СЕКЦІЯ 2
ПРИРОДНИЧО-ГЕОГРАФІЧНІ ТА ГЕОЕКОЛОГІЧНІ ДОСЛІДЖЕННЯ

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RECENT MORPHODYNAMICS AND CLOSURE IMPLICATIONS OF A NON-TIDAL INLET: LAZURNENSKA PRORVA, BLACK SEA COAST, UKRAINE

Ephemeral inlets are important and specific components of the coastal barriers of the World Ocean. Within tidal coasts, the corresponding channels are called tidal inlets, and within non-tidal coasts – breaches (prorvas, promoiny, prorany). Ephemeral inlets are important for the development of coastal barrier systems. First of all, they perform the function of hydrological control, determining the features and scale of water exchange between the water bodies adjacent to the barrier. The function of ephemeral inlets aimed at determining the volume and direction of coastal and marine sediment movement is called geological control. The peculiarities of the movement of different species of plants and animals through ephemeral inlets are called ecological control. In this context, the parameters of the studied inlets, the duration of their functioning, and the frequency of closure and opening determine the specific conditions of the adjacent water bodies.

Within the coastal barriers of the non-tidal seas, ephemeral inlets most often occur and function for a long period of time within the accumulative forms of the Tendra-Dzharylgach system. The corresponding barrier is characterized by a certain variety of prorvas associated with the hydrodynamic conditions of the adjacent water bodies.

Among all the prorvas of the above coastal system, the Lazurnenska prorva is the most famous. It should be noted that this name should be understood as all ephemeral inlets that periodically appeared and functioned in the root part of the Dzharylgach Spit. Interest in the Lazurnenska prorva increased after news of its artificial closure spread through a significant number of Ukrainian information resources.

Information about the peculiarities of the emergence and functioning of the Lazurnenska prorva is based on certain field materials from almost sixty years ago (Pravotorov I., Shuisky Y., Kotovsky I., Vykhovanetz G., and Davydov O.). The available historical and cartographic material, which covers approximately two hundred and thirty years, allows us to determine the frequency and duration of the functioning of the breaches. The available satellite images make it possible to determine the patterns of evolution of the studied breach over a forty-year period.

The Lazurnenska prorva has certain dynamic trends throughout the year. In the cold season, when waves and wind currents from the east and northeast dominate, the breach widens and deepens. In the warm season, when waves and wind currents from the west and southwest become more active, the breach channel narrows.

In June 2022, it was determined that the studied prorvas was closed (based on satellite images analysis). The analysis indicates that there is a natural tendency for the prorvas closure, but we do not have reliable information on the main reason for the closure. At the beginning of June 2023, the breach has been closed for a year. Under the conditions of long-term closure or artificial maintenance of this condition, very unfavorable consequences will occur within Dzharylgach Bay.

Key words: ephemeral inlets, coastal barrier, non-tidal seas, tidal seas, non-tidal inlets, prorva.

Давидов О.В., Буйневич І.В. Недавня морфодинаміка та закриття безприливної протоки: Лазурненська прорва, узбережжя Чорного моря, Україна

Важливими та специфічними складовими берегових бар'єрів Світового океану є ефемерні протоки. В межах припливних берегів відповідні протоки називаються tidal inlets, а в межах неприпливних – прорви (промоїни, прорани). Ефемерні протоки мають важливе значення для розвитку берегових бар'єрних систем. Насамперед, вони виконують функцію гідрологічного контролю, зумовлюючи особливості та масштаби водообміну між прилеглими до бар'єру водоймами. Функція ефемерних проток спрямована на визначення об'ємів та напрямків руху прибережно-морських наносів має назву геологічний контроль. Особливості руху через ефемерні протоки різних видів рослин та тварин виділяються під назвою «екологічний контроль». В цьому контексті параметри досліджуваних проток, тривалість їх функціонування, періодичність закриття та відкриття визначають специфічні умови прилеглих водойм.

В межах берегових бар'єрів неприпливних морів ефемерні протоки найбільш часто виникають та тривалий період часу функціонують в межах акумулятивних форм системи Тендра – Джарилгач. Для відповідного бар'єру характерне певне різноманіття прорв, пов'язане із гідродинамічними умовами прилеглих водойм.

Серед всіх прорв наведеної берегової системи найбільш відома Лазурненська. Необхідно зазначити, що під відповідною назвою слід розуміти всі ефемерні протоки, які періодично з'являлися та функціонували у прикореневій частині Джарилгацької коси. Інтерес до Лазурненської прорви збільшилась після того, як значну кількість українських інформаційних ресурсів облетіла вістка про її штучне закриття.

Інформація про особливості виникнення та функціонування Лазурненської прорви базується на певних польових матеріалах майже шістдесятирічного періоду (Правоторов І., Шуйський Ю., Котовський І., Вихованець Г. та Давидов О.). Наявний історико-картографічний матеріал, який охоплює приблизно двісті тридцять років, дозволяє визначити періодичність та тривалість функціонування прорв. Наявні супутникові знімки дозволяють визначити закономірності еволюції досліджуваної прорви за сорокарічний період.

Лазурненська прорва має певні динамічні тенденції протягом року. В холодний період року під час домінування хвиль та вітрових течій східного та північно-східного напрямку русло прорви розширюється та поглиблюється. В теплий період року, коли активізуються хвилі та течії західного та південно-західного напрямків, русло прорви навпаки звужується.

В червні 2022 року, за даними аналізу супутникових знімків, було визначено, що досліджувана прорва є закритою. Проведений аналіз вказує на наявність природньої тенденції до закриття прорви, але ми не маємо достовірної інформації щодо основної причини закриття. На початок червня 2023 року прорва знаходиться у зачиненому стані вже рік, за умов тривалого закриття або штучного підтримання цього стану, в межах Джарилгацької затоки будуть проявлятися дуже несприятливі наслідки.

Ключові слова: ефемерна протока, береговий бар'єр, неприпливне море, неприпливна протока, припливна протока, прорва.

Introduction

Along ~13% of the shoreline of the World Ocean is fronted by coastal barrier systems (Leontiev, Nikiforov, 1965; Stutz, Pilkey 2011; McBride et al., 2013). These accumulation forms are separated from the mainland by back-barrier wetlands, such as bays, lagoons, estuaries, or saltmarshes (Buynevich, FitzGerald, 2018). Inlets (ephemeral or long-lived) are integral parts of barrier spits (one side) and islands (both sides).

In areas characterized by tides, such channels are called tidal inlets, with tidal currents crucial for inlet dynamics, though not origin (Lucke 1934; Gudelis 1993; FitzGerald 1996; Hayes, FitzGerald 2013; FitzGerald, Buynevich, 2018). Along small enclosed or semi-enclosed seas, as well as some lakes, non-tidal inlets exist and have been given names prorvas ("breach") regardless of their life span (Borisenko, 1946; Budanov, Ionin, 1953; Zenkovich, 1960; Pravotorov, 1966; Shuisky, Vikhovanetz, 1989, 1999; Cooper 1990; FitzGerald et al., 2012; Seminack, Buynevich, 2013; Davydov, Karaliunas, 2022). Morphodynamically, these are complex coastal features with essential elements being a channel proper and accumulation forms on one or both ends (seaward and back-barrier surge deltas; Davydov, Buynevich, 2023).

Depending on hydrodynamic forcing, prorvas represent ephemeral channels, which are characterized by diverse patterns of evolutionary at annual and multi-decadal scales. The main stages include opening (during storms, anthropogenic, etc.), dynamic functioning (longshore migration, widening, rotation), and closure. It is important to note, that these are characteristic of both tidal and non-tidal inlets (FitzGerald 1996; FitzGerald et al., 2012; Bond et al., 2013; Buynevich, Davydov, 2023).

Inlet closure is a rare and important event that has wide-reaching implications for the rapid re-structuring of associated coastal landforms and processes. The aim of this study is to document the recent evolution of the Lazurnenska Prorva, Ukraine, with a focus on its recent closure (June 2022) and potential consequences for near-term impact on sediment transport, coastal morphology, and ecology.

Study area

Lazurnenska Prorva is one of the most accessible inlets of the Tendra-Dzharylgach double-spit system and has been documented to exist within several hundred meters east of the town of Lazurne (46°05'2.40"N / 32°31'46.38" E; Fig. 1). As aforementioned, the ephemeral channels undergo closure and it is important to consider the study site in the context of all openings that existed at the root of the Dzharylgach Spit (Fig. 1c; Davydov, Buynevich 2023). Analysis of historical documents and satellite data (Fig. 1 d-f) spanning the early 19th to early 21st centuries, indicates that ephemeral inlets existed during the entire history of this coastal segment, with only short-term closure phases (up to 3 years). Along the rest of the narrow spit to the east, other prorvas existed, but were short-lived (1-2 years), so were largely non-functional (Pravotorov, 1966; Shuisky, Vykhovanetz 1999).

The genesis of ephemeral channels at the study site were largely due to hydrodynamic forcing from the bay side, similar to an ebb-surge origin of many tidal inlets (Pravotorov, 1966; Davydov, Karaliunas, 2022). Such a scenario is due to the dominance of regional east and northeast wind stress. The hydrodynamic head (water-level rise) is due to the resulting trapping (set-up) of back-barrier water in the western corner of Dzharylgach Bay (Fig. 1c). At the same time, such wind patterns cause a drop in water level (offshore wind) along the seaward side of the barrier (Karkinit Bay). Wave-generated erosion of the rear side of the narrow barrier and the hydraulic differential combine to result in frequent breaching.

It is important to note that ephemeral channels to the east are largely due to storm wave set-up, erosion, overtopping, and overwash from the seaward side of the barrier (Shuisky, Vykhovanetz, 1999). Such processes were documented along Dzharylgach Spit in the early-to-mid-20th century, however, they have not occurred during the past 30 years.

Within Dzharylgach Bay, the wind regime and its hydrodynamic forcing (seiching) are characterized by opposite seasonal trends (Fig. 2). During the cold period, east and northeast wind fields dominate, producing the aforementioned set-up within the bay. In contrast, the warm season is characterized by southwest winds, which stimulate incident waves along the seaward flank of the barrier and drop in back-barrier water level. These patterns result in cold-season intensification of inlet activity and its enlargement (length and width; Fig. 2a). Warmer periods are characterized by the formation of secondary spits extending to the east (down-drift relative to longshore transport), often causing a reduction in active channel morphology (Fig. 2b) and sometimes leading to its closure.

Analysis of satellite images of the root (attachment) segment of the Dzharylgach Spit indicates that Lazurnenska Prorva exhibits certain multi-annual patterns. Within the overall life cycle of the inlet system, the patterns of

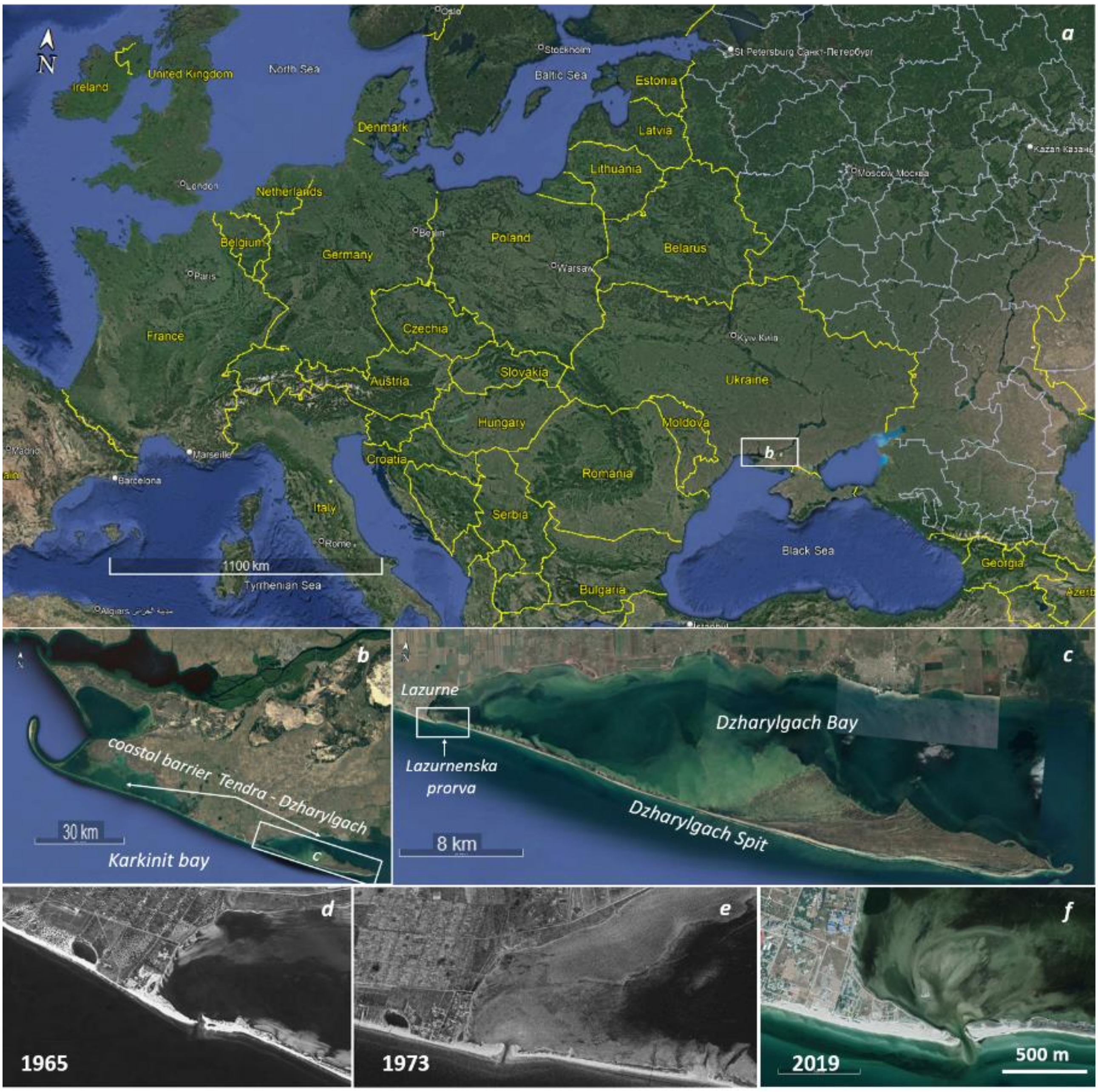

Fig. 1. Location of the study area and general stages of Lazurnenska Prorva: a – general location along the south coast of Ukraine; b – position within the Tendra-Dzharylgach barrier system; c – the root segment of the Dzharylgach spit (note recurved segment to the east); d – detail of the inlet in 1965; e –1973; f – 2019 (note a large bay-side surge delta; image source: GoogleEarthTM)

opening-dynamics-closure occur at varying time intervals. During intensification of storm activity, which controls the longshore transport, opening, and activity of the inlet typically does not exceed several months, whereas it may remain closed for up to 3-4 years. Such trends have been cataloged for the period of the 1980s and the first half of the 1990s.

During periods of reduced storminess, but with greater offshore wind duration, the increased exchange between the Dzharylgach and Karkinit Bays results in longevity and intensified activity of the channel. Beginning in the latter half of the 1990s, the active phase lasted for 10-15 years, with occasional closures for 1-2 years.

Materials and methods

This study is part of a larger regional research campaign based on the analysis of satellite and aerial imagery, as well as field data collection, along the Tendra-Dzharylgach barrier system

Fig. 2. Seasonal trends in the development of Lazurnenska Prorva: ***a*** **– general view during the cold season;** ***b*** **– warm-season scenario (image source: Land Viewer)**

(Fig. 1b) and focuses on the period of 1997-2023. Within this system, a number of ephemeral inlets (prorvas) have been documented but are largely characterized by three active channel sites. Two of them are located along the root (attachment) segments of each spit complex, with one (and sometimes two or three) along the central parts of the Tendra Spit (see recent summary by Davydov, Karaliunas, 2022).

Because of varying spatial and temporal aspects of inlet life cycle, an integrated approach is required, including historical document analysis, photogrammetry, and satellite image comparison, remotely sensed data, field visits, and personal communication with local residents and authorities. The overall morphodynamic trends are analyzed using photogrammetry and video materials using a DJI Mini 2 Fly More Combo drone (altitude: up to 120 m) and a UAV (altitude: up to 400 m). Data post-processing and analysis were performed using Pix4D software. Satellite images were rectified and examined public resources: GoogleEarthTM, Land Viewer, and Sentinel Hub (Figs. 1-3). Free-access Key Hole images from 1965 and 1973 (Fig. 1) were extended by Landsat and Sentinel platforms that covered the period of 1982-2023.

Field research typically occurred semi-annually, typically at the end of warm and cold seasons. This research includes leveling using an electronic NTS-350 unit, both along and across the barrier. These investigations allow a multi-year comparison of morphometric and hydrodynamic aspects of the channels and associated barrier and surge delta regions. Geo-location and mapping using GPS units, such as Garmin eTrex 10, provide unique high-resolution spatio-temporal datasets. It is worth noting, that such data will have a gap due to full-scale military operations and potential mine hazards beginning in February 2022.

Results

Lazurnenska Prorva functioned for ~20 years (2003-2022) and during this period its size shrunk substantially several times, narrowing to 12.3 m in July 2020 based on field measurements. However, it expanded annually during colder phases when more efficient water-mass exchange prevented it from closing. From May 2021 to May 2022, there existed a stable tendency of decreasing width and depth.

Based on field surveys, by the beginning of May 2021, the channel width was ~71 m, with a depth of 1.48 m. Morphologically, the inlet had dimensions typical of the earlier half of that year, oriented perpendicular to the barrier. Satellite images (Fig. 3a, b) are supported by field data, with channel width diminishing from 62 m (April) to 53 m (June). During the summer months, wave approach from west/southwest resulted in easterly longshore transport. As a result, a secondary spit

Fig. 3. Chronology of recent changes in the region of Lazurnenska Prorva: ***a*** **– open (width: 62 m), April 2021;** ***b*** **– open (width: 53 m), June 2021;** ***c*** **– open (width: 48 m), August 2021;** ***d*** **– open (width: 31 m), October 2021;** ***e*** **– open (width: 33 m), April 2022;** ***f*** **– closed, June 2022;** ***g*** **– closed, October 2022;** ***h*** **– closed, March 2023;** ***i*** **– closed, June 2023 (yellow values refer to channel width; image source: Land Viewer)**

began extending eastward, steadily reducing inlet width and forcing a channel angle to approach 45° (Fig. 3c, d). During the fall, there were no east/south-east wind forcing and no activization of water exchange through the prorva. As a consequence, the secondary spit essentially blocked the channel, reducing its orientation angle to 25° (Fig. 4a). By the beginning of December 2021, the most recent field surveys revealed that the channel was 21 m wide and relatively inactive morphodynamically (Fig. 4b).

The beginning of full-scale military operations in February 2022, including in the Kherson Region along the eastern (left) bank of the Dnieper River, prevented further field investigations. The subsequent analysis relied on remotely sensed databases and personal communications with local contacts. Dense cloud cover during winter and early spring precluded satellite observations of inlet behavior. In April 2022, Lazurnenska Prorva lacked morphological features consistent with active water exchange between the water bodies during the preceding cold period. Its width did not exceed 30 m, which was smaller than at this time during previous years (Fig. 3e). In early May, the inlet was still active, although its dimensions were

Fig. 4. Lazurnenska Prorva during fall-winter of 2021: a – 11 September; b – 9 December (B – inlet width; photos by O. Davydov)

anomalously small, suggesting a tendency toward impending closure.

By the beginning of June 2022, the inlet eat of Lazurne ceased to exist (Fig. 3f). The precise reason for its closure is not clear, however, local residents indicated that it was closed artificially, with water exchange limited to pipes. To date, this has not been independently verified. Analysis of satellite images spanning from June 2022 to June 2023, indicates that Lazurnenska Prorva is not active (Fig. 3f-i). Along the seaward side of the barrier, there is a clearly defined nearshore sandbar consistent with active longshore transport. The barrier width at the former inlet site is 89.5 m, although just 2.58 km to the east, active erosion reduced it to 31.3 m, with the potential for this site to breaching in the future.

Discussion

As of summer 2023, Lazurnenska Prorva has been closed for at least a year, which is not anomalous, since according to satellite data spanning the past 50 years its phases of closure lasted for up to 3 years. It is important to know that in the event of a prolonged absence of an active channel in this part of Dzharylgach Spit, the following consequences may be expected:

1) wave approach from south/southwest will cause water-level rise along the seaward margin of the barrier, which will result in erosion, overwash, and even breaching, thereby forming a new inlet cycle;

2) behind the barrier, within the southwest corner of Dzharylgach Bay, east/northeast wind stress will cause seiching. This may result in mainland erosion and flooding of the eastern shore of Lazurne settlement (last event: March 2007) and “ebb-surge”-style breaching due to water set-up.

3) water exchange between Dzharylgach and Karkinit Bays has stopped, which will undoubtedly influence its physicochemical properties and will trigger progressive shoaling and siltation of the back-barrier;

4) the migration pathways of free-swimming organisms have been severed, including fish and mammals, as well as many species of invertebrates;

5) the status of Dzharylgach Bay as a coastal wetland habitat of national importance will substantially deteriorate, which will lead to a decline in aquatic ecosystems and a reduction of biodiversity.

Conclusions

This study presents a unique integrated database of evolutionary trends of Lazurnenska Prorva, including the morphodynamic tendencies from May 2021 to May 2022 that led to its closure. We suggest that this is likely caused by a reduction in east/northeast wind forcing during colder seasons, decreasing the water set-up within the southwest corner of Dzharylgach Bay. Inlet closure is a natural process, although this most recent event may have been anthropogenic in nature. If maintained over a number of years, such closure may lead to a number of negative consequences, both for Dzharylgach Spit and the bay. This study is especially prescient due to ongoing military activity in the region, with likely long-term consequences to research and the livelihood of coastal communities that rely on marine resources and recreation.

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REFERENCES:

1. Bond, J., Green, A.N., Cooper, J.A.G., Humphries, M.S., (2013). Seasonal and episodic variability in the morphodynamics of an ephemeral inlet, Zinkwazi Estuary, South Africa. *Journal of Coastal Research 65 (sp.1)*, 446–451. URL: https://doi.org/10.2112/SI65-076.1.

2. Buynevich, I. V., FitzGerald, D. M. (2018). Barrier Island Landforms. В C. W. Finkl & C. Makowski (Ред.), *Encyclopedia of Coastal Science* (cc. 1–10). Springer International Publishing. URL: https://doi.org/10.1007/978-3-319-48657-4_367-1.

3. Buynevich, I.V., and Davydov, O. (2023). Cross-sectional morphometry and georadar signature of small non-tidal inlet (prorva) channels, Black Sea, Ukraine. *Eurasian Scientific Discussions, Proceedings of the 13th International Scientific and Practical Conference.* Barca Academy Publishing, Barcelona, Spain, 214–218.

4. Cooper, J.A.G. (1990). Ephemeral stream-mouth bars at flood-breach river mouths: comparison with ebb-tidal deltas at barrier inlets. *Marine Geology 95*, 57–70.

5. Davydov, O., Buynevich, I.V., (2023). Morphological diversity of non-tidal inlet (prorva) channels. *Proceedings of the 15th Marine Science and Technology Conference*, Klaipėda University Press, Lithuania, 41–45.

6. Davydov, O., Karaliūnas V. (2022). Genetic diversity of inlet systems along non-tidal coasts: examples from the Black Sea and Sea of Azov (Ukraine). *Baltica*, 35(2), 125–139. URL: https://doi.org/10.5200/baltica.2022.2.3.

7. FitzGerald, D. M. (1996). Geomorphic Variability and Morphologic and Sedimentologic Controls on Tidal Inlets. *Journal of Coastal Research*, Vol. SI, № 23, 47–71.

8. FitzGerald, D.M., Buynevich, I.V., (2018). Tidal Inlets. In: Finkl C., Makowski C. (eds) *Encyclopedia of Coastal Science. Encyclopedia of Earth Sciences Series.* Springer, Cham. URL: https://doi.org/10.1007/978-3-319-48657-4_316-2.

9. FitzGerald, D.M., Buynevich, I.V., and Hein, C.J., (2012). Morphodynamics and facies architecture of tidal inlets and tidal deltas. *In* Davis, R.A., Jr. and Dalrymple, R.W., (eds.). *Principles of Tidal Sedimentology*, Springer Verlag, pp. 301–333.

10. Gudelis, V. (1993). *Jūros krantotyros terminų žodynas.* Vilnius: Academia: 408 [Gudelis, V. (1993). *A Glossary of Coastal Research Terms.* Vilnius : Academia: 408]. [In Lithuanian].

11. Hayes, M. O., FitzGerald, D. M., (2013). Origin, Evolution, and Classification of Tidal Inlets. In: Kana, T.; Michel, J., and Voulgaris, G. (eds.), Proceedings, Symposium in Applied Coastal Geomorphology to Honor Miles O. Hayes, *Journal of Coastal Research*, Special Issue No. 69.

12. Lucke J.B. (1934). Tidal inlets: A theory of evolution of lagoon deposits on shorelines of emergence. *Journal Geology*. 42 p.

13. McBride, R. A., Anderson, J. B., Buynevich, I. V., Cleary, W., Fenster, M. S., FitzGerald, D. M., Harris, M. S., Hein, C. J., Klein, A. H. F., Liu, B., de Menezes, J. T., Pejrup, M., Riggs, S. R., Short, A. D., Stone, G. W., Wallace, D. J., & Wang, P. (2013). 10.8 Morphodynamics of Barrier Systems: A Synthesis. В *Treatise on Geomorphology* (cc. 166–244). Elsevier. URL: https://doi.org/10.1016/B978-0-12-374739-6.00279-7.

14. Seminack, C.T. and Buynevich, I.V., 2013. Sedimentological and geophysical signatures of a relict tidal inlet complex along a wave-dominated barrier: Assateague Island, Maryland. *Journal of Sedimentary Research,* 83, 132–144.

15. Stutz, M. L. and Pilkey, O. H. (2011). Open-ocean barrier islands: Global influence of climatic, oceanographic, and depostional settings. *Journal of Coastal Research*, 27(2), 207–222.

16. Борисенко, А.М. (1946). *Количественный учет донной фауны Тендровского залива* [Borisenko, A. M. (1946). [*Quantitative inventory of the bottom fauna of the Tendra Bay*]. Karadag. 201 p. [In Russian].

17. Буданов, В. И., Ионин, А. С. (1953). Аккумулятивные формы и динамика берегов. *Природа*. № 5, 108–111. [Budanov, V. I., Ionin, A. S. (1953). Accumulative forms and coastal dynamics. *Priroda*. № 5, 108–111 pp.]. [In Russian].

18. Зенкович, В.П. (1960). *Морфология и динамика советских берегов Черного моря. Т. İİ (Северо-западная часть)*. Москва. АН СССР. 216 с. [Zenkovich, V. P., (1960). *Morphology and dynamics of the Soviet shores of the Black Sea. T. II (North-western part)*. Moscow: Academy of Sciences of the USSR, 216 p.]. [in Russian].

19. Леонтьев, О. К., Никифоров, Л. Г. (1965). О причинах планетарного распространения береговых баров. *Океанология*. Т. V. Вып. 4, 653–661 с. [Leontiev, O. K., Nikiforov, L. G. (1965). On the reasons for the planetary spread of coastal bars. *Okeanologiya*, T. V, Vyp. 4, 653-661 p.] [In Russian].

20. Правоторов, И.А., (1966). *Геоморфология лагунного побережья северо-западной части Черного моря (Изучение эволюции береговых форм гидрометеорологическим методом)*. Москва, Университет М.В. Ломоносова. 324 с. [Pravotorov, I. A., (1966). *Geomorphology of the lagoon coast of the northwestern part of the Black Sea (Study of the evolution of coastal forms using the hydrometeorological method)*. Moscow, University M. V. Lomonosova, 324 p.]. [in Russian].

21. Шуйский, Ю.Д., Выхованец, Г.В. (1989). *Экзогенные процессы развития аккумулятивных берегов в северо-западной части Черного моря.* Москва. Недра. 198 с. [Shuisky, Yu. D., Vykhovanetz, G. V. (1989). *Exogenous processes of development of accumulative shores in the North-Western part of the Black Sea.* Moskva, Nedra, 198 pp.]. [In Russian].

22. Шуйський, Ю.Д., Вихованець, Г.В. (1999). Про динаміку гирл в берегових акумулятивних формах на узбережжі Чорного моря. *Ерозія на берегах Чорного та Азовського морів*. Київ. 44–48 с. [Shuisky, Yu.D., Vykhovanetz, G.V. (1999). On the dynamics of breaches located through coastal accumulative forms on the Black Sea coast. *Erosion of the shores of the Black and Azov seas.* Kyiv. 44–48]. [in Ukrainian].

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