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PRIMARY CRITERIA FOR THE EXPANSION OF PROTECTED AREA NETWORKS (NATURE RESERVE FUND OF UKRAINE CASE STUDY)

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Primary criteria for the expansion of protected area networks (Nature Reserve Fund of Ukraine case study)

The article concerns the expansion of protected area networks. Nowadays this is one of the main directions of its development. There are three main questions to be answered: How much area to conserve? Which kind of area to conserve? Where to conserve? They can be solved through three primary criteria: percentage, representativeness, and connectivity. The article reveals the experience of their application to nature conservation and applies them for the Nature Reserve Fund of Ukraine. The conclusion contains the "coarse-filter" guidelines, which will help to localize new protected areas in Ukraine. The framework can be profitably applied to other large-scale regions.

Key words: protected area networks (PAN), National Reserve Fund (NRF), primary criteria, percentage, representativeness, connectivity, Ukraine

INTRODUCTION

The development of protected area networks (PAN) is one of the ways society balances human transformation of the environment. The expansion of PANs is one of the main directions of its development today.

There are literally a hundred questions that would greatly influence nature conservation, if answered, and thousands of similar questions can be asked (Sutherland et al. 2009). Conservation starts with the essential question – what to protect (Vane-Wright et al. 1991)? In the context of PAN expansion it turns into – where to conserve? It branches out into two and then into three questions (Fig.1): How much area to conserve? Which kind of area to conserve? Where to conserve? In this line the question "where to conserve?" acquires a more specific meaning.

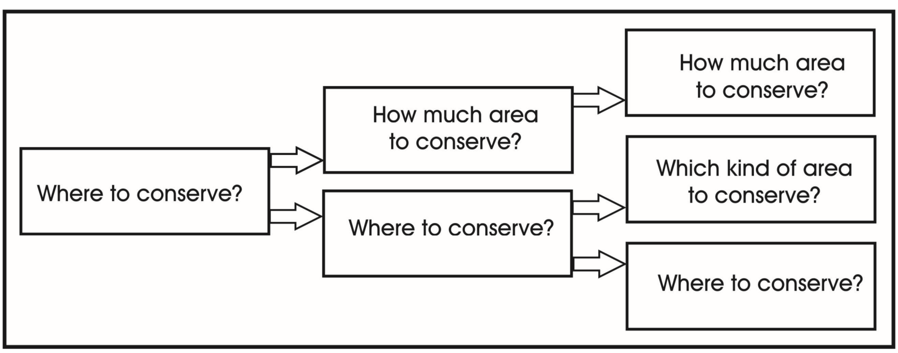

Fig. 1. Questions of PAN expansion

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Three criteria will help to answer these questions:

1. Percentage increase of protected areas (percentage criterion).
2. Representation of natural area diversity by the PAN (representativeness criterion).
3. Functional connection of PAN elements (connectivity criterion).

There are several other conservation criteria, principles and concepts such as efficiency, flexibility, irreplaceability (Possingham et al. 2006), population viability/thresholds, ecological resilience, disturbances (Vold and Buffett 2008), diversity, rarity, naturalness (Margules and Usher 1981), etc. Nevertheless, only three criteria were chosen to provide a "coarse-filter" (Schwartz 1999) for localization of areas, which require primary conservation activities. To delineate individual protected areas (PAs) some other problems have to be solved (minimum dynamic area (Pickett and Thompson 1978), SLOSS problem (Tjørve 2010), species conservation "gaps" (Scott et al. 1993, etc.), but they are outside the scope of the article.

Therefore, the aim of the article is to provide a framework for PAN expansion through three primary criteria. The framework is precise enough but not so strict to avoid mistakes, which are caused by known uncertainties of conservation planning (Margules and Pressey 2000 and Meir et al. 2004). The case study of the Nature Reserve Fund (NRF) of Ukraine requires necessary specification of the approach, but the framework may be successfully adapted for other PANs.

The NRF is the Ukrainian national PAN. Compared to other national and international PANs, which were established in Ukraine, the NRF has the largest area and the most effective protection means. It is the only PAN, which has individual administrations in the appropriate places (Parks and Reserves). Therefore, the NRF is the main nature conservation tool in Ukraine.

PERCENTAGE CRITERION

The percentage of PAN can be determined for areas of different types and scales. The percentage is defined by certain requirements (species protection, maintenance of healthy environment, maintenance of aesthetic and/or resource values of nature, etc.). It is also defined by the protection method (strict protection, seasonal activities, sustainable use, etc.).

The required percentage is usually determined for the purpose of biodiversity protection. The idea of such a determination is based on the species-area relationship developed by O. Arrhenius in 1921 in the following formula: $S=cA^2$, in which S – area, A – number of species, c – empirically estimated constant that varies among taxa and areas (Vreugdenhil et al. 2003).

The percentage principle was introduced into several national and international nature conservation documents. The Strategic Plan for Biodiversity 2011–2020 and Aichi Targets are among them. They were developed and adapted by the parties of the Convention on Biological Diversity in Japan 2010. The Eleventh Aichi target expects 17% of terrestrial and water areas and 10% of coastal and marine areas to be conserved through PANs and other effective area-based conservation measures. 14% of the world's terrestrial areas and 3.41% of the world's marine area are currently protected (Deguignet et al. 2014).

A similar target was adopted in Ukrainian national environmental policy. It expects NRF to reach 15% of the territory by 2020. About 6% of the territory is currently protected by means of NRF and one big PA (402 500 ha) was designated in the Ukrainian Black Sea exclusive economic zone (NRFU 2014).

Nighty nine percent of NRF areas correspond to the IUCN categories of PAs, as well as some other areas, which are not part of NRF (forests of the first category, some wetlands, pastures etc.). The Ukrainian national target is thus stricter and favourable for nature than the eleventh Aichi target. Fifteen percent of the total national area is the target value for the area of NRF in this research.

Arrhenius' modified formula helps us to quantify the relationship between species diversity and PAs percentage (Vreugdenhil et al. 2003). Fifteen percent of PAs in the continental region are thought to be able to maintain 75% of current species diversity. To cover 90% of species half of the area has to be protected. If less than 3% of the area is under protection, then more than a half of species diversity is threatened. It is the critical level of PAs extent.

The Ministry of ecology and natural resources of Ukraine provided the NRF GIS-database. It contains 89% of NRF PAs according to the statistics in 2014. The lacking 11% of areas is mainly due to communication weaknesses between the Ministry and the local authorities. The database is being filled with a significant time delay. But the present database includes all the most important PAs – Parks and Reserves of national importance. Therefore, in general, the database is sufficient for large-scale analysis and planning of the NRF.

REPRESENTATIVENESS CRITERION

The representativeness criterion is based on the "gap analysis". In the context of PAN expansion it implies three steps: 1) selection of a regional classification method, 2) identification of the status of PAN in each region and detection of the "gaps" and 3) concentration of the efforts to fill the "gaps" (Ivanov and Chizhova 2003). Gap analysis is also widely used in nature conservation to assess the coverage of biodiversity within PAN (Scott et al. 1993 and Rodrigues et al. 2004b).

V. V. Dokuchaiev was one of the first to use the representativeness criterion for development of PAN. He planned to create a network of nature "laboratories" by conserving sites in each natural zone, which were defined using the soil type. The first three sites were chosen on the Ukrainian steppe in 1894 (Boreyko 1995).

The first classification of the world regions for the conservation purpose was developed by Dasman and Udvardy during 1972–1975 (Udvardy 1975). It was employed by IUCN within the framework of the MAB programme. The scheme consists of 193 biogeographical continental provinces. A more detailed scheme was developed by Olson and Dinerstein (1998 and 2002) and Olson et al. (2001) during the next years for WWF purposes. This scheme includes 867 continental ecoregions worldwide.

For classification of regions several other methods were used: floristic, biogeographic, life zones method, etc. (Vreugdenhil et al. 2003).

The first step in the representativeness criterion implementation is the decision how to divide the territory into regions. The political division includes countries, provinces, districts and so on. It is used for PA statistics worldwide. It is also widely used for the NRF statistics and management in Ukraine due to the considerable influence of the local authorities in this field. However, natural division may be more appropriate for centralized PAN planning.

Common natural division is based on the distribution of vegetation, which indicates the distribution of ecosystems and biomes. It is based on the information from the land/sea surface, which is obtained from fieldwork, aerial photography and satellite imagery.

The advantages of this approach are obvious. Vulnerable biota is the primary natural element for conservation. The analysis of its distribution provides the first input for development of PANs. Modern remote sensing brings data for fast and detailed analysis. However, this approach can be misleading in highly transformed territories, where the vegetation distribution is losing its natural features.

Natural division of highly transformed environments must correspond to the most persistent natural components, which are relevant to renaturalization of native biota. These are: climate, relief, and parent material. The subordinate components are: surface water, ground water and soils. They are less resistant to human influence (Klijn and Udo de Haes 1994). Their distribution is not going to be considered here.

Over 70% of the Ukrainian territory is covered by agricultural lands and over 50% by arable lands. The percentage of agricultural and arable lands is even greater in the productive regions of central, southern and eastern Ukraine (MENRU 2011). People have been cultivating the lands of Ukraine for millennia. There are few virgin natural areas left – mainly in the higher mountains. Therefore the delineation of natural vegetation regions within Ukraine may be imprecise.

Classification of physico-geographical regions was developed in the late 1950s (Popov et al. 1968) and it was improved during the following decades (NASU 2007). Several levels of division depend on distribution of natural conditions. There is one level, which is based mainly on the distribution of the above mentioned natural components (climate, relief, parent material) – province level. Ukrainian territory was divided into 14 physico-geographical provinces. Delineation of smaller regions is based on the distribution of natural elements, which are basically important for agriculture (soils, surface water, landscape pattern, etc.). The lowest level includes 278 regions.

The system was developed only for land. Since the Ukrainian border includes territorial waters of the Black Sea and the Sea of Azov, these two marine regions will be considered as two additional physico-geographical provinces.

Such a coarse division was selected to represent the large-scale patterns in environmental heterogeneity. Large regional units will facilitate cooperation with local authorities and society. Small-scale natural diversity will be considered when designating individual PAs.

Some publications (e.g. Stetsenko 2000, Kovalchuk 2002 and Popovich 2007) brought out an opinion to develop at least one natural Park or Reserve in each of 57 regions (domain level) and to designate smaller PAs in each of 278 regions (district level). There are series of other similar approaches, but most of them are based on the representativeness criterion alone, without referring to other criteria.

CONNECTIVITY CRITERION

Implementation of the connectivity criterion aims to provide spatial and functional association of the fragmented natural environment for the free biota movement. Since fragmentation of the natural environment was caused mostly by human activities, the recovery of connectivity has to move through the "reconquest" of cultural lands in favour of nature. To provide a large-scale rewilding by the means of connectivity some specific attention has to be paid to keystone species. Often they are large carnivores (Soulé and Noss 1998) although all biota is an object of connectivity.

The connectivity criterion is based on several theories. The fundamental theories are:

E. O. Wilson's and R. H. MacArthur's island biogeography theory (MacArthur and Wilson 1967). The theory was developed after researching the species diversity on marine islands. Its main idea is that small islands are thought to lose their species diversity more rapidly than bigger islands. Subsequently, the theory was applied to fragmented terrestrial environment, which is characterized by a series of specific phenomena: edge effect, matrix effect, altered ecosystem processes, environmental synergism, elevated dynamics and so on (Powledge 2003 and Laurance 2010).

R. Levins' metapopulation theory (Levins 1969). The theory deals with groups of spatially separated local populations of the same species, which interact at a higher metapopulation level. The theory is worth considering in relation to the reintroduction of local species and the fight against exotic species (Akçakaya et al 2007).

H. R. Pulliam's source-sink theory (Pulliam 1988). According to the theory, habitats are divided into "sources", where the birth-death relation is positive, and "sinks", where birth-death relation is negative. Conservation of "sources" is thought to be more significant for nature protection.

The connectivity criterion was applied to ecological networks and design of ecological corridors. Connectivity can be both spatial and functional. It can be maintained or restored by continuous and/or "stepping-stones" corridors, allowing biota to move without excessive constraints.

One of the main connectivity parameters is the distance between the PAs. Optimal distance should facilitate biota movements in the mosaic of natural and cultural landscapes. However, zero distances between PAs in spatially continuous natural environment are not necessarily the best solution. In the case of spread of disease or some other hazards this kind of connectivity may even be dangerous (Shafer 2001 and Minor and Urban 2008).

In this article the general model of connectivity will be common for the widest possible variety of natural environments (except sea-land division) and taxa of living organisms, including infraspecific. The model is depicted by a regular hexagonal grid with the 15% of PAs, as a desired percentage within each cell (hexagon). The model can be visualized as both spatially connected (Fig. 2) and disconnected (Fig. 3) PANs.

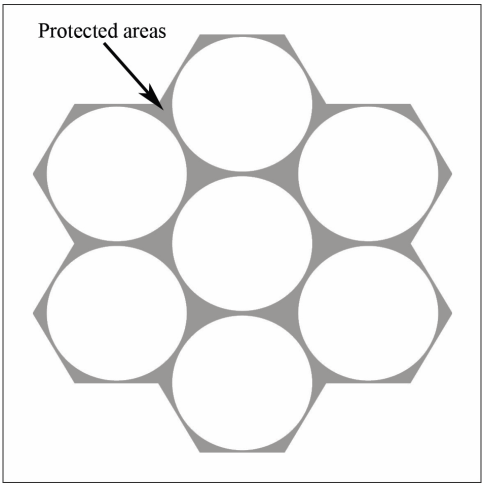

Fig. 2. Model of spatially connected PAN (15% of PAs)

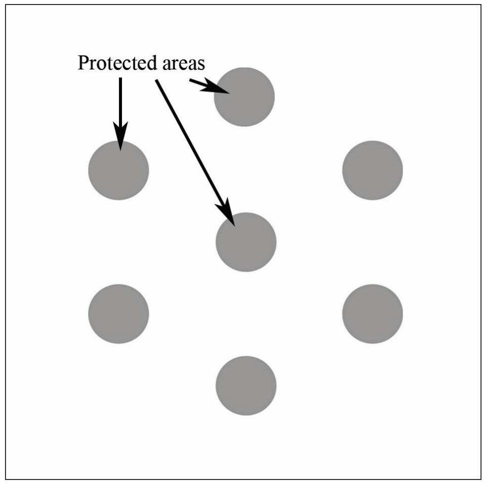

Fig. 3. Model of spatially disconnected PAN (15% of PAs)

The first variant (Fig. 2) is a case of an ecological network with its core areas and corridors. Ecological networks were designed for Ukraine (Sheliah-Sosonko 1999), Slovakia (Ružičková 1995) and for other countries all around the world (Bennett and Mulongoy 2006). The parameters of this kind of connectivity vary according to the territorial heterogeneity and depend on the landscape resistance to biota movements (Zeller et al. 2012).

The second variant (Fig. 3) is more typical for the NRF; therefore it seems more appropriate as a default model. This model does not provide the design of the corridors between its elements, though the elements can be considered the core areas of the ecological network. Methodology for this kind of model was developed within the graph theory (Minor and Urban 2008).

For model parameterization the following variables were used: distances between centres of the nearest cells – d_c, cell area – S_c, distances between the nearest PAs – d_{pa} and size of the PA – S_{pa} (Fig.4).

Distances between the nearest PAs can be a limiting factor primarily for the non-mobile and small species, while the size of PA may limit species with large home ranges. The value of d_{pa} is in direct relation to S_{pa} value, therefore their interdependence is the key for parameterization of the model.

Animals are among the taxa, which are most vulnerable to the fragmentation of natural environment. Therefore, an optimal distance between the PAs might be determined accordingly to their movement ranges. One of the most important kinds of movement for ecological analysis is the natal dispersal. Sutherland et al. (2000) have analysed representative samples of land birds and mammals. Maximum natal dispersal distance varies from 1.3 to 1,305 km among birds and from 0.068 to 432 km among mammals. Most carnivorous birds exceed a distance of 10 km; most herbivorous and omnivorous birds – over 3 km; most carnivorous mammals – over 10 km; more than a half of herbivorous and omnivorous mammals (mainly rodents and insectivores less than 1 kg weight) – less than 1 km, and most of the other herbivorous and omnivorous mammals – over 3 km.

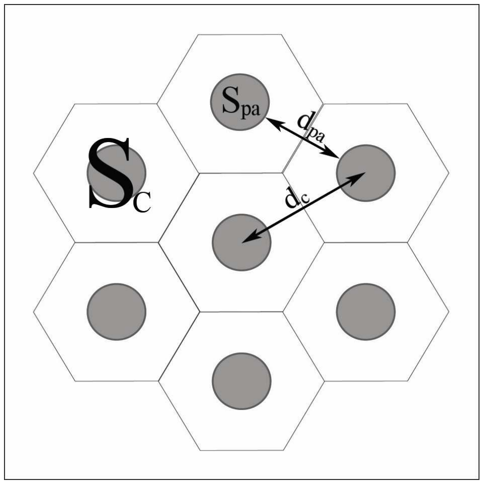

Fig. 4. Model of PAN connectivity with its parameters

$$S_{pa} = 0{,}15 S_c,$$

$$d_{pa} = d_c - 2\sqrt{\frac{S_{pa}}{\pi}},$$

$$d_c = 2\sqrt{\frac{S_c}{2\sqrt{3}}} = 2\sqrt{\frac{10 S_{pa}}{3\sqrt{3}}},$$

$$d_{pa} = 2\sqrt{\frac{10 S_{pa}}{3\sqrt{3}}} - 2\sqrt{\frac{S_{pa}}{\pi}} = \sqrt{S_o}\left(2\sqrt{\frac{10}{3\sqrt{3}}} - 2\sqrt{\frac{1}{\pi}}\right),$$

$$d_{pa} \approx 1{,}65\sqrt{S_{pa}}.$$

Thus in the majority of animals the maximum natal dispersal distance exceeds 3 km. If d_{pa} = 3 km, then S_{pa} = 330 ha. Such an area is big enough to embrace a local population of animals with small home ranges such as shrews, moles and marmots, to give a refuge for groups of animals with medium home ranges such as foxes, hares and deer) and to be a distinct patch of a home range for animals, which can easily overcome 3 km distance, for example wolves, lynxes and bears (Harestad and Bunnell 1979).

The smallest PAs are not adequate for residence of most species. Many small PAs consist of just a single tree or group of trees. So the lower threshold excludes patches of PAs , smaller than 100 ha (Rodrigues et al. 2004a).

RESULTS

The application of percentage and representativeness criteria results in the map (Fig. 5) and the table (Tab. 1). The percentage value on the map is divided into four categories: < 3% – critical level for species diversity; 3.1 – 6% – less than the average level; 6.1 – 10% – less than was scheduled by 2015 but more than the average; 10.1 – 13% – sticks to the schedule.

The application of connectivity criterion results in the map “Connectivity of NRF of Ukraine” (Fig.6). PAs and 1.5 km buffer zones are filled white. New PAs must not be designed within this area, so they will be protected from the negative aspects of proximity by the buffer zone. The buffer width is half of the optimal distance, thus the distance between PAs within the white areas ranges from 0 to 3 km. The rest of the areas are shaded grey according to the distance to the nearest PA: 1.51 – 10 km, 10.1 – 25 km, 25.1 – 55 km. Sea regions were not analysed, since they have a broader scale of connectivity. Inland water areas were analysed together with terrestrial areas, since they are comparatively small.

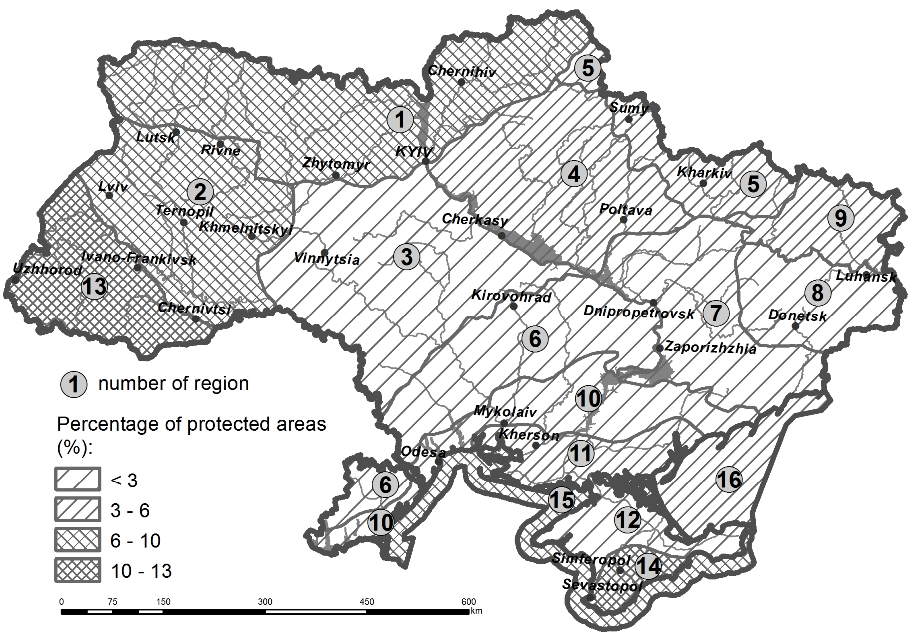

Fig. 5. Representation of physico-geographical provinces by NRF of Ukraine (2015)

Tab. 1. Percentage of NRF of Ukraine in physico-geographical provinces (2015)

Number of the province	Province name	Percentage of NRF in province (%)
1	Poliska	8.39
2	Zakhidnoukrainska	9.12
3	Podilsko-Prydniprovska	1.31
4	Livoberezhnodniprovska	4.42
5	Skhidnoukrainska	3.90
6	Dnistrovsko-Dniprovska	0.98
7	Livoberezhnodniprovsko-Priazovska	2.28
8	Donetska	1.53
9	Zadonetsko-Donska	4.35
10	Prychornomorska serednostepova	2.76
11	Prychornomorsko-Pryazovska	5.44
12	Krymska stepova	1.73
13	Ukrainski Karpaty	13.00
14	Krymska hirska	11.25
15	Black Sea	7.66
16	The Sea of Azov	4.73

There are two naturally separated groups of terrestrial regions on the map (Fig. 5): 1 – percentage of NRF is less than the average (steppe and forest-steppe regions); 2 – percentage is greater than the average (forest and mountain regions). Steppe and forest-steppe areas have been more extensively used during the last centuries, thus conservation faces more barriers here.

Ukrainian territorial waters in the Black Sea have a higher percentage of NRF than in the Sea of Azov, because coastal waters are more often protected than the open sea (territorial waters in the Black Sea are less distant from the coast and adjoin a longer coastline).

Black spots on the map (Fig. 6) show the most remote regions to the PAs. They are grouped into two zones: along the steppe region and along the right bank of the River Dnieper. The best connectivity is provided in the Carpathians and in the western and eastern parts of Polissya (woodland in the north).

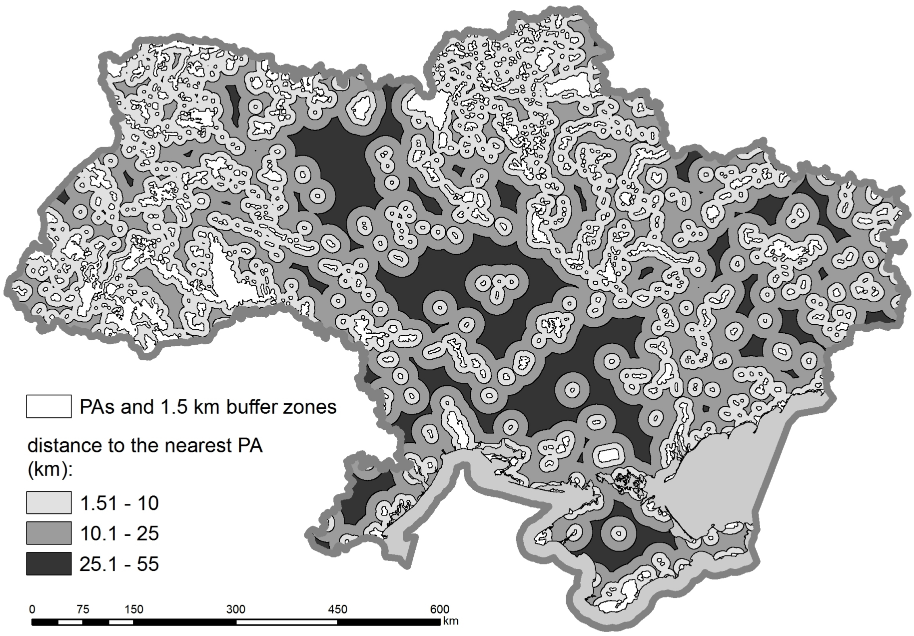

Fig. 6. Connectivity of NRF of Ukraine (2015)

DISCUSSION AND CONCLUSION

The primary criteria for expansion of PANs are: 1 – percentage increase of the area under conservation (percentage criterion), 2 – representation of natural areas diversity by PAN (representativeness criterion) and 3 – functional connection of PAN elements (connectivity criterion).

The percentage criterion was introduced into several national and international nature conservation documents. The NRF of Ukraine must be expanded to 15% of the country's area by 2020. Species-area relation curve shows that such an area can maintain around 75% of species diversity. If PAs cover less than 3%, the species diversity decreases rapidly.

In order to apply the representativeness criterion for PAN development, it is advisable to use natural classification of the regions. For the extensively transformed environment of Ukraine it is better to use physico-geographical regional classification. Comparatively coarse regional division (14 terrestrial provinces 2 marine regions) may facilitate further work with local authorities and society.

Buffer zones and distances to the nearest PA (1.51-10 km, 10.1-25 km, 25.1-55 km) were determined in order to map the connectivity. The buffer zone helps to prevent new PAs from the negative proximity to other PAs and the distances reveal remote areas for primary conservation activities.

PAN design is a time consuming process, therefore it is necessary to prioritize steps on the way to its extension. When applying the percentage and representativeness criterion to the NRF we should primarily focus on the regions showing critical percentage (< 3%). These are regions numbered 3, 6, 7, 8, 10, and 12 (Tab. 1). The other three groups are next in priority according to their percentages: 5, 9, 11, 16 (3 – 6%); 1, 2, 15 (6 – 10 %); and 13, 14 (10 – 13%).

While localizing new NRF areas we should first of all pay attention to the black spots on the connectivity map (Fig. 6). It is preferable to designate large objects with their own administration (Parks and Reserves) in those spots. At least 30 new Parks and Reserves are required. Next in priority are the territories less distant from the white spots. In general it is advisable to facilitate the connection of the white and light grey areas, so they would form a network around the country.

The proposed methodology can face amendments and criticism at various phases of its development. For example, this can concern the determination of PAN percentage, differentiation of PAN percentage in the regions, differentiation of PAN extension by the protected categories, completeness of the GIS database, method of regional classification, precision of regional division, differentiation of a development plan for land and sea separately, determination of connectivity parameters, consideration of socio-political conditions in some regions, etc.

A series of likely questions can be answered by three statements: 1) coarser generalization may be acceptable at the national scale; 2) in view of further work with local authorities and society it seems important to keep the results understandable to both experts and the general public; 3) the conservation process cannot wait for the completion of the GIS database, which may take years.

The proposed methodology is open to discussion and appropriate amendments. It can be effectively implemented along with the recently published methodology (Ivanenko 2014), which includes "fine-filter" conservation principles and criteria.

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Eugene I v a n e n k o

PRIMÁRNE KRITÉRIÁ PRI ROZŠIROVANÍ SIETE CHRÁNENÝCH ÚZEMÍ (PRÍPADOVÁ ŠTÚDIA UKRAJINSKÉHO NÁRODNÉHO FONDU PRÍRODNÝCH REZERVÁCIÍ)

Pri rozširovaní siete chránených území sa vynárajú tri základné otázky: Aké veľké územie je potrebné chrániť? Aký druh územia chrániť? Kde chrániť?

Pri hľadaní odpovedí na tieto otázky sa použili tri kritériá: percento zväčšenia chráneného územia (kritérium percenta), zastúpenie druhovej pestrosti v prírodných oblastiach siete chránených území (kritérium reprezentatívnosti) a funkčné spojenie prvkov v sieti chránených území (kritérium konektivity).

Kritérium percenta využíva niekoľko národných a medzinárodných dokumentov o ochrane prírody. Ukrajinský národný fond prírodných rezervácií (hlavná národná sieť chránených území) sa má do roku 2020 rozšíriť na 15 % z celkovej rozlohy krajiny. Vzťah medzi druhmi a územím poukazuje na to, že takéto územie môže udržiavať 75 % súčasnej druhovej diverzity. Ak chránená oblasť pokrýva menej ako 3 %, druhová pestrosť bude rýchlo klesať.

Ak sa má pri rozvoji siete chránených území uplatniť kritérium reprezentatívnosti, je potrebná klasifikácia regiónov z hľadiska prírodného charakteru. Pre obrovské transformované krajinné oblasti Ukrajiny je výhodnejšie použiť fyzicko-geografickú klasifikáciu regiónov. Na zjednodušenie ďalšej práce s miestnymi orgánmi a spoločnosťou sa vybralo značne generalizované regionálne členenie (14 vnútrozemských provincií a dve pobrežné provincie).

Na uplatnenie kritéria konektivity sa určila prítomnosť chránených oblastí v každej bunke hexagonálnej mriežky. Je možné určiť optimálnu vzdialenosť medzi chránenými územiami podľa rozsahu pohybu živočíchov, ktoré sú pri fragmentácii prírodného prostredia najzraniteľnejšie. Jeden z najdôležitejších druhov pohybu pri ekologickej analýze je natálny rozptyl. Jeho analýza ukazuje, že modelové vzdialenosti medzi najbližšími chránenými územiami môžu byť približne 3 km a každé z chránených území by malo mať rozlohu 330 km^2. Chránené územia a 1,5-kilometrové ochranné pásma sú znázornené bielou a ostatné oblasti sú v odtieňoch sivej podľa vzdialenosti k najbližšiemu chránenému územiu: 1,51 – 10 km, 10,1 – 25 km a 25,1 – 55 km. Hlavné výsledky sú prezentované na dvoch mapách (obr. 5 a 6) a v tabuľke 1.

Preložila H. Contrerasová