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IMPACT OF MILITARY ACTIVITIES AND HOSTILITIES ON THE ECOSYSTEM SERVICES OF THE NORTH-WESTERN BLACK SEA COASTAL ZONE

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Satisfaction of human needs for living environment and food, as well as level and quality of life, depend on ecosystem services. The article studies the main methodological principles of ecosystem services assessment for the coastal zone of the North-Westen Black Sea region. Reduction of opportunities for using the ecosystem services negatively reflects the growing anthropogenic impact on environmental components due to urbanization processes, development of industry, energy sector, transport, agricultural sector of the economy, etc. and, since February 2022, - due to military activities and hostilities. The research presents the main indicators used to assess the ecosystem services. Prior to the outbreak of hostilities, the environment of Odesa Oblast was subject to the highest anthropogenic pressure across the whole NWBS region. The forecast indicators of anthropogenic pressure on the components of the NWBS's environment for the next 10 years showed that, within Odesa Oblast, there was a trend towards increasing level of anthropogenic pressure for almost all components. As for Mykolaiv Oblast, an increasing load was predicted for air basin and water bodies, and as for Kherson Oblast – for air basin and soil and geological environment. The article considers the groups of ecosystem services and the factors reducing the possibility of their use as a result of ongoing military operations. Affected by military activities and hostilities, the possibilities of using the resource component of the ecosystem services are brought to minimum. Military activities and hostilities practically stopped the recreational and health function within the coastal zone of the NWBS region. The primary task is to determine the needs of local communities in terms of use of ecosystem services, to collect and summarize information on their condition, agree on methods for assessment of services for the NWBS region, and conduct such assessment. It is necessary to identify the ways to transition to the models of natural resource management across the coastal zone of the NWBS region, taking into account the decline in delivery of the ecosystem services due to both anthropogenic load and military activities and hostilities affecting environmental components.

Key words: ecosystem services; coastal zone; military activities; the North-Western Black Sea region.

1 INTRODUCTION

Ecosystem services (ES) usually mean all useful resources and benefits that modern humanity can receive from nature, that is, material benefits that humanity receives from abiogenic and biogenic components of various natural ecosystems (NES). Satisfying the needs of mankind for a habitat and food products, as well as a level and a quality of its life depends on ES. In the UN Document "Millennium Ecosystem Assessment", ES is called "a direct and indirect contribution to the human well-being" [1].

All ESs are free because people do not pay for their using or consuming, but some of these services can be monetized to estimate the extent of losses due to losing the useful properties of the NES components. Assessing ES is necessary to understand how important for the normal human life is to preserve the biological diversity and to maintain natural processes in the environment. Assessing ES is an important step in the direction of determining their contribution to various sectors of the economy, and also it allows to judge the potential opportunities for providing these services in a specific context and for specific recipients of the material requirements. Herewith it is determined how stable ES providing is, as well as the opportunities to identify the thresholds and the

tipping points. The study of ES is important for making decisions that can affect NES, because maintaining the balance of NES depends on the maintenance of the socio-economic possibilities for the human existence. Unfortunately, ES are still absent in the Ukrainian legislation, and taking them into account when making decisions is not a very common phenomenon [2], and therefore assessing the ES of the North-Western Black Sea (NWBS) coastal zone various ecosystems is an urgent ecological and socio-economic problem.

According to the European Commission definition, the coastal zone is a strip of the land and the sea and its width varies depending on the nature of the environment and the management tasks. Sometimes it coincides with the administrative boundaries or planning units. Natural coastal systems and areas, where men carry out their activities, which are closely related to using the coastal resources, can cover both inter-coastal waters and stretch to many kilometers inland. The coastal zone of the NWBS is a universal natural resource, and its development will allow all branches of the economy to develop steadily in the coastal-sea areas of the southern part of Ukraine. Taking into account the fact that the Black Sea affects the climatic conditions of the southern coast of Ukraine (in winter the action of the warm Black Sea extends deep into the territory of Ukraine for 140 – 280 km), most of the territory of the Odesa, Mykolaiv and Kherson regions can be considered as a coastal zone.

2 MATERIALS AND METHODS

Material benefits can be obtained from the abiogenic and biogenic components of various NES of the NWBS coastal zone, but decreasing the possibility of using the ES reflects the growing technogenic impact on the components of the environment due to the processes of urbanization, the development of industrial, energetic, transport and agrarian sectors of the economy, etc., and from February 2022 – as a result of military activities and hostilities.

The main approach for assessing NES in the EU countries is the method described in the analytical report "Mapping and Assessment of Ecosystems and their Services (MAES)" [3], which is based on the selection of the load indicators on the NES and their mapping. The essence of this methodology is that the current state of NES is related to well-being through the ES, and therefore NES should be in the favorable conditions to provide the basic services those, in turn, benefit and increase this same well-being. At the same time, the destructive forces of the changes can have a positive (for example, maintaining the NES homeostasis) or a negative (technological loading) impact on the state of the NES. The main indicators of the NES state are: 1) indicators of loading on the terrestrial and freshwater ecosystems (a change in the forest areas, the polluted air pool, a balance of the biogenic elements, etc.); 2) the state indicators of the terrestrial and freshwater ecosystems (the percentage of the population exposed to the effects of noise pollution; the content of NO_2, PM_{10}, $PM_{2.5}$, O_3 and other pollutants in the atmospheric air; a share of the built-up areas; the index of water resources using; the indicator of birds on the agricultural land and etc.); 3) the marine ecosystems state indicators (a level of pollution, suitability for swimming, the fish catch, the spawning stock biomass, the industrial species age and size composition, a number of invasive species annual introductions, etc.).

About half of the indicators used to assess the ecosystem in the EU countries [3, 4] are based on the spatial data and thus they can be marked on the maps that combine loading and state indicators: a number of indicators showing the result of improvement; a number of indicators showing the result of deterioration; a number of indicators showing no change.

3 RESULTS AND DISCUSSION

Modern society is focused on the causes of losing the ES and the biological diversity, as well as on the responsibility for them. The financial sector is seen as a key lever for influencing on these losses, as well as a mechanism for improving the ES assessment and the management system. Some sectors of the economy are particularly prone to the risk associated with their reduction, and these are primarily sectors that directly depend on the availability of natural products (for example, fishing and forestry), sustainably functioning ecosystems (for example, obtaining the agricultural products, biofuels, food and beverages), or the services derived from them (e.g. water supply, recreation, etc.) [5].

Assessing the ES value can be a tool for monetary evaluating the biological diversity or a concrete value that it provides to support the population and its way of living [6]. The most desirable approach [7] for nature management optimization is the management taking into account that only biological diversity can provide some ES. Currently, there are no studies using quantitative

values of the biological diversity as a tool for forecasting the consequences of alternative management decisions [8], apart from the rare exceptions [9].

In recent years, before the start of hostilities the environment of the Odesa region experienced the maximum technogenic load among the NWBS-regions (Fig. 1). A comprehensive analysis of the technogenic load on the individual components of the environment according to the relevant impact indicators (Fig. 2) showed that, according to the impact indicators on the air basin (M_{AB}) and water bodies (M_{WB}), the maximum load is also experienced by the Odesa region, and according to the impact indicators on the geological environment (M_{GE}) – the Mykolaiv region [10].

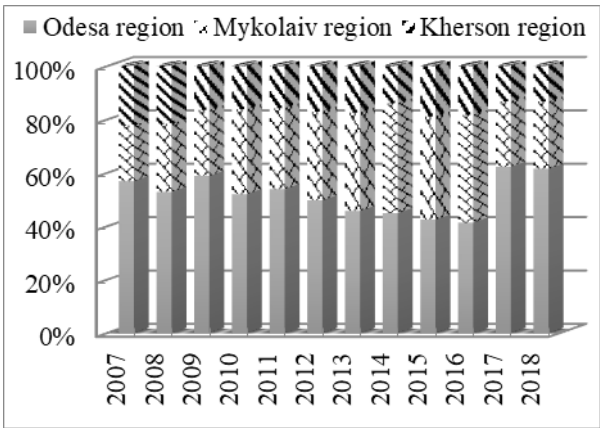

Fig. 1 – Comparative analysis of the level of technogenic loading on the regions of the NWBS for 2007 – 2018 (a) and by average indicators (b)

The assessment of the predicted indicators of technogenic loading on the components of the NWBS environment for the next 10 years showed that in the Odesa region there was a trend towards

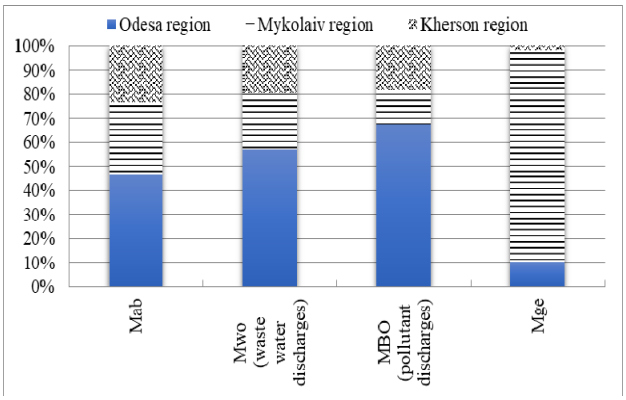

Fig. 2 – Comparative analysis of technogenic loading on the individual environmental components of the NWBS coastal zone

an increase in the level of technogenic loading for almost all components. In the Mykolaiv region, an increase in the load was predicted for the air basin and the water bodies, in the Kherson region – for the air basin and the soil-geological environment [10].

It should also be noted that the ecosystems state individual indicators, given above, are also used to assess the processes of sustainable development, namely the Environmental Dimension Index for Sustainable Development (I_e). The previous studies have shown that among the regions of the NWBS the most unfavorable ecological situation from the point of view of sustainable development was noted in the Odesa region (Fig. 3). The Kherson region, which at the moment has suffered perhaps the greatest destruction and stress as a result of the military operations was characterized by the best conditions. It should be noted that among all the analyzed indicators, the predominant role is played by the policy category "Environmental load" [10].

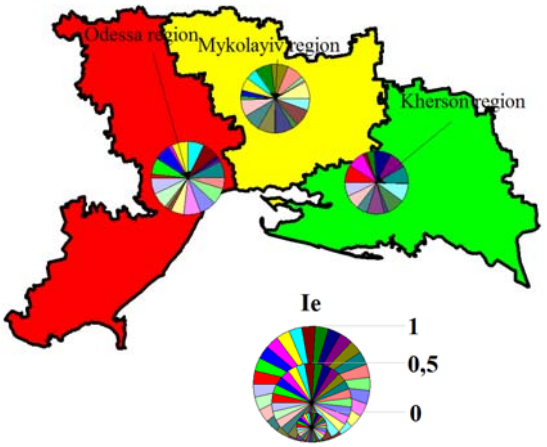

Fig. 3 – Spatial distribution of the environmental dimension index for sustainable development I_e for the NWBS territories

The COVID-19 pandemic also hit the economy of the coastal zone of the NWBS. But it is clear that military actions also significantly contribute to the deterioration of the state and the quality of the components of the environment within the water area and the coast of the NWBS-part.

So far, no large-scale studies have been conducted to assess the ecosystem services of the NWBS coastal zone, with the exception of assessing the state, the problem and the perspectives of the ecosystem services of the northwestern part of the Black Sea [11].

There are the following groups of ecosystem services: 1) resource (wood, food, fresh water, etc., that is, something that has a market value and price); 2) regulatory (for example, forest areas that regulate moisture and prevent floods); 3) cultural and sociological - benefits obtained by admiring nature, while receiving, at the same time, some educational, scientific functions, etc.; 4) supporting (the most complex natural cycles, deep, biogeochemical cycles, soil formation, etc.) A brief description of them using the example of the NWBS coastal zone is below.

Resource services. The NWBS has previously had problems with the toxic and biogenic pollution of anthropogenic origin, as well as with the reduction of biodiversity, but military activities and hostilities have greatly complicated these problems due to ships maneuvering, missiles launching from the submarines, toxic waste rocket fuel dumping into the marine environment, the acoustic and electromagnetic pollution.

Navigation possibilities are very limited due to mining the sea water area. Due to the Russia's war against Ukraine and the hostilities in the Black Sea, the economy of all countries whose goods are exported through the seaports is suffering. Some companies refuse to work with the Russian Federation due to the sanctions, some are simply afraid to enter a dangerous zone where the Russian forces have already fired or captured several merchant ships. 60% of the Ukrainian exports take place through the Black Sea ports, therefore it is pointless to deny the losses of Ukraine itself [12].

An ineffective system of management and handling the solid household waste, uncontrolled recreational activities in the coastal strip have led to the formation of spontaneous dumps, which are the source of forming the marine litter, which transforms in the marine environment and negatively affects the biota. For example, waste plastic materials (microplastics) that have entered the marine environment are gradually destroyed, generating a huge number of microparticles that pose a danger to the state of the marine environment and biota [13]. Military activities and hostilities have led to a decrease in the efficiency of the system for managing and handling the various production and consumption wastes, and also have led to the pollution of the environment of the NWBS coastal zone with the specific toxic waste.

Biological diversity is negatively affected by intentional and accidental invasion of the biological species. An example of this is the invasion of the *Mnemiopsis leidyi*, which multiplied actively and its biomass was 1 billion tons in 1989 (90% of the total biomass of the Black Sea), which led to the destruction of zooplankton, fish eggs and fry, that is, to the reduction of the fish food base 30 times over two years. As a result of increasing the warships in the waters of the NWBS, the processes of invading the biological species may also become more active.

Explosions, chemical and acoustic pollution have led to the mass death of vulnerable dolphins on the coast of the entire Black Sea. Sinking ships, planes, unmanned aerial vehicles and other military equipment have led to spilling the oil products and other substances which are toxic to the marine biota and can poison the marine environment for many years. An additional threat is posed by ammunition, which can be a source of contamination with heavy metals, white phosphorus and other pollutants. Shell fragments are dangerous to birds, which ingest small rock particles to aid in digestion. Unexploded projectiles and mines have created a danger to the marine environment and the coast, as well as to commercial fishing and recreational activities. In the NWBS coastal zone, there are ecologically dangerous objects (maritime complexes, oil storage facilities, treatment plants, industrial sites, drilling platforms, landfills, etc.), and their damage as a result of shelling have led to the leakage of the dangerous substances into the marine environment. In particular, as a result of the destruction of many sewage treatment plants and the decrease in the efficiency of their operation, the scale of chemical and bacterial pollution of the marine environment has increased. Combat actions have a negative impact on individual hydrobionts, endangering their existence. As a result of the underwater explosions that cause a shock wave, fish and other marine organisms are deafened [14, 15]. As a result of the hostilities, commercial fishing in the NWBS water area was practically stopped.

Thus, as a result of military activities and hostilities, the possibilities for using the resource component of the ecosystem services have been reduced to a minimum.

Regulatory services. Wetlands, which are widely developed in the coastal zone of the NWBS, act as a regulator of such processes as accumulating and keeping fresh water, filtrating the water, absorbing and accumulating carbon from the atmosphere, returning oxygen to the atmosphere, regulating the surface runoff, stabilizing the level of groundwater, participating in forming the climatic conditions, preventing and restraining the erosion processes, supporting and preserving the biodiversity, forming the habitats for various species of plants and animals, including rare and red-listed species, as well as maintaining the maximum biological productivity of the aquatic ecosystems. Biological regulation means to regulate the interaction between the different trophic levels, that helps to maintain a balanced ecological pyramid. This is confirmed by sharp reducing the specific fish and the invertebrate's species as a result of sharp reducing the Phyllophora crispa phytomass, which has led to the degradation of the "phyllophore biocenosis". Military activity and hostilities in the NWBS coastal zone had an extremely negative impact on functioning the hydrobionts, in particular ichthyofauna, dolphins. Ecological damage was caused to the phyllophorous field of Zernov – a concentration of macrophyte algae, the dominant species among them are red algae of the *Phyllophoraceae* family, as well as the entire "phyllophore biocenosis" of this national importance botanical reserve. The hostilities have threatened existing the rare bird species in the Ramsar wetlands, disturbing their peace and impeding their nesting and migration.

Cultural and social services. Within the NWBS coastal zone, there are unique coastal and marine habitats (estuaries, islands, salt flats, lakes, wetlands, etc.), which are a habitat for the rare biological species. A large number of nature-reserved territories and water areas that are under the threat of destruction are located right here (the Black Sea Biosphere Reserve, the "Azov-Syvaskyi" and "Dzharylgatskyi" national nature parks, the "Filophorne Pole of Zernov" national importance botanical reserve, the Kinburnska spit reserve, etc.), and in other nature-reserved territories (the Danube Biosphere Reserve, the Tuzlovsky Limans and the Nizhnyodnistrovsky National Parks, etc.), the functions of the services that ensure the proper protecting and preserving the rare species have become more difficult.

The various ecosystems of the NWBS coastal zone play an important role in providing recreational and health services. The aesthetic value is the attractive marine and coastal landscapes of the NWBS with the unique visual environment. The Danube and Black Sea Biosphere Reserves, "The Tuzlovsky Limans", "The Kuyalnytskyi Liman" and "The Dzharylgatskyi Liman" national natural parks, the regional landscape parks, nature reserves and other objects and territories of the nature reserve fund can provide the educational services, as they are natural scientific laboratories where it is possible to carry out the research activities in the field.

Comfortable bioclimatic conditions, a considerable length of the beach area and other natural and recreational resources allow to talk about the perspective of the NWBS coastal zone for the various recreational forms, including thalassotherapy (a treatment with the sea climate and swimming combined with sunbathing). However, relatively low salinity, eutrophication and increased sea water pollution, especially in the estuarine areas, limit the possibilities of thalassotherapy, but the presence of pus, therapeutic mud and comfortable bioclimatic conditions in the distribution zones of some individual estuaries determine their high recreational impact. There are deposits of therapeutic mud (mud sulphide peloids) in the coastal zone of the NWBS: the Tuzlovsky Liman (a stock of 35185 m^3), the Budaksky Liman (a stock of 4190 m^3), the Khadzhibey Liman (a stock of 11048 m^3), the Kuyalnytsky Liman (a stock of 15327 m^3); the Tyligulsky Liman (a stock of 11276 m^3), the Berezansky Liman (a stock of 10910 m^3) and others. Only the Kuyalnytskyi Liman and some limans of the Odesa region are currently used for mud treatment and medical preparations, although the potential of other estuaries in the NWBS is very large.

Because numerous technogenic objects that are often coastal sources of pollution are located on a large part of the coast, they underestimate the recreational opportunities of the marine environment. The possibilities of thalassotherapy and mud therapy were also very limited due to mining the NWBS water area. Military activity and hostilities practically stopped the recreational and recreational function within the NWBS coastal zone.

Support services. The marine and coastal ecosystems of the NWBS are habitats and sources of nutrition for numerous organisms. The role of the wetlands protected by the Ramsar Convention (the Kiliy estuary, the Sasyk, the Shagany-Alibey-Burnas, the southern part of the Dniester Liman, the Tyligul Liman, the Yagorlytsk Bay, etc.) is especially important, they are of great importance as a habitat for aquatic and near-aquatic birds and is characterized by the biological diversity. As

regulating services, the wetlands play an important role in producing the primary products and photosynthesis, as well as they are a source of food, raw materials, genetic resources for medicines; they mitigate floods, protect coastlines and increase a resistance to natural disasters, and they also play an important role in developing the transport system and the recreational and tourist activities and in the human cultural and spiritual well-being.

The continued irrational using the natural resources, and even interfering in the course of the processes, as well as military activities and hostilities in the NWBS cause practically irreversible processes of changing the coastal and marine ecosystems, which restoration needs new approaches, oriented not on the temporary economic benefit, but on receiving the sustainable ecosystem services in the future as well.

4 CONCLUSIONS

Thus, based on the lack of information about the state of the ecosystem services of the NWBS coastal zone various ecosystems, the primary task is to determine the needs of the local communities in using the ecosystem services, collecting and summarizing the information about their state, coordinating the methods for assessing services for this region and carrying out this assessment. It is necessary to consider the ways of further transition to the natural resources management models of the NWBS coastal zone, taking into account reducing the ecosystem services due to technogenic loading, military activities and military operations on the components of the environment. To do this, it is necessary to raise the public awareness and to deep the society's understanding concerning the value of the ecosystem services of the NWBS coastal zone, as well as to justify the complex measures to restore the components of the environment.

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ВПЛИВ БОЙОВИХ ДІЙ НА ЕКОСИСТЕМНІ ПОСЛУГИ ПРИБЕРЕЖНОЇ ЗОНИ ПІВНІЧНО-ЗАХІДНОГО ПРИЧОРНОМОР'Я

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Від екосистемних послуг залежить задоволення потреб людства в середовищі існування й продуктах харчування, а також рівень та якість його життя. У роботі розглянуто основні методичні засади оцінки екосистемних послуг для території прибережної зони Північно-Західного Причорномор'я. Зниження можливості використання екосистемних послуг негативно відображає зростаючий техногенний вплив на складові довкілля через процеси урбанізації, розвиток промисловості, енергетики, транспорту, аграрного сектора економіки тощо, а з лютого 2022 року – внаслідок військової діяльності та бойових дій. Наведено основні показники, які використовуються для оцінки екосистемних послуг. До початку військових дій серед регіонів Північно-Західного Причорномор'я максимального техногенного навантаження зазнавало довкілля Одеської області. Прогнозовані показники техногенного навантаження на складові довкілля Північно-Західного Причорномор'я на майбутні 10 років свідчили, що в Одеській області майже по всіх складових відзначався тренд до збільшення рівня техногенного навантаження. У Миколаївській області збільшення навантаження прогнозувалось для повітряного басейну і водних об'єктів, у Херсонській області – для повітряного басейну і ґрунтово-геологічного середовища. Розглянуто групи екосистемних послуг та фактори зниження можливостей їх використання внаслідок військових дій. Внаслідок військової діяльності та бойових дій можливості використання ресурсної складової екосистемних послуг зведені до мінімуму. Військова діяльність та бойові дії практично зупинили рекреаційно-оздоровчу функцію у межах прибережної зони Північно-Західного Причорномор'я. Першочерговим завданням є визначення потреб місцевих спільнот щодо використання екосистемних послуг, збирання та узагальнення інформації про їх стан, узгодження методів оцінки послуг для Північно-Західного Причорномор'я та проведення цієї оцінки. Необхідним є визначення шляхів переходу на моделі управління природними ресурсами прибережної зони Північно-Західного Причорномор'я з урахуванням зниження екосистемних послуг внаслідок техногенного навантаження, військової діяльності та бойових дій на складові довкілля.

Ключові слова: екосистемні послуги; прибережна зона; військова діяльність; північно-західна частина Чорного моря.

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