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Black Sea Network of Marine Protected Areas: European Approaches and Adaptation to Expansion and Monitoring in Ukraine

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Introduction

This chapter brings together several strands of current research concerning Marine Protected Areas (MPAs) in the Black Sea in general, and in Ukraine in particular. First, it provides a more accurate assessment of the total area of MPAs of different status within six Black Sea countries. Second, the impact of eutrophication on the features and the development of MPAs in Ukraine is considered. This is followed, thirdly, by a brief overview of the method used for identifying and justifying the designation of new MPAs (or expanding existing MPAs) in Ukraine, based on integrated evaluation of anthropogenic impact, aquatic plant morphological indicators, and determining the ecological value of marine areas. Finally, the opportunity of developing public ecological monitoring for the Black Sea is explored.

Overview of MPAs in the Black Sea

It is well known that the reproduction of most living marine natural resources takes place in the coastal zones (Zaitsev, 2006) because of the edge effect in which physicochemical and biological interactions are most intense at the interface between land and water. It is no coincidence that most protected areas are located near coasts. At the same time, this zone suffers the highest human pressure because of urban expansion, transport and other infrastructure development, exploitation of living and non-living resources and steady extension of recreation areas. Around 15 million people live in the 2 km wide coastal zone of the Black Sea, 6 million of them in Ukraine alone (Panchenko, 2009).

Conflict between economic activities and the need to maintain living resources has led to the establishment of MPAs. One of the first Black Sea MPAs, the Black Sea Biosphere Reserve, was established in Ukraine as early as 14 July 1927 to protect coastal and marine communities near the Dnieper River delta.

It is difficult to determine the precise extent of the existing Black Sea MPA network. First, almost all the MPAs comprise not only marine waters but also terrestrial areas, which are generally larger. Second, parts of the aquatic area are lagoons or closed limans, isolated from the sea, which

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cannot be included with the Black Sea by definition. Third, the definition and classification of protected areas in the Black Sea countries differ to a greater or lesser degree from the IUCN classification (Lausche, 2011). For example, where the IUCN has seven categories of protected area, Bulgaria has five, Romania has 10 (Begun *et al.*, 2012), and Ukraine has 11; moreover their classification criteria are different.

Another difficulty in determining the total area of MPAs in different countries is that their areas often include sites with multiple designations. For example, the transnational Danube Delta Biosphere Reserve in Romania and the Danube Biosphere Reserve in Ukraine also include wetlands in the Ramsar list. The Natura 2000 protected area 'Ropotamo' (Ropotamo wetland complex) in Bulgaria contains four natural reserves (Begun *et al.*, 2012), several Ramsar wetlands (Marushevsky, 2003) and the Blato Alepu nature monument. A recent publication on Black Sea MPAs says that there are no protected areas in Turkey apart from Ramsar wetlands in the Kizilirmak River delta (Begun *et al.*, 2012). However, we know about two nature reserves (Igneada Flooded Forest and Sarikum Lake) and a permanent wildlife reserve in Yesilirmak Delta (Marushevsky, 2003; Öztürk *et al.*, this volume).

To consolidate the existing data about the actual area of the existing Black Sea MPAs, they were divided into three groups: (i) protected areas (reserves) of international significance (importance); (ii) Ramsar wetlands; and (iii) areas of national significance. Protected areas of local importance were not taken into account. Map measurement was used to determine the areas of the MPAs connected with the Black Sea in cases where the figures were absent from the available literature (Marushevsky, 2003).

Analysis of the information collected enabled us not only to map the current distribution of MPAs in the Black Sea (Figure 12.1), but also to establish some important quantitative characteristics about them. Thus, the area of water-bodies in the MPAs connected with the Black Sea amounts to a total of 755 840 ha. The Black Sea countries can be ranked by their MPA extent as follows: Ukraine – 82.0%; Romania – 14.7%; Georgia – 2.2%; Turkey – 0.7%; Bulgaria – 0.4%; and Russia – 0.1%.

Ecological Characteristics of the Ukrainian Part of the Black Sea

Geographic Features

The Ukrainian part of the Black Sea coast has a length of some 1829 km. It has special geographical conditions and associated ecosystems that have to be taken into account when planning a network of MPAs. The vast, shallow (15 to 55 m depth) shelf platform in the north-western Black Sea (Öztürk *et al.*, this volume), from the Danube River to Cape Tarchankut, extends over more than 55 000 km^2. It receives the waters from three large nutrient-rich European rivers: the Danube, Dniester and Dnieper. These conditions result in the shelf being the most biologically productive area of the Black Sea (Zaitsev, 2006), contrasting with the Crimean Peninsula coast (acknowledged by IUCN as one of nine centres of European biological diversity) which is less productive but has the highest national level of landscape and biological diversity (Yena *et al.*, 2004).

Biodiversity

According to the Black Sea Transboundary Diagnostic Analysis, Annex 4 (Commission on the Protection of the Black Sea Against Pollution, 2007), the Black Sea hosts 44 distinct habitat types. Of these, 42 are present in the Ukrainian part of the Black Sea,

Table 12.1 Black Sea MPAs of international and national level in Ukraine.

No.[a)]	MPA	Protected status	General area (ha)	Marine area (ha)
1	Danube	Biosphere Reserve	50 253	6686
10	Chornomorskyi	Biosphere Reserve	109 255	93 960
25	Karadag	Natural Reserve	2874	809
14	Lebiazhi Islands	Natural Reserve	9612	9612
23	Cape Martian	Natural Reserve	240	120
27	Cape Opuk	Natural Reserve	1592	62
3	Tuzla liman complex	National Natural Park	27 865	883
16	Tarchankut Cape	National Natural Park	10 900	360
9	Biloberezhia Sviatoslava	National Natural Park	35 223	25 000
11	Dzharylgachskyi	National Natural Park	10 000	2469
5	Zernov's Phyllophora Field	State Significance Preserve (botanical)	402 500	402 500
12	Small Phyllophora Field	Nationally Important Reserve (botanical)	38 500	38 500
2	Zmiyiny Island	Nationally Important Reserve (zoological)	640	232
13	Karkinitskyi Gulf	Nationally Important Reserve (zoological)	27 646	27 646
19	Kozachia Bay	Nationally Important Reserve (zoological)	23	23
21	Cape Aiya	Nationally Important Reserve (landscape)	1132	208
Total areas			728 256	609 070

a) Numbers refer to sites shown in Figure 12.3.

high level of marine biodiversity, include only 0.2% of all Ukrainian MPAs of international and national importance.

Approaches to Management and Monitoring of MPAs in Ukraine

Taking Account of Anthropogenic Influence in the Justification of an MPA

As mentioned above, the coastal zone supports high biological diversity and concentration of life due to edge effects. This zone also experiences significant conflicts between different human economic activities (such as construction, agriculture, industry and recreation). These conflicts adversely affect the state of marine ecosystems to a greater or lesser degree. A matrix comprising 27 human-caused stress factors and 15 types of biota response (Zaitsev, 2006) was proposed for integrated assessment of the anthropogenic impact (AI).

If the intensity of anthropogenic impacts is assessed on a seven-point scale from 'very negative' (1) to 'very positive' (7), it is possible to estimate an overall AI score for a given area. For this purpose, a matrix of expert

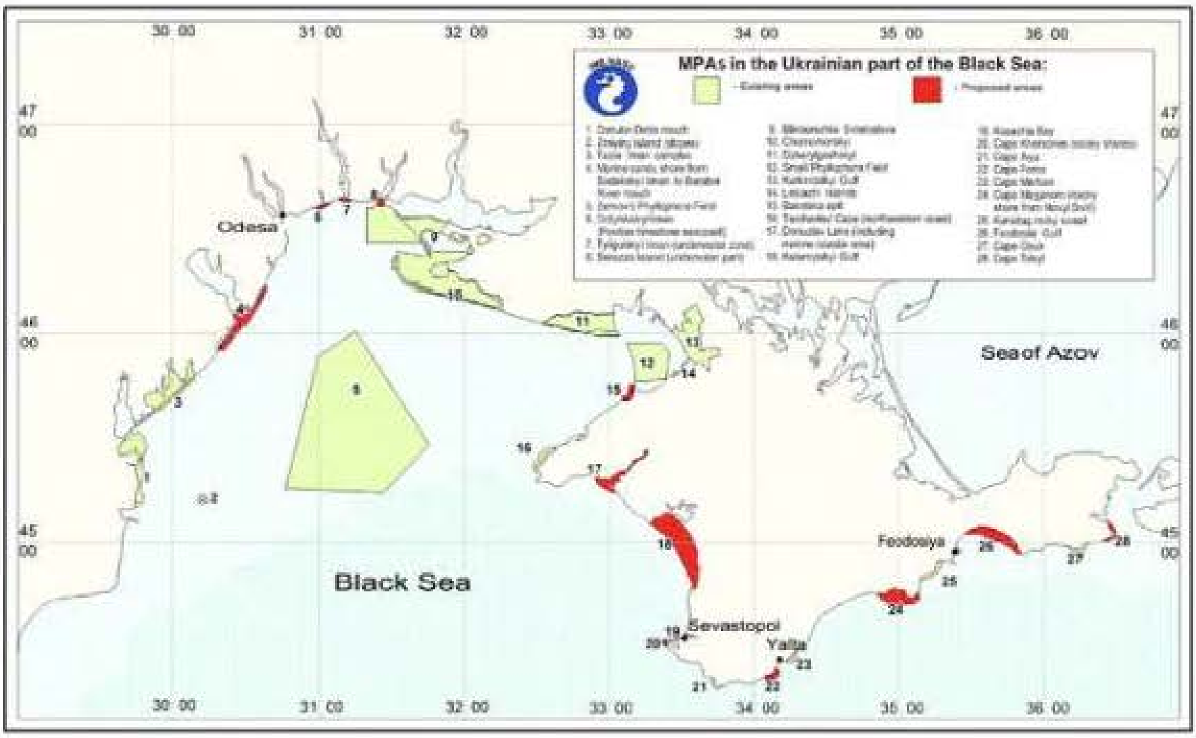

Figure 12.3 Current Ukrainian MPA network and proposed new MPAs.

assessment of stress factors and biota responses can be used (see Table 12.2). For example, the average AI scores for 26 areas of the Black Sea in Ukraine, from the Danube Delta to the Kerch Strait, are given in Table 12.3. The AI scores correspond well with protected areas and can be used as an additional indicator in support of the MPA.

The least number of stress factors (3) influenced the Zernov's Phyllophora Field MPA, while the most (24) affected the Odessa Gulf ecosystem. The AI scores show that Sukhoy liman, which hosts a commercial seaport, had the highest level of anthropogenic impact. In contrast, the marine areas having protected status and situated at some distance from the coastline (Zernov's Phyllophora Field and Zmiyiny Island) had the lowest level of anthropogenic impact.

Plant Morphological Indicators for Rapid Monitoring of MPAs

In 2015, the Commission on the Protection of the Black Sea Against Pollution approved the use of plant morphological indicators (Minicheva *et al.*, 2014) as part of the Black Sea Integrated Monitoring and Assessment Programme standards. These indicators directly reflect the ecological function of the bottom vegetation and therefore have advantages over other structural phytoindicators such as floristic composition, biomass and cover. The simple morphological methods involved allow rapid and accurate assessment of the intensity of autotrophic processes and thus the ESC of the marine ecosystem.

The main aim of the Marine Strategy Framework Directive (MSFD, 2008/56/EC) is to achieve Good Environmental Status (GES) of marine waters, such that they provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive. Reaching GES is not only the main aim of joint efforts by European states in marine protection and management, but also an important aspect of MPA monitoring and assessment. To interpret what GES means in practice, the MSFD sets out 11 descriptors, which describe what the environment will look like when GES has been achieved. Each descriptor reflects different aspects of the marine environment's resilience to the most widespread and intensive human impacts on it. Quantitative evaluation of the descriptors requires a measuring tool, and different indicators of the ecosystem's state could be used as such a tool. The selection of the most suitable indicators for GES assessment out of the huge number of available hydro-ecological parameters is a vital task. If the indicators selected for monitoring MPA condition only reflect the dynamics of biological features, then the functional state of biological elements and the real ecological status of the protected ecosystem could be obscured. Thus, the GES indicators should reflect the functional properties of biological elements (intensity of production and destruction processes on which high biological diversity depends, branching of food chains, good quality of biological resources and aquatic environment) and at the same time applicable to several descriptors at once.

Indicators based on morphological features of aquatic vegetation, in particular the active surface area to weight ratio, could be a sensitive means for rapid assessment of the ESC as part of MPA monitoring (Minicheva, 1998). The main advantage of such an indicator is that it is based on simple measurement methods of macrophytes (which are permanent and functionally important components of coastal ecosystems). In addition to the assessment of ESC, indicators based on macrophyte morphology can be used for quantitative evaluation of four GES descriptors, namely:

- Descriptor 1: Biodiversity is maintained
- Descriptor 4: Elements of food webs ensure long-term abundance and reproduction
- Descriptor 5: Eutrophication is minimised
- Descriptor 6: The sea floor integrity ensures functioning of the ecosystem.

Table 12.2 Generalized matrix of expert assessments of ecological processes in the Black Sea coastal zone.

Stress \ Response		Changes of life conditions									Biological and general changes					
		Salinity	Currents	Transparency	Pollution	Trophicity	Bottom sediments	Oxygen content	Disturbance	Concentration	Biological diversity	Bottom hypoxia	Stocks	Health risks	Marine food quality	Aesthetic qualities
I	Fishing	4	4	3	3	4	1	2	1	4	2	3	1	3	4	3
	Mining	4	3	2	2	3	1	2	1	4	2	3	1	3	4	3
	Industrial wastes	1	4	2	1	3	3	2	1	1	1	1	1	1	1	1
II	Pesticides	4	4	2	2	3	2	2	2	1	1	1	1	1	1	1
	Soil erosion	4	4	1	2	3	1	2	3	3	2	3	1	2	2	2
	Agricultural runoff	3	4	1	1	3	1	1	2	1	2	1	1	1	1	1
III	Residual foods	4	4	2	1	5	3	2	3	4	4	3	4	3	3	2
	Genetic degeneration	4	4	4	4	4	4	4	4	4	2	4	5	4	4	4
IV	Ports development	4	2	2	1	3	1	1	1	1	3	3	3	2	3	3
	Deepening, dumping	4	2	2	2	2	1	2	1	4	2	3	3	3	4	3
	Ballast waters and exotic species	4	4	4	3	4	4	4	4	4	3	4	2	4	4	4
	Shipwrecks	4	4	3	2	3	4	4	3	1	1	4	4	3	3	3
V	Urban sewage	3	4	2	1	3	2	2	3	1	1	1	1	1	1	2
	Rain waters	3	3	2	2	3	3	3	3	1	2	3	3	2	2	2
VI	Addition of sand	4	4	3	4	4	1	4	3	4	1	4	2	2	4	4
	Coast protection constructions	4	2	3	2	3	2	2	2	4	6	4	4	3	4	3
VII	Dams	3	3	4	4	4	4	4	2	4	4	4	1	4	4	4
	Reservoirs	3	3	4	4	4	4	4	2	4	4	4	1	4	4	4
VIII	Resort development	4	3	3	2	3	3	3	2	3	3	4	4	3	3	4
	Resort sewage	4	3	2	2	3	3	2	2	2	2	3	3	2	2	2
	Recreational activities	4	3	4	3	4	4	3	1	4	4	4	4	4	4	4
IX	Nature conservation	4	5	5	7	6	6	6	7	4	7	6	7	7	7	7
	Environmental control	4	5	5	6	6	6	6	7	6	6	6	7	7	7	7
	Artificial reefs	4	3	6	6	6	6	7	7	4	7	6	6	6	6	7
X	Environmental education	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7
	Field trips	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7
	Books, posters, films	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7
Integrated coastal zone management		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Source: After Zaitsev (2006).

Key: *Consequences:* 1, very negative; 2, negative; 3, more negative than positive; 4, uncertain; 5, more positive than negative; 6, positive; 7, very positive. *Uses:* I, industry; II, agriculture; III, pisciculture; IV, sea transport; V, municipal economy; VI, coastal protection; VII, hydro-power engineering; VIII, tourism, resorts; IX, nature conservation; X, environmental education and environmental ethics.

activity of macrophytes (see previous section) as an index of primary production of phytobenthos (K_{EAM}); ratio of biomass of plankton to benthos ($K_{P/B}$); and (ii) direct indices of biodiversity such as: number of macrozoobenthic species (K_{MZB}); total number of benthic biocoenoses (K_{BB}); and number of Red Data Book species (K_{RDB}). The numbers of direct and indirect biodiversity indicators in K_f are equal. However, there is a feedback between these indicators: high primary production reduces the species diversity of ecosystems. It was shown above that the value of anthropogenic impact (K_{AI}) is highly correlated with the state of ecosystems in protected areas. Thus K_{AI} can also be treated as an indirect indicator of biological value and included in K_f calculations. All of these metrics reflect the indicative lists of characteristics, pressures and impacts (MSFD Annex III, Table 1; 2008/56/EC): physical and chemical features, habitat types (structure and substrata composition of the seabed), biological features (phytoplankton and zooplankton communities; macroalgae and invertebrate bottom fauna; status of species), and other features (chemicals, sediments contamination, hotspots, health issues).

The weight coefficients of characteristics (a_i) were determined from paired correlation coefficients of the selected metrics value with two of them, K_{RDB} and K_{EAM}, as these were the most important direct and indirect metrics respectively for assessing the biological significance of a marine area (Table 12.4).

The approach was applied to 26 brackish or marine areas in the Ukrainian part of the Black Sea coast from the Danube Delta to the Kerch Strait: 11 limans, eight bays and gulfs, one island, one delta, one open shelf area, one reservoir, one lake, one coastal cliff and one strait (Table 12.5). The characteristics required for calculating K_f values were taken from Alexandrov *et al.* (2010). Special attention was paid to the fact that values of K_f have to be determined not for the whole area, but for each component ecosystem present (Alexandrov, 2012). To determine the boundary values of K_f for the five classes envisaged by the MSFD (High, Good, Moderate, Poor, Bad), the percentile rule was used (Ohio Environmental Protection Agency, 1987). When a metric tends to decrease with the increase of human pressure, a deviation of more than 25% from the norm is evidence of an aggravated ecological situation.

Applying the method described here (which now incorporates K_{AI} in the K_f calculation originally used by Alexandrov, 2012; values of AI metric normalized similar to direct indices of biodiversity) shows that those marine ecosystems having the highest biological significance (and thus protected

Table 12.4 Matrix of cross-correlation between seven selected biological characteristics of marine ecosystems for determination of their weight coefficients (a_i).

Characteristics (metrics)	RDB	EAM	BB	MZB	P/B	PP	AI
RDB	—	0.24	**0.51**[a]	**0.48**	−0.09	−0.03	0.31
EAM	0.24	—	**0.43**	**0.37**	−0.22	−0.18	**0.40**
Weight coefficients of characteristics (a_i)	0.6	0.6	0.9	0.9	0.5	0.1	0.8

a) Bold values indicate significant coefficients of cross-correlation at <5% confidence level ($k = 32$).
Key: RDB, number of Red Data Book species; EAM, ecological activity of macrophytes; BB, number of benthic biocoenoses; MZB, total number of macrozoobenthic species; P/B, ratio of total plankton to benthos biomass; PP, gross primary production of phytoplankton; AI, integrated anthropogenic impact.

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for local handicrafts. Similarly, in the neustonic biotope, the abundance of the neustonic copepods *Pontella mediterranea* and *Anomalocera patersoni*, decapod larvae, flathead grey mullet *Mugil cephalus* larvae, and fry belonging to the genera *Mugil*, *Liza*, *Belone*, *Solea* and *Callionymus* and other fish developing in the neuston layer also shrank by several orders of magnitude.

The number of grey mullet fry coming to the Black Sea coast in summer is a particularly important indicator of the ecological state of the neuston. This fish hatches from eggs laid on the water surface in the open sea, tens of kilometres away from the coastline. Reaching a body length of 4–5 mm, the fry remain in the neuston while migrating towards the coast to feeding grounds in shallow bays and limans. The quantity of fry reaching the coast between July and September could be used to assess the ecological condition of the sea surface for the period from their hatching until arrival at the coast (Alexandrov and Zaitsev, 1989).

Phytoplankton blooms are easily recognized. On sandy beaches they can clog the interstices between sediment particles with detritus, which decreases the rinsing and drainage of the sand by seawater and reduces its aeration. On rocky coasts a phytoplankton bloom could impede filter feeding by sedentary organisms such as sponges and polychaetes. Furthermore, the production of toxic substances by algal metabolites can occur.

Thus, the most dramatic ecological changes, when entire populations of marine organisms practically disappear, take place only in peripheral biotopes. By contrast, in the water column of the pelagic zone and at great depths, the chemical composition and other properties of the water mass are more stable. This explains why stocks of the commercial pelagic fish species sprat *Sprattus phalericus* and whiting *Merlangius euxinus* hardly changed during the major eutrophication episode from the 1980s to 1990s and retained their socioeconomic value.

Using ES to assess the ecological status of peripheral marine biotopes has a number of advantages compared to traditional methods: it requires no research vessels; it clearly reveals sharp changes in the marine environment; it shows precisely the location of ecological 'hotspots' and time of their emergence; and it encourages the involvement of amateur naturalists (especially young ones), under the leadership of experienced specialists, in ecological monitoring of the coastal zone.

A preliminary list of ES genera comprises: attached brown algae of *Cystoseira* and *Sargassum*; gastropod molluscs of *Littorina* and *Melaraphe*; bivalve molluscs of *Patella*, *Fissurella* and *Diodora*; polychaetes of *Ophelia*, *Janua*, *Spirobranchus* and *Serpula*; mullet fry of *Mugil* and *Liza*; and piscivorous birds hunting for mullet fry: little egret *Egretta garzetta* and grey heron *Ardea cinerea*.

Expansion of the Ukrainian MPA Network

The Ukrainian ecological network to date has been formed based on the principles of nature protection and conservation of areas having high ecological value. The functionally integrated network is aimed at maintaining high biological diversity (Verkhovna Rada Ukrainy, 2000). Future expansion of the Ukrainian ecological network implies taking account of innovative European concepts and approaches demonstrating importance not only for nature conservation, but also for socioeconomic aspects. Further development of a European MPA network and its Ukrainian component should therefore consider the specific natural features of marine ecosystems resulting from the interactions between coastal and offshore, pelagic and bottom ecosystems (which have a three-dimensional structure and function), together with physical, covering more than 1040 km^2 (about 17% of the existing area). To help correct the misbalance of distribution between the MPAs in the shelf area and the Crimean Peninsula, eight of the proposed new MPAs lie in the coastal part of Crimea. The expansion of the Ukrainian MPA network takes account of such important natural characteristics as the main cyclonic Black Sea current and the influence of river discharges (as a main factor of eutrophication).

In order to integrate the Ukrainian MPA network into the European Coastal and Marine Ecological Network, a number of new methods of identifying MPAs were elaborated based on the requirements and standards of the WFD and MSFD. These methods and indicators should be incorporated into the Black Sea Integrated Monitoring and Assessment Programme (2015–2020) of Ukraine.

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