplex tatarica* |
|----------------------------------------------|--------------------------|---------------------|
|                                              | abundance, points        | C, points           |
|                                              | +                        | 1                   |
|                                              | 2                        | 1                   |
|                                              | 3                        | 1                   |
|                                              | 4                        | I                   |
|                                              | 5                        | I                   |
|                                              | I                        | I                   |
|                                              | II                       | II                  |
|                                              | V                        | V                   |
| Cl. *Crypsidetea aculeata*                   |                          |                     |
| Ass. *Alismato-Salicornietum*                | -                        | -                   |
| Ass. *Argusio-Phragmitetum*                 | -                        | +                   |
| Cl. *Phragmito-Magno-Caricetea*              |                          |                     |
| Subass. *Phalaroido-Scirpetum bolboschoenetusum* | -                        | +                   |
| Typha *laxmanii*-community                   | -                        | +                   |

Table 2. Summary table of lower syntaxa of classes *Phragmito-Magno-Caricetea* and *Crypsidetea aculeatae* with alien species

| Syntaxa                                                        | Number of species | Number of alien species |
|---------------------------------------------------------------|-------------------|------------------------|
|                                                               | total             | average | absolute | % of the total number of species |
| Cl. *Crypsidetea aculeata*                                    |                   |         |          |                                   |
| Ass. *Alismato-Salicornietum*                                 | 27                | 8       | 1        | 3.7                                 |
| Ass. *Argusio-Phragmitetum*                                   | 20                | 8       | 1        | 5.0                                 |
| Cl. *Phragmito-Magno-Caricetea*                               |                   |         |          |                                   |
| Subass. *Phalaroido-Scirpetum bolboschoenetusum*               | 50                | 17      | 1        | 2.0                                 |
| *Typha laxmanii*-community                                    | 18                | 5       | 1        | 5.5                                 |

The invasions of both alien species occur in an insignificant part of the range of each class in Southeastern Europe [10, 11, 21-24]: in *Crypsidetea aculeatae* - only in the extreme west, in *Phragmito-Magno-Caricetea* - in the extreme southwest of the range. Geographically, it is limited to the Lower Volga region [10, 11, 20, 25] and since it is noted exclusively in Astrakhan oblast, in order to avoid unnecessary repetitions further in the text, characterizing the geography of the introduction of species, we indicate only its administrative regions (omitting the name of the oblast).

The information for both classes is detailed below.

Cl. *Crypsidetea aculeatae* Vichereck 1973: both alien plant species (table 1) are recorded in its communities as rare (C = I) and low-abundant (abundance = 1 point). They are found in WSI (Ikryaninsky district) and the Volga delta (Volodarsky district). The total share of alien species in the coenoflora of associations of the class is small - about 4-5% (table 2). However, in some coenoses where there are invasive species, it can be 10-20% due to the greater species depletion.
Ass. Alismato-Salicornietum Golub 1985 - Atriplex tatarica is registered only in one of its coenosis in WSI (Ikraynskiny district, low-lying meadow on the right bank of the Podstepok River) [20]. The share of alien species in the coenoflora of the association is 3.7% (table 2), but in the floristically highly depleted (5 species) coenosis, where A. tatarica is found, the share increases to 20%. However, A. tatarica, obviously, is unable to significantly transform the coenosis, due to the strong competitive dominant Aeluropus littoralis s. I. (incl. A. littoralis ssp. pungens) and codominant Crypsis schoenoides (species abundance is 5 and 2 points, respectively), which mainly form the herbage.

Ass. Argusio-Phragmitetum Golub et Mirkin 1986 is distributed in highly saline (salt content - 1.2–1.8%) alluvial meadow soils in plant complexes of the Volga delta. Echinochloa crus-galli is found in one of its coenosis (Volodarsky district, leveled area of the island) [25]. The share of an alien component in the coenoflora of the association is 5.0% (table 2), but in a specific coenosis with an invasive species it is 10%. However, since the abundance of this cereal is rather small, one cannot expect its strong influence on the coenosis due to the more massive presence of quite numerous dominating and codominants (Scirpus maritimus ssp. Maritimus, Phragmites australis, etc.).

Cl. Phragmito-Magno-Caricetum Klika in Klika et Novák 1941: only Echinochloa crus-galli is registered in its communities. It is also found rarely here (C = 1), as in Crypsidetea aculeatae, but more massively (abundance = 2-3 points) (table 1). It is found in WSI (Narimanov district) and the Volga delta (Volodarsky district). The share of alien species in the coenoflora of the lower units of this class, as in the previous one, is small - 2.0-5.5% (table 2), but in specific coenoses with invasive species it grows to about 11% due to greater species depletion.

Ass. Phalarido-Scirpetum Golub et Mirkin 1986 = subass. Ph.-S. bolboschoenetosum Golub et Mirkin 1986: subass. Ph.-S. bolboschoenotosum is found on alluvial meadows of weakly or moderately saline soils of the Volga delta [10, 11, 25]. In terms of species richness, it surpasses all the considered lower syntaxa, while having the lowest share of an alien component in the coenoflora - 2.0% (table 2). But in its only coenosis (Volodarsky district, depression), where Echinochloa crus-galli is found not very massively (abundance = 2 points), this indicator increases to 5.5%.

Typha laxmanii-community [20]: its coenoses occupy weakly and moderately saline (0.5–0.9%) soils, occurring on the periphery of slightly saline and fresh water bodies. Echinochloa crus-galli is found in one of them in WSI (Narimanov district, southern coast of fresh ilmen) [10, 11, 20]. The share of the alien component in the whole coenoflora of the Typha laxmanii-community is 5.5% (table 2); but in the coenosis with Echinochloa crus-galli it is 11.1%. In addition to the dominant Typha laxmanii (abundance = 4 points), most of the other species in this coenosis are random. Therefore, we can assume that the invasive cereal significantly influences its formation as a rather massive codominant (abundance = 3 points).

4. Conclusion
The author notes a rather weak invasion of alien species into the communities of aquatic and coastal aquatic vegetation found in saline ecotopes in Southeastern Europe (classes Crypsidetea aculeatae Vicherek 1973 and Phragmito-Magno-Caricetea Klika in Klika et Novák 1941). This introduction affected a small number of lower syntaxa of both classes and is observed only in a number of points in the western part of the range of each of them, without going beyond the Volga delta and its environs (Astrakhan oblast).

Alien species are represented by only 2 species from 2 families - Atriplex tatarica L. (Chenopodiaceae Vent.) and Echinochloa crus-galli (L.) P. Beauv. (Poaceae Barnhart). Their total share in the coenoflora of the lower-class units is small - 2-5.5%.

Echinochloa crus-galli invades coenoses of this vegetation type most successfully. Unlike Atriplex tatarica, it penetrates into the communities of both classes, is present in them more massively and has a wider geography of invasiveness. This cereal crop can invade communities of lower syntaxa, which are found throughout the entire range of soil salinity. It is found in them equally rarely (C = 1), but is more abundant (2-3 points) in syntaxa with soils of the category of weakly and moderately saline.
(class *Phragmito-Magno-Caricetea*). However, in highly saline soils (class *Crypsidetea aculeatae*), its abundance decreases (1 point).

**Funding**

This work was carried out within the framework of the Program of Fundamental Research of the State Academies of Sciences in 2013-2020 (projects nos. AAAA-A17-117112040040-3 and AAAA-A17-117112040039-7).

**References**

[1] Lonsdale W M 1999 Global patterns of plant invasions and the concept of invisibility *Ecology* **80** 1522–1536

[2] Mack R N, Simberloff D, Lonsdale W M, Evans H, Clout M and Bazzaz F A 2000 Biotic invasions: causes, epidemiology, global consequences, and control *Ecological Applications* **10** 689–710

[3] Pimentel D et al 2001 Economic and environmental threats of alien plant, animal, and microbe invasions *Agroecosystems and Environment* **84** 1–20

[4] Hulme P E 2003 Biological invasions: winning the science battles but losing the conservation war? *Oryx* **37** 178–193

[5] Yuritsyna N A and Vasjukov V M 2018 Family Amaranthaceae Juss. in communities of saline soils in Southeastern Europe *Russian Journal of Biological Invasions* **9** (4) 392–396

[6] Yuritsyna N A and Vasjukov V M 2019 Alien species from the Brassicaceae Burnett family in the saline ecotope communities of Southeastern Europe *Russian Journal of Biological Invasions* **10** (4) 394–403

[7] Yuritsyna N A 2019 Alien species in communities of strongly saline soils of southeastern Russia (classes *Thero-Salicornietea* Tx. in Tx. et Oberd. 1958 and *Salicornietea fruticosae* Br.-Bl. et Tx. ex A. de Bolòs y Vayreda 1950) *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences* **21** (6) 110–115

[8] Yuritsyna N A, Vasjukov V M and Saksonov S V 2019 Invasions of *Bidens frondosa* L. (Asteraceae) in communities of saline soils of South-East Europe *Samara Scientific Bulletin* **8** (3) 89–92

[9] Mirkin B M and Naumova L G 2012 *Modern State of Basic Concepts of Vegetation Science* (Ufa: AN RB, Gilem)

[10] Yuritsyna N A 2014 *Saline Soils Vegetation of the South-East Europe and Adjacent Regions* Ed S V Saksonov (Tolyatti: Kassandra)

[11] Yuritsyna N A 2016 Features of vegetation of saline ecotopes in Southeastern Europe and adjacent areas *Diss. Dr. Sci. (Biol)* (Tolyatti)

[12] *Flora Europaea* 1964–1993 Eds T G Tutin et al (Cambridge: Cambridge Univ. Press)

[13] Weber H E, Moravec J and Theurillat J-P 2000 International code of phytosociological nomenclature *Journal of Vegetation Science* **11** (5) 739–769

[14] *Classification and Diagnosis of Soils in the USSR* 1977 Eds V V Egorov et al (Moscow: Kolos)

[15] Mirkin B M and Rozenberg G S 1983 *The Glossary of Modern Phytocenology* (Moscow: Nauka)

[16] Mirkin B M, Rozenberg G S and Naumova L G 1989 *The Glossary of Concepts and Terms of Modern Phytocenology* (Moscow: Nauka)

[17] Tsvelev N N 1976 *Cereals of the USSR* (Leningrad: Nauka)

[18] Protopopova V V 1991 *Synanthropic Flora of Ukraine and Ways of Its Development* (Kiev: Naukova Dumka)

[19] *Vascular Plants of the Republic of Mordovia* 2010 Ed T B Silaeva (Saransk: Mordovian State Univ)

[20] Golub V B and Chorbadze N B 1988 Syntaxonomic characteristics of plant communities of Western Substeppe Ilmens of the Volga delta Moscow *Dep. VINITI* no. 6909-B88
[21] Golub V B and Yuritsyna N A 2001 Some halophytic communities of Volga-Ural area Samarskaya Luka 11 29–37
[22] Yuritsyna N A 2003 Ecology and syntaxonomy of halophytic vegetation of the Volga-Ural interfluve Diss. Cand. Sci. (Biol) (Tolyatti)
[23] Yuritsyna N A 2010 Class Crypsidetea aculeatae Vicherek 1973 in the South-East Europe Bulletin of the Samara Scientific Center of the Russian Academy of Sciences 12 (1) 58–60
[24] Yuritsyna N A 2012 Vegetation of saline habitats on southeastern border of Europe Arid Ecosystems 2 (4) 239–244
[25] Golub V B and Mirkin B M 1986 Grasslands of the Lower Volga valley Folia Geobotanica et Phytotaxonomica 21 (4) 337–395