Hacquetia 21/1 • 2022, 163–172 DOI: 10.2478/hacq-2021-0021 sciendo

Vegetation mapping of the Dzharylhach Island (Ukraine)

Anastasia Davydova[1]

Key words: vegetation map, disappearance of plant communities, changes of vegetation.

Ključne besede: vegetacijska karta, izginjanje rastlinskih združb, spremembe vegetacije.

Abstract

Dzharylhach Island is the largest one in the Black Sea. It is the part of the "Dzharylhatskyi" National Nature Park, which located in the Southern Ukraine. A 1 : 10000 scale vegetation map of Dzharylhach Island has been developed. The main unit for mapping is a complex of associations. In total 28 of such complexes were identified. The map shows the territorial differentiation of vegetation. It has also been used to reconstruct the island vegetation changes over the past 90 and 20 years. A comparison of cartographic materials revealed that the predominant processes in vegetation cover are halophytization and xerophytization of communities. The most distributed types of communities on the island are aquatic – *Zosteretea*, halophytic – *Festuco-Puccinellietea* and psammophytic – *Festucetea vaginatae*. Due to specific hydrological and soil conditions, the northern spit and shores of the island represent natural vegetation types only.

Izvleček

Otok Dzharylhach je največji otok v Črnem morju in je del Narodnega naravnega parka "Dzharylhatskyi", ki se nahaja v južni Ukrajini. Izdelala sem vegetacijsko karto otoka Dzharylhach v merilu 1 : 10000. Glavni nivo kartiranja je kompleks asociacij in vse skupaj sem jih določila 28. Na karti je predstavljena raznolikost vegetacije na otoku in prikaz sprememb vegetacije v zadnjih 90. in 20. letih. Primerjava kartografskega materiala je pokazala, da so glavni procesi v vegetacijskem pokrovu halofitizacija in kserofitizacija združb. Največ motenj na otoku imajo vodni vegetacijski tipi – *Zosteretea*, halofitski – *Festuco-Puccinellietea* in pasmofitski – *Festucetea vaginatae*. Zaradi posebnih hidroloških in talnih razmer je naravna vegetacija prisotna samo na severnih plažah in obalah.

Corresponding author:
Anastasia Davydova
E-mail: anasta3Kz@gmail.com

Received: 21. 1. 2021
Accepted: 13. 9. 2021

1 M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, Kyiv, Ukraine.

Introduction

Vegetation mapping is one of the most important methods of investigation of natural and semi-natural plant communities. It is also a necessary tool for the management of protected areas. Mapping allows to observe and analyze the dynamics of vegetation under the influence of natural and anthropogenic factors. Identifying patterns of vegetation changes provides an opportunity to plan restoration measures and methods of biotope conservation. Nowadays, more often mapping is carried out using classical methods (mapping in the field) and combination with remote sensing (Leprieur et al.. 2000; Laris, 2005; Akasheh et al., 2008; Mehrabian et al., 2009; Malatesta et al., 2013; Rapinel et al., 2014).

This work is the first stage that precedes the monitoring of vegetation by remote sensing. Vegetation mapping was carried out and the obtained data were issued as a project in a geographic information system. Using GIS for vegetation mapping is helpful for: determining the area of communities; update and change of polygon boundaries during re-mapping; availability of material for comparison and study of vegetation dynamics processes; linking information to polygons – geobotanical relevés, data about distribution of some species or the results of population studies, phenological observations, pictures.

Material and methods

Study area

Dzharylhach Island is located in the south of Ukraine in the Skadovsk district of the Kherson region (Figure 1). It is the part of the "Dzharylhatskyi" National Nature Park. Area of the island is 5065 hectares. It consists of two parts: the eastern (wide) – 23.2 km long and up to 4.6 km wide, and the western (narrow) – 18.5 km long and 100–200 m wide (Ardamatskaya et al. 2000). The relief of Dzharylhach is mostly flat, with low sand dunes and inter-dune depressions. The total area of fresh and brackish water bodies of the island is 948.8 ha. Most of the salt lakes dry up in summer. The predominant sedimentary deposits of the island are sands, sand-shell and shell-sand deposits, on which sod-sand soils (15–60 cm layer) have a slightly humus horizon.

Data analysis

A large-scale mapping of vegetation was made using the geographic information system QGIS 2.18.24 in order to study the differentiation of plant communities. The work consisted of several stages: 1) drawing the boundaries of communities on a base map within individual polygons, which were linked to geographical coordinates; 2) transfer the boundaries of communities from the base map to the interactive map; 3) compiling the legend of the map; 4) analysis of the spatial distribution of syntaxa; 5) comparison of the author's map with a map of 20 years ago (Ardamatskaya et al. 2000).

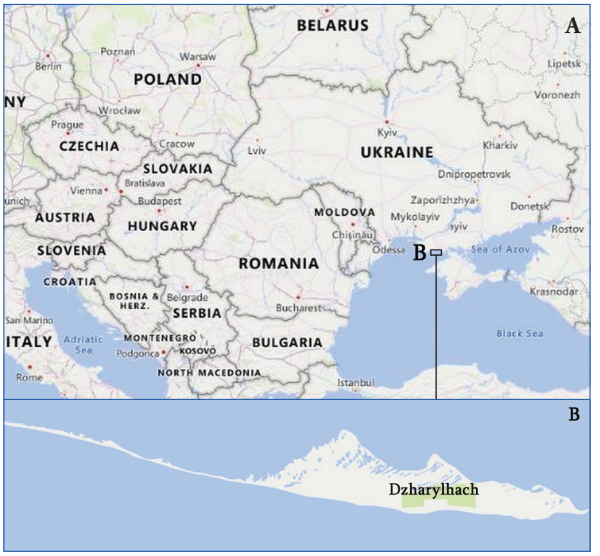

Figure 1: Map of the research area: A – location in the Europe, B – Dzharylhach Island.
Slika 1: Zemljevid preučevanega območja: A – lokacija v Evropi, B – otok Dzharylhach.

For mapping, the island was divided into 89 areas on a Google satellite map in QGIS 2.18.24. These satellite images were used as base maps to draw boundaries of communities complexes or associations and binding of the geographic coordinates. The orientation of the terrain and the subsequent interpretation of the data were performed using five ecological-coenotic profiles with GPS-binding, which were laid across the island in the direction from north to south. The transfer of the boundaries of plant complexes was carried out by creating on a cartographic basis of polygons and correction of their boundaries (scale during the application of polygons – 1 : 5000; the scale of the created map for convenience of perception and reproduction in the printed version – 1 : 10000) (Figure 2) (Pedrotti, 2013). Using QGIS 2.18.24 software, the raster image of the 2000 map was linked to the grid and compared with a modern vegetation map. An accurate comparison of the boundaries of the main mapping units is made by increasing the percentage of transparency of the raster image of the upper layer.

The vegetation categories were derived from author's publications and PhD thesis (Shaposhnikova, 2017; Davydova et al., 2019; Davydova, 2019, 2020a,b; Davydov &

Davydova, 2020) in which the results of phytosociological field survey on the island in 2017–2019 (including 605 relevés) were published. Geobotanical relevés were carried out in sites of different area (1–5 m² on average for aquatic and ruderal vegetation, 3–5 m² for halophytic, 5–10 m² for psammophytic) within the physiognomic boundaries of phytocoenoses and on strip transects (from 0.2 to 3.6 km) (Braun-Blanquet, 1964; Mirkin et al., 2001). Names of vascular plant species are used in accordance with Euro+Med PlantBase (The Euro+Med PlantBase accessed in 21 May 2021).

Results and Discussion

The map of current vegetation of the Dzharylhach Island was created on a scale of 1 : 10000 on the basis of cartographic material and original geobotanical relevés (Figure 2) (Küchler, 1988).

There are three hierarchical levels in the legend of the map according to the adapted methodical approaches by Vinogradov (1966). The highest (first) level is a type of complex, the formation of which is mainly due to the leading ecological factors (salinization and soil moisture). The map includes xeromorphic, halomorphic, hydromorphic types of complexes and non-complex type of woody and shrubby vegetation, which appeared as a result of artificial afforestation (Bioret et al., 2019). The middle (second) level summarizes the groups of complexes, which are separate forms of microrelief with plant communities at the level of the alliance. They are marked with letters of the Latin alphabet. The lower (third) level is a complex of associations (in some cases – associations), which are groups of homogeneous phytocoenoses, in the case when it is impossible to map the boundaries of individual phytocoenoses. 16 classes, 19 orders, 22 alliances, 58 associations, 4 sub-associations, 4 derivative and 3 basal communities were found on the island. The characteristics of the complex include the names of communities that predominate in area over others. The names of indigenous associations are also given, because in the case of transformed communities, their areas are so insignificant that such communities should be subordinated to indigenous ones. Complexes are marked with Arabic numerals. Areas without vegetation and buildings are marked with out-of-scale signs. The equivalents of EUNIS2020 biotopes for our proposed complexes are given (Chytrý et al., 2020).

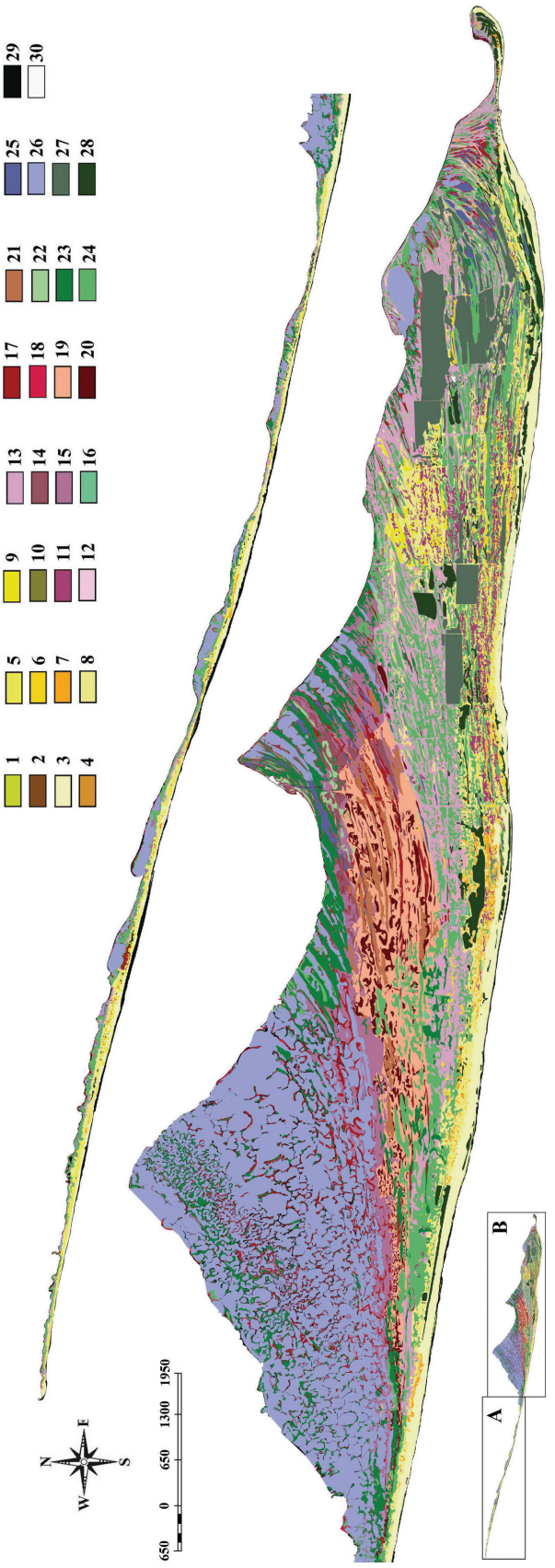

Figure 2: Vegetation map of Dzharylhach Island (A – western (narrow) part, B – eastern (wide) part).

Slika 2: Vegetacijska karta otoka Dzharylhach (A – zahodni (ožji) del, B – vzhodni (širši) del).

The hierarchical classification scheme of vegetation on the territory of the Dzharylhach Island

Cl. *Potamogetonetea* Klika in Klika et Novák 1941
Ord. *Potamogetonetalia* Koch 1926
All. *Potamogetonion* Libbert 1931
Ass. *Potametum pectinati* Carstensen ex Hilbig 1971
Ord. *Zannichellietalia pedicellatae* Schaminée, Lanjouw et Schipper ex Mucina et Theurillat 2016
All. *Zannichellion pedicellatae* Schaminée, Lanjouw et Schipper ex Passarge 1996
Ass. *Potameto-Zannichellietum pedicellatae* Soó 1944
Cl. *Ruppietea maritimae* J. Tx. ex Den Hartog et Segal 1964
Ord. *Ruppietalia* J. Tx. ex Den Hartog et Segal 1964
All. *Ruppion maritimae* Br.-Bl. ex Westhoff in Bennema et al. 1943
Ass. *Ruppietum maritimae* Beguinot 1941
Cl. *Zosteretea* Pignatti 1953
Ord. *Zosteretalia* Béguinot ex Pignatti 1953
All. *Zosterion marinae* Br.-Bl. et Tx. ex Pignatti 1953
Ass. *Zosteretum marinae* Harmsen 1936
All. *Nanozosterion noltii* Den Hartog ex Mucina 2016
Ass. *Zosteretum nanae* Pignatti 1953
Cl. *Phragmito-Magnocaricetea* Klika in Klika et Novák 1941
Ord. *Phragmitetalia* Koch 1926
All. *Phragmition communis* Koch 1926
Ass. *Phragmitetum australis* Savich 1926
Ord. *Bolboschoenetalia maritimi* Hejny in Holub et al. 1967
All. *Scirpion maritimi* Dahl et Hadac 1941
Ass. *Bolboschoenetum maritimi* Eggler 1933
Ass. *Scirpetum tabernaemontani* Soó (1927) 1947
Ass. *Junco maritimi-Cladietum marisci* (Br.-Bl. & O. de Bolòs 1957) Géhu & Biondi 1988
Cl. *Molinio-Arrhenatheretea* Tx. 1937
Ord. *Molinietalia caeruleae* Koch 1926
All. *Molinion caeruleae* Koch 1926
Ass. *Molinietum euxinae* Davydova prov.
BC *Schedonorus pratensis* [*Arrhenatherion elatioris*]
Cl. *Festucetea vaginatae* Soó ex Vicherek 1972
Ord. *Festucetalia vaginatae* Soó 1957
All. *Festucion beckeri* Vicherek 1972
Ass. *Festucetum beckeri* Ad. Oprea 1998
Ass. *Aperetum maritimae* Popescu et Sanda 1972
Ass. *Secaletum sylvestre* Popescu et Sanda 1973
Ass. *Secali sylvestri-Caricetum colchicae* Davydova 2019
Ass. *Centaureo odessanae-Caricetum colchicae* Tyschenko 1999
Ass. *Apero maritimi-Chrysopogonetum grylli* Davydova 2019
Subass. *Apero maritimi-Chrysopogonetum grylli typicum* Davydova 2019
Subass. *Apero maritimi-Chrysopogonetum grylli stipetum borysthenicae* Davydova 2019
Ass. *Carici colchicae-Holoschoenetum vulgaris* Sorbu et al. 1995
BC *Stipa borysthenica* [*Festucion beckeri*]
Cl. *Helichryso-Crucianelletea maritimae* Géhu et al. in Sissingh 1974
Ord. *Ephedro distachyae-Medicaginetalia romanicae* Dubyna et Dziuba 2019
All. *Ephedro distachyae-Medicaginion romanicae* Dubyna et Dziuba 2019
Ass. *Ephedro-Caricetum colchicae* (Prodan 1939) Sanda et Popescu 1973
Ass. *Artemisietum arenariae* Popescu et Sanda 1977
Cl. *Juncetea maritimi* Br.-Bl. in Br.-Bl. et al. 1952
Ord. *Juncetalia maritimi* Br.-Bl. ex Horvatić 1934
All. *Juncion maritimi* Br.-Bl. ex Horvatić 1934
Ass. *Phragmito-Juncetum maritimi* Korzhenevsky et Klyukin in Dubyna et al. 2007
Ass. *Juncetum maritimi* (Soó 1930) Borhidi 1958
Ass. *Junco maritimi-Caricetum extensae* (Corillion 1953) Géhu 1976
Ass. *Juncetum maritimo-acuti* Horvatić 1934
Ass. *Juncetum littoralis* Popescu et. al. 1992
All. *Junco maritimi-Schoenion nigricantis* Dubyna et Dziuba prov.
Ass. *Junco maritimi-Schoenetum nigricantis* Dubyna et Dziuba prov.
Cl. *Festuco-Puccinellietea* Soó ex Vicherek 1973
Ord. *Scorzonero-Juncetalia gerardii* Vicherek 1973
All. *Juncion gerardii* Wendelberger 1943
Ass. *Limonio gmelinii-Juncetum gerardii* (Warming 1906) Géhu et Géhu-Franck 1982
Ord. *Artemisio santonicae-Limonietalia gmelinii* Golub et Solomakha 1988
All. *Plantagini salsae-Artemision santonicae* Shelyag-Sosonko et Solomakha in Lysenko, Mucina et Iakushenko 2011
Ass. *Limonio meyeri-Artemisietum santonicae* Shelyag-Sosonko et Solomakha 1987
Ass. *Agropyretum elongatae* Şerbănescu 1965
Ass. *Artemisio santonicae-Elytrigietum elongatae* Dubyna, Neuhäuslová et Shelyag-Sosonko in Dubyna et Neuhäuslová 2000
Ass. *Limonio meyeri-Elytrigietum elongatae* Tyshchenko 1996
Ass. *Cynancho acutae-Lepidietum latifolii* Dubyna, Neuhäuslová et Shelyag-Sosonko 1994

Ord. *Puccinellietalia* Soó 1947
All. *Puccinellion giganteae* Dubyna et Neuhäuslová 2000
Ass. *Puccinellietum giganteae* Solomakha et Shelyag-Sosonko in Dubyna et Neuhäuslová 2000
Ass. *Artemisio santonicae-Puccinellietum giganteae* Shelyag-Sosonko et Solomakha 1987
All. *Salicornio-Puccinellion* Mirkin in Golub et Solomakha 1988 nom. inval.
Ass. *Salicornio-Puccinellietum giganteae* Shelyag-Sosonko et Solomakha 1987
Ass. *Salicornio-Puccinellietum fominii* Shelyag-Sosonko et Solomakha 1987
Ass. *Aeluropodetum littoralis* Krausch 1965
Ass. *Puccinellio fominii-Aeluropodetum littoralis* Shelyag-Sosonko, Golub et Solomakha 1989
Ass. *Aeluropodo-Salicornietum* Krausch 1965
Ass. *Tripolietum vulgaris* Korzhenevsky et Klyukin in Korzhenevsky, Klyukin et Korzhenevskaya 2000
Ass. *Astero tripolii-Phragmitetum* Krisch (1972) 1974

Cl. *Therosalicornietea* Tx. in Tx. et Oberd. 1958
Ord. *Camphorosmo-Salicornietalia* Borhidi 1996
All. *Salicornion prostratae* Gehu 1992
Ass. *Salicornietum prostratae* Soó 1927
Ass. *Bassietum hirsutae* Şerbănescu 1965
Ass. *Halimionetum pedunculatae* Şerbănescu 1965

Cl. *Kalidietea foliati* Mirkin et al. ex Rukhlenko 2012
Ord. *Halimionetalia verruciferae* Golub et al. 2001
All. *Artemisio santonicae-Puccinellion fominii* Shelyag-Sosonko, Golub et Solomakha 1989
Ass. *Puccinellio fominii-Halimionetum verruciferae* Shelyag-Sosonko, Golub et Solomakha 1989
Ass. *Artemisio santonicae-Puccinellietum fominii* Shelyag-Sosonko et Solomakha 1987
Ass. *Halimionetum verruciferae* (Keller 1923) Ţopa 1939
Ass. *Halocnemo-Limonietum caspii* Korzhenevsky et Klyukin in Korzhenevsky 2000
Ass. *Limonio caspii-Salicornietum* Korzhenevsky et Klyukin 1990
Ass. *Salicornio prostratae-Halocnemetum strobilaceae* Korzhenevsky et Klyukin in Korzhenevsky 2000
Ass. *Puccinellio fominii-Halocnemetum* Shelyag-Sosonko, Golub et Solomakha 1989

Cl. *Cakiletea maritimae* Tx. et Preising in Tx. ex Br.-Bl. et Tx. 1952
Ord. *Thero-Atriplicetalia* Pignatti 1953
All. *Cakilion euxinae* Géhu et al. 1994
Ass. *Lactuco tataricae-Cakiletum euxinae* Korzhenevsky et Klyukin in Korzhenevsky 2001
Ass. *Cakilo euxinae-Salsoletum tragi* Vicherek 1971
Subass. *Cakilo euxinae-Salsoletum tragi typicum* Vicherek 1971
Subass. *Cakilo euxinae-Salsoletum tragi elytrigietosum bessarabicae* Korzhenevsky et Klyukin in Korzhenevsky 2001

Cl. *Ammophiletea* Br.-Bl. et Tx. ex Westhoff et al. 1946
Ord. *Ammophiletalia* Br.-Bl. et Tx. ex Westhoff et al. 1946
All. *Elymion gigantei* Morariu 1957
Ass. *Tournefortietum sibiricae* Popescu et Sanda 1975
Ass. *Elymetum gigantei* Morariu 1957
Ass. *Centaureo odessanae-Elymetum gigantei* Vicherek 1971
BC *Poacynum russanovii* [*Elymion gigantei*]

Cl. *Robinietea* Jurko ex Hadač et Sofron 1980
DC *Elaeagnus angustifolia* [*Robinietea*]
DC *Tamarix ramosissima* [*Robinietea*]

Cl. *Stellarietea mediae* Tx. et al. in Tx. 1950
Ord. *Sisymbrietalia sophiae* J. Tx. ex Görs 1966
All. *Atriplicion* Passarge 1978
Ass. *Atriplicetum tataricae* (Morariu 1943) Ubrizsy 1949
DC *Ambrosia artemisiifolia* [*Stellarietea mediae*]

Cl. *Artemisietea vulgaris* Lohmeyer et Al. in Tx. ex von Rochow 1951
Ord. *Agropyretalia intermedio-repentis* T. Müller et Görs 1969
All. *Convolvulo arvensis-Agropyrion repentis* Görs 1967
Ass. *Agropyretum repentis* Felföldy 1942
Ass. *Calamagrostietum epigei* Kostylev in Solomakha et al. 1992
DC *Xanthium orientale* [*Artemisietea vulgaris*]

Legend to the vegetation map

Xeromorphic type of complex

A. Vegetation of the driftline with communities of *Cakilion euxinae*
(EUNIS2020: N12. Mediterranean and Black Sea sand beach)

1. Communities of *Cakilo euxinae-Salsoletum tragi* in alluvial areas of the initial stage of formation of the beach ridge in complex with communities of *Lactuco tataricae-Cakiletum euxinae* on sandy-shell deposits and *Cakilo euxinae-Salsoletum tragi elytrigietosum bessarabicae* on the formed alluvial elevations.

B. Vegetation of the beach ridge and the initial stages of dune formation with communities of *Elymion gigantei*
(EUNIS2020: N14. Mediterranean, Macaronesian and Black Sea shifting coastal dune)

2. Communities of *Tournefortietum sibiricae* on loose sands at the foot of the littoral shaft or on compacted shell sediments.

3. Communities of *Elymetum gigantei* at the foot and tops of the sandy beach ridge with dominance of *Eryngium maritimum* on the spit.
4. Communities of *Centaureo odessanae-Elymetum gigantei* on the upper parts of sloping spit dunes.
5. Communities of *Artemisietum arenariae* on the upper parts and inner slopes of dunes.

C. Vegetation of old "grey" dunes with communities of *Festucion beckeri*

(EUNIS2020: N17. Black Sea coastal dune grassland (grey dune)

6. Communities of *Secaletum sylvestre* on the upper parts of dunes in complex with *Festucetum beckeri* communities on lower areas (or at the foot of dunes) and occasionally with *Stipa borysthenica*-dominated communities.
7. Communities of *Secali sylvestri-Caricetum colchicae* on upper parts and slopes of dune.
8. Communities of *Carici colchicae-Holoschoenetum vulgaris* on sandy areas and shallow inter-dune depressions in complex with *Centaureo odessanae-Caricetum colchicae* on low dunes on the spit.

D. Vegetation of psammophytic steppe with communities of *Festucion beckeri*

(EUNIS2020: N17. Black Sea coastal dune grassland (grey dune)

9. Communities of *Apero maritimi-Chrysopogonetum grylli* in the formed psammophytic-steppe areas in complex with communities of *Aperetum maritimae*, which were formed under the influence of grazing, communities of *Apero maritimi-Chrysopogonetum grylli* with the dominance of *Scirpoides holoschoenus* on sparsely overgrown flat sandy areas.

E. Vegetation of slightly saline psammophytic steppe and saline meadows on light sandy soils with communities of *Juncion maritimi*

(EUNIS2020: R62. Continental inland salt steppe)

10. Communities of *Juncetum littoralis* on slightly saline sand-steppe areas.

Halomorphic type of complex

F. Vegetation of interdune depressions with communities of *Junco maritimi-Schoenion nigricantis*

(EUNIS2020: N1J. Mediterranean and Black Sea moist and wet dune slack)

11. Communities of *Junco maritimi-Schoenetum nigricantis* on moist sandy-shell soils.

G. Vegetation of salted meadows with communities of *Juncion gerardii*

(EUNIS2020: R62. Continental inland salt steppe* – identic for complexes H-N)

12. Communities of *Limonio gmelinii-Juncetum gerardii* on saline depressions.

H. Vegetation of solonetzes with communities of *Plantagini salsae-Artemision santonicae*

13. Communities of *Agropyretum elongatae* on elevations with loose sandy salt marshes in combination with *Artemisio santonicae-Elytrigietum elongatae* communities on more compacted sandy salt marshes and *Limonio meyeri-Elytrigietum elongatae* on small depressions.

J. Vegetation of wet salt marshes and solonetzes with communities of *Puccinellion giganteae*

14. Communities of *Puccinellietum giganteae* on saline wet depressions in complex with *Artemisio santonicae-Puccinellietum giganteae* on saline elevations.

K. Vegetation of heavy loamy salt marshes with communities of *Salicornio-Puccinellion*

15. Communities of *Salicornio-Puccinellietum giganteae* on saline depressions that have been flooded for a long time, in combination with *Salicornio-Puccinellietum fominii* communities on saline soils with periodic flooding.
16. Communities of *Aeluropodetum littoralis* in depressions with moist loamy salt marshes.

L. Vegetation of salt marshes with prolonged flooding with communities of *Salicornion prostratae*

17. Communities of *Salicornietum prostratae* in the place of dried salt water bodies and saline depressions in complex with *Halimionetum pedunculatae* in short-flooded saline areas.
18. Communities of *Bassietum hirsutae* on sandy-shell elevations along salt water bodies and beach ridges along the bay.

M. Vegetation of loose saline elevations with communities of *Artemisio santonicae-Puccinellion fominii*

19. Communities of *Puccinellio fominii-Halimionetum verruciferae* on saline plains with loose soils in complex with *Halimionetum verruciferae* on short-flooded areas with more compacted soils.
20. Communities of *Puccinellio fominii-Halocnemetum* on flat areas in complex with *Halocnemo-Limonietum caspii* on loose saline elevations.
21. Communities of *Salicornio prostratae-Halocnemetum strobilaceae* on wet saline depressions in combination with *Limonio caspii-Salicornietum* on small elevations with loose loamy saline soils.

N. Vegetation of wet saline areas with communities of *Juncion maritimi*

22. Communities of *Phragmito-Juncetum maritimi* on wet depressions in complex with *Junco maritimi-Caricetum extensae* on sandy-shell depressions.
23. Communities of *Juncetum maritimi* in wet depressions with shell-silty saline soils and *Juncetum maritimo-acuti* on plain areas with little moisture or in shallow depressions.

O. Vegetation of fresh and salt water bodies and wet depressions with communities of *Phragmition communis* (EUNIS2020: Q51. Tall-helophyte bed)

24. Communities of *Phragmitetum australis* on the shores of inland islands, along the bay and on drying depressions.

Hydromorphic type of complex

P. Vegetation of shallow brackish water bodies with communities of *Zannichellion pedicellatae*, *Potamogetonetea* and *Ruppion maritimae*

25. Communities of *Ruppietum maritimae* and *Potameto-Zannichellietum pedicellatae* in shallow brackish lakes with silty sandy or sandy-shell sediments.
26. Communities of *Zosteretum marinae* and *Zosteretum nanae* in salty shallow lakes and in a bay with silty sandy or sandy-shell sediments.

Non-complex type

Q. Vegetation of trees and shrubs (EUNIS2020: V.63. Lines of planted trees)

27. Communities with dominance of *Tamarix ramosissima* in psammophytic-steppe areas.
28. Communities with dominance of *Elaeagnus angustifolia* on beach ridges and psammophyte-steppe areas.

Extra-scale allocations

29. Buildings.
30. Beach without vegetation.

Features of meso- and microrelief determine the mosaic of the vegetation cover. In the Dzharylhach Island author allocated 10 tracts (Figure 3). The tract is understood as a combined system of genetically, dynamically and territorially related facies (the smallest units of the landscape, which are characterized by homogeneity of natural conditions) (Isachenko, 1991).

Dzharylhach Island (Figure 3) consists of a narrow spit and an extended part, which are also differentiated into separate tracts. According to the peculiarity of the microrelief, the spit can be divided into three longitudinal strips: northern, central and southern. The northern strip (tract 1 in the figure 3) is represented by a shore of shell sediments and mats of *Zostera*, on which phytocoenoses of *Bassietum hirsutae* is widespread. On the beach ridge *Phragmitetum australis* communities, which border on silty shallow salt lakes, dominate. *Salicornietum prostratae* and *Salicornio-Puccinellietum giganteae* are common around the lakes. *Juncetum maritimi* communities are also sporadically found here. Only in the western direction the shore expands and the substrate changes to sandy. The southern strip (tract 2 in the figure 3) consists of a sand beach without vegetation, hilly sandy sediments with phytocoenoses of *Cakilo euxinae-Salsoletum tragi* and *Cakilo euxinae-Salsoletum tragi elytrigietosum bessarabicae*, beach ridge with *Elymetum gigantei* and sporadic distribution of *Centaureo odessanae-Elymetum gigantei* communities, high and sloping dunes with *Artemisietum arenariae* communities in complex with *Centaureo odessanae-Caricetum colchicae*. The central strip (tract 3 in the figure 3) is a depression with sandy-shell soils, where the *Agropyretum elongatae* predominates with a significant participation of *Daucus carota* and *Koeleria glauca*. They are gradually being replaced by the *Secali sylvestri-Caricetum colchicae* and *Artemisietum arenariae* communities. The sequence of these coenoses is periodically disturbed due to the effects of storms, therefore along the littoral strip there are steep sandy shores with *Artemisia arenaria*. In the wide part of the island there are also northern and southern shores. In the north, in addition to the above-mentioned coenoses, communities of *Tournefortietum sibiricae* and single plants of *Crambe maritima* sometimes occur in the eastern part. The southern coast is characterized by the absence of *Centaureo odessanae-Elymetum gigantei* and *Artemisietum arenariae* communities, there are only a few findings of their diagnostic species. The Pyndyky tract, which is located in the widest part of the island (tract 4 in the figure 3), is a complex of salt lakes of different size and depth. Shallow lakes (0.1–0.2 m) are often devoid of vegetation or occasionally its vegetation represents by small areas of *Ruppietum maritimae* communities. In deeper lakes (0.3–1 m) phytocoenoses of *Zosteretum marinae* are common, in some of them communities of *Zosteretum nanae* are rare. The shores of these lakes are covered with halophytic vegetation – *Salicornietum prostratae* and *Salicornio-Puccinellietum giganteae*, and in large areas there are communities of *Juncetum maritimi*. A few wet depressions (tract 5 in

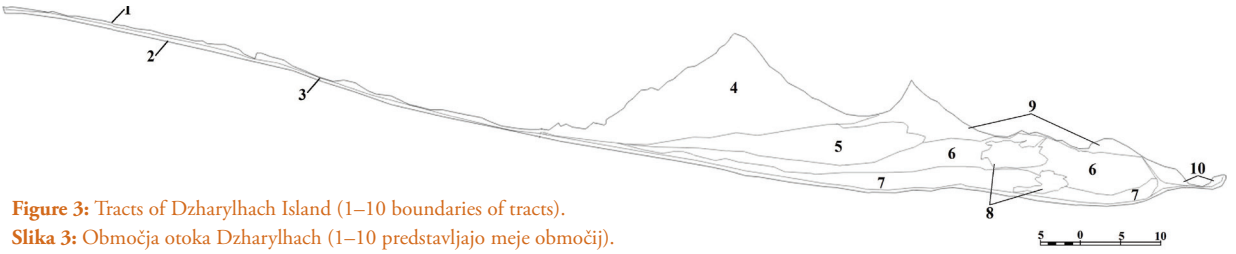

Figure 3: Tracts of Dzharylhach Island (1–10 boundaries of tracts).
Slika 3: Območja otoka Dzharylhach (1–10 predstavljajo meje območij).

the figure 3) with *Salicornio-Puccinellietum giganteae* pass into large areas of *Puccinellio fominii-Halimionetum verruciferae* communities on saline plains with loose soils in complex with *Halimionetum verruciferae* on more dense soils. There are sporadic small depressions with *Juncetum maritimi* and very rarely with *Aeluropodo-Salicornietum* and *Aeluropodetum littoralis*. Communities of *Salicornio prostratae-Halocnemetum strobilaceae* on wet salt marshes in complex with *Limonio caspii-Salicornietum* are also formed in elongated (several hundred meters long) depressions. Further to the south the tract 6 (Figure 3), which crosses almost the entire wide part of the island, is located. Its separation is due to a slight increase and change of saline soils to sod slightly salted sands. Large areas are occupied by *Agropyretum elongatae* communities with sporadic prevalence of *Artemisio santonicae-Elytrigietum elongatae*, *Limonio meyeri-Elytrigietum elongatae* and *Limonio gmelinii-Juncetum gerardii* communities. Communities of *Limonio meyeri-Artemisietum santonicae* and *Artemisio santonicae-Puccinellietum giganteae* are widespread in small areas, and *Aeluropodetum littoralis* – in depressions. *Aperetum maritimae* communities occur on soils with a predominance of sand fraction. Wet saline depressions with *Salicornietum prostratae* communities are very rare in this tract. In this part of the island the communities of *Juncetum littoralis* are concentrated among the phytocoenoses of *Agropyretum elongatae*. Sporadically, *Apero maritimi-Chrysopogonetum grylli* occurs in sandy areas, less frequently sparse phytocoenoses of *Secaletum sylvestre* and *Carici colchicae-Holoschoenetum vulgaris* occur on low dunes. In slightly saline natural and artificial lakes the communities of *Potametum pectinati* and *Potameto-Zannichellietum pedicellatae* are represented. Rare phytocoenoses of *Junco maritimi-Cladietum marisci* occur around some lakes and in drying depressions. Tract 7 (Figure 3) consists of a system of sand and sand-shell dunes and depressions. In the north-south direction there are low dunes with formed vegetation of *Carici colchicae-Holoschoenetum vulgaris* in the interdune depressions and *Secali sylvestri-Caricetum colchicae* on the dunes. Dunes with poor vegetation are located closer to the coast. Phytocoenosis of *Secaletum sylvestre* are common at the top of dunes in combination with *Festucetum beckeri* on dune slopes or in depressions. Communities of *Phragmitetum australis* dominate in dry depressions, and *Junco maritimi-Schoenetum nigricantis* forms a dense cover on wet depressions with salinization. The phytocoenoses of *Molinietum euxinae* represent small areas of true meadow vegetation. Psammophytic steppe in tract 8 (Figure 3) is represented by phytocoenoses of *Apero maritimi-Chrysopogonetum grylli* and *Carici colchicae-Holoschoenetum vulgaris* with inclusions of *Secaletum sylvestre*. Communities of *Bolboschoenetum maritimi* and *Scirpetum tabernaemontani* are very rare here. The shore of tract 9 (Figure 3) is covered with sparse phytocoenoses of *Bassietum hirsutae*, the communities of *Cynancho acutae-Lepidietum latifolii* and *Phragmito-Juncetum maritimi* sporadically occur on the beach ridge. Communities of *Puccinellietum giganteae* in complex with *Artemisio santonicae-Puccinellietum giganteae* is widespread on wet salt marshes. Phytocoenosis of *Juncetum maritimi* and *Junco maritimi-Caricetum extensae* dominate in the marshy lowlands. Tract 10 (Figure 3) differs from the previous one by much less swampy soils. Phytocoenosis of *Carici colchicae-Holoschoenetum vulgaris*, *Secaletum sylvestre* and *Ephedro-Caricetum colchicae* are rare on the shell beach ridges. Salt marshes, which are flooded in spring, dry up in the second half of summer and are overgrown with *Salicornietum prostratae*. In wet saline depressions, the communities of *Tripolietum vulgaris* and *Astero tripolii-Phragmitetum* are well represented. Tree and shrub artificial communities on the island are represented by *Elaeagnus angustifolia* and *Tamarix ramosissima* phytocoenoses. On the beach ridge along the southern coast of the island there are *Elaeagnus angustifolia* in complex with *Elymetum gigantei* communities.

Changes of vegetation over the 90-year period

Due to the intensification of xerophytization, some phytocoenoses have already disappeared, others are endangered. It is possible to investigate these changes in time due to publications of 1920–1940th (Desyatova-Shostenko & Levin, 1928; Desyatova-Shostenko, 1936; Illichevskyi, 1940). The main trends of vegetation dynamics was studied by comparing with old profiles. Five ecological-coenotic profiles (from 0.2 to 3.6 km) in the direction from north to south were carried out. The choice of locations for the profiles is due to the availability of material for comparison - in the work of 1936 the profiles on the island were made by Desyatova-Shostenko (1936).

Natural and artificial lakes on the island have been significantly freshwater since the early XX century and are now undergoing halophytization. Currently, communities of *Lemna minor* L. disappeared. Phytocoenosis of *Typhetum angustifoliae* and *Schoenoplectetum lacustris* were widespread along the shores of freshwater lakes and in wet depressions. In the XXI century, there are only a few finds of *Schoenoplectus lacustris* (L.) Palla, and *Typha angustifolia* L. has completely disappeared. Similarly, the area of communities with *Cladium mariscus* (L.) Pohl. decreased. Communities of *Schedonorus pratensis* (Huds.) P. Beauv. and *Molinietum euxinae* almost disappeared due

to xerophytization, and in their place are now widespread phytocoenoses of *Phragmitetum australis* and *Agropyretum elongatae*. In the wet depressions there were thickets of *Salix repens* L. and *S. cinerea* L. Over an 90-year period, these communities were replaced by *Phragmitetum australis* and phytocoenoses of *Calamagrostis epigejos* (L.) Roth. According to geobotanical relevés of the 1930th (Desyatova-Shostenko & Levin, 1928; Desyatova-Shostenko, 1936) *Artemisia arenaria* DC. was widespread in the central part of the island, but now grows only on the beach ridge of the spit.

Changes of vegetation over the 20-year period

In order to analyze the changes in vegetation, the author's map (Figure 2) was compared with the vegetation map of 1997 (Ardamatskaya et al., 2000). The old map consisted of 21 positions with vegetation. Their characteristics were based on the dominant classification. Thus, the main trends in the vegetation of the Dzharylhach Island over 20 years have been identified: 1) due to the peculiarities of the microrelief, the complex character of vegetation has been preserved; 2) linear location of communities from the bay to the sea proved stable; 3) decreased areas of psammophytic communities on shell-sand beach ridges in the southern and eastern parts of the island and changed to *Agropyretum elongatae* phytocoenoses; 4) decreased areas of phytocoenoses with a predominance of *Apera maritima* Klokov, *Bromus squarrosus* L. and *Calamagrostis epigejos* (L.) Roth on salted sands and increased the area of *Plantagini salsae-Artemision santonicae* and *Artemisio santonicae-Puccinellion fominii*; 5) communities of *Schoenus nigricans* L. and *Juncus maritimus* Lam. in wet depressions changed by *Phragmitetum australis* and *Agropyretum elongatae* at dry depressions.

Conclusions

The main trends of vegetation dynamics of the NNP Dzharylhatsky are overgrowth of sand and halophytic communities by certain species and communities. This is due to the instability and dynamism of ecosystems in natural conditions, which are vulnerable due to the processes of sand movement and catastrophic changes even without the intervention of recreational or economic activities. Landscape changes is characterized mainly by climatic changes, due to which freshwater and hydrophylous species and their communities disappear. Changes of individual phytocoenoses is mainly due to recreational effects, which leads to degradation and destruction of phytocoenoses.

Thus, according to observations, the vegetation of the island is quite diverse – 16 classes, 19 orders, 22 alliances, 58 associations, 4 sub-associations, 4 derivative and 3 basal communities were found on the Dzharylhach Island. The largest number of syntaxa was found in the central part of the island. The most widespread types of plant communities are aquatic (*Zosteretea*), halophytic (*Festuco-Puccinellietea*) and psammophytic (*Festucetea vaginatae*).

Mapping the vegetation of the island and comparing these materials with works of eighty and twenty years ago, confirmed that under the influence of halophytization and xerophytization, freshwater communities disappear or reduce their area, and halophytic communities on the contrary increase their area.

Acknowledgements

The autor are very grateful to editor in chief Urban Šilc and two anonymous reviewers for comments and recommendations that greatly improved the manuscript.

Anastasia Davydova https://orcid.org/0000-0003-2267-9969

References

Akasheh, O. Z., Neale, C. M. U., & Jayanty, H. (2008). Detailed mapping of riparian vegetation in the middle Rio Grande River using high resolution multi-spectral airborne remote sensing. *Journal of Arid Environments*, *72*(9), 1734–1744. https://doi.org/10.1016/j.jaridenv.2008.03.014

Ardamatskaya, T. B., Bilinskaya, O. S., Boyko, M. F., Geluta, V. P., Davydok, V. P., Dubyna, D. V., Zykov, A. E., Kondratenko, N. G., Kotenko, A. G., Kotenko, T. I., Movchan, Ju. V., Moysienko, I. I., Monchenko, V. I., Seljunina, Z. V., Starenkij, O. F., Tihonenko, Ju. Ja., Khodosovtsev A. E., Chernjakov, D. A., Shejgas, I. Ja., & Shelyag-Sosonko, J. R. (2000). Biodiversity of the Jarylgach: Modern State and Ways for Conservation. *Vestnik zoologii*, Supplement [in Russian].

Bioret, F., Boullet, V., Choisnet, G., Roux, C., Thébaud, G., Panaïotis, C., Chalumeau, A., Delbosc, P., Demartini, C., Gauberville, C., Cianfaglione, K., Bensettiti, F., & Lalanne, A. (2019). Landscape phytosociology concepts and definitions applied to serial and catenal vegetation mapping. *Contribuţii Botanice*, *54*, 47–53. https://doi.org/10.24193/Contrib.Bot.54.3

Braun-Blanquet, J. (1964). *Pflanzensoziologie – Grundzüge der Vegetationskunde*. Springer Verlag.

Chytrý, M., Tichý, L., Hennekens, S., Knollová, I., Janssen, J., Rodwell, J., Peterka, T., Marcenò, C., Landucci, F., Danihelka, J., Hájek, M., Dengler, J., Novák, P., Zukal, D., Jiménez-Alfaro, B., Mucina, L., Abdulhak, S., Aćić, S., Agrillo, E., Attorre, F., Bergmeier, E., Biurrun, I., Boch, S., Bölöni, J., Bonari, G., Braslavskaya, T., Bruelheide, H., Campos, J. A., Čarni, A., Casella, L., Čuk, M., Ćušterevska, R., Bie, E., Delbosc, P., Demina, O., Didukh, Y., Dítě, D., Dziuba, T., Ewald, J., Gavilán, R., Gégout, J., Galdo, G. D., Golub, V., Goncharova, N., Goral, F., Graf, U., Indreica, A.,

Isermann, M., Jandt, U., Jansen, F., Jansen, J., Jašková, A., Jiroušek, M., Kącki, Z., Kalníková, V., Kavgacı, A., Khanina, L., Korolyuk, A., Kozhevnikova, M., Kuzemko, A., Küzmič, F., Kuznetsov, O., Laiviņš, M., Lavrinenko, I., Lavrinenko, O., Lebedeva, M., Lososová, Z., Lysenko, T., Maciejewski, L., Mardari, C., Marinšek, A., Napreenko, M., Onyshchenko, V., Pérez-Haase, A., Pielech, R., Prokhorov, V., Rašomavičius, V., Rojo, M. P., Rūsiņa, S., Schrautzer, J., Šibík, J., Šilc, U., Škvorc, Ž., Smagin, V. A., Stančić, Z., Stanisci, A., Tikhonova, E., Tonteri, T., Uogintas, D., Valachovič, M., Vassilev, K., Vynokurov, D., Willner, W., Yamalov, S., Evans, D., Lund, M. P., Spyropoulou, R., Tryfon, E., & Schaminée, J. (2020). EUNIS Habitat Classification: expert system, characteristic species combinations and distribution maps of European habitats. *Applied Vegetation Science*, *23*, 648–675. https://doi.org/ 10.1111/avsc.12519

Davydov, D. A., & Davydova, A. O. (2020). Two new associations for the halophytic vegetation of Ukraine. *Chornomorski Botanical Journal*, *16*(2), 118–134. [in Ukrainian]. https://doi.org/10.32999/ksu1990-553X/2020-16-2-2.

Davydova, A. (2020a). A Mediterranean element of the vegetation: *Junco maritimi-Cladietum marisci* – a new association for Ukraine. *Hacquetia, 19*(2), 275–291. https://doi.org/10.2478/hacq-2020-0010

Davydova, A. O. (2020b). Phytodiversity of NNP "Dzharylhatsky": structure, dynamics, protection. [Unpublished doctoral dissertation]. M.G. Kholodny Institute of Botany of the NASU. [in Ukrainian].

Davydova, A. O. (2019). Syntaxonomy of vegetation of National Nature Park «Dzharylhatskyi». The class *Festucetea vaginatae*. *Biology and ecology*, *5*(1), 34–43. [in Ukrainian]. https://doi.org/ 10.33989/2414-9810.2019.5.1.195113

Davydova, A. O. (2019). Syntaxonomy of vegetation of NPP "Dzharylgatsky". The classes *Cakiletea maritimae* and *Ammophiletea*. *Thaiszia – Journal of Botany, 29*(2), 111–132. https://doi.org/10.33542/TJB2019-2-01

Davydova, A. O., Ponomareva, A. A., & Davydov, D. A. (2019). Investigation of vegetation as a precondition for improving the management of a national nature park (on the example of Dzharylhatskyi NP). *Biosystems Diversity*, *27*(1), 69–75. https://doi.org/10.15421/011911

Desyatova-Shostenko, N. O. (1936). *Botanical exploration of the Nadmorskyi Reserves: Spit Dzharylgach, Tender and the Babyn and Smalen Islands*. Trudy Institutu botaniky pry Kharkiv. derzh. unti 1: 116–173. [in Ukrainian].

Desyatova-Shostenko, N., & Levin, F. (1928). Botanical study of the Black Sea spit and islands: Tender, Dzharilgach, Orlov and Dovgy. *Materials for Conservation of Nature in Ukraine*, *1*, 3–72. [in Ukrainian].

Illichevskyi, S. O. (1940). Vegetation of the island of Dzharylgach on the Black Sea. *Botanical Journal of the USSR*, *1*(25), 38–51. [in Russian].

Isachenko, A. G. (1991). *Landscape science and physical-geographical zoning*. Vyshaya shkola.

Küchler, A. W. (1988). Aspects of Maps. In A. W. Küchler, & I. S. Zonneveld (Eds.), *Vegetation mapping. Handbook of vegetation science*, *Vol 10* (pp. 97–104). Springer. https://doi.org/10.1007/978-94-009-3083-4_10

Laris, P. S. (2005). Spatiotemporal problems with detecting and mapping mosaic fire regimes with coarse-resolution satellite data in savanna environments. *Remote Sensing of Environment*, *99*(4), 412–424. https://doi.org/10.1016/j.rse.2005.09.012

Leprieur, C., Kerr, Y. H., Mastorchio, S., & Meunier, J. C. (2000). Monitoring vegetation cover across semi-arid regions: Comparison of remote observations from various scales. *International Journal of Remote Sensing*, *21*(2), 281–300. https://doi.org/10.1080/014311600210830

Malatesta, L., Attorre, F., Altobelli, A., Adeeb, A., De Sanctis, M., Taleb, N. M., Scholte, P. T., & Vitale, M. (2013). Vegetation mapping from high-resolution satellite images in the heterogeneous arid environments of Socotra Island (Yemen). *Journal of Applied Remote Sensing*, *7*(1), 073527. https://doi.org/10.1117/1.JRS.7.073527

Mehrabian, A., Naqinezhad, A., Mahiny, S. A., Mostafavi, H., Liaghati, H., & Kouchekzadeh, M. (2009). Vegetation mapping of the Mond Protected Area of Bushehr Province (south-west Iran). *Journal of Integrative Plant Biology*, *51*(3), 251–260. https://doi.org/10.1111/j.1744-7909.2008.00712.x

Mirkin, B. M., Naumova, L. G., & Solomeshch, A. I. (2001). *Modern science of vegetation*. Logos. [in Russian].

Pedrotti, F. (2013). *Plant and Vegetation Mapping*. Springer Verlag. https://doi.org/10.1007/978-3-642-30235-0

Rapinel, S., Clément, B., Magnanon, S., Sellin, V., & Hubert-Moy, L. (2014). Identification and mapping of natural vegetation on a coastal site using a Worldview-2 satellite image. *Journal of Environmental Management*, *144*, 236–246. https://doi.org/10.1016/j.jenvman.2014.05.027

Shaposhnikova, A. O. (2017). Synphytosociological investigation of vegetation of the island Dzharylgach. *Chornomorski Botanical Journal*, *13*(3), 278–294. [in Ukrainian]. https://doi.org/10.14255/2308-9628/17.133/3

Euro+Med (2066-). Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. Retrieved May 21, 2021, from http://ww2.bgbm.org/EuroPlusMed/query.asp [last accessed in 21 May 2021].

Vinogradov, V. B. (1966). *Mapping of complexes of fragments of plant associations in the semidesert (m. 1:3000–1:100000). Geobotanical mapping*. Nauka. [in Russian].