THE STATE OF UKRAINE'S PROTECTED AREAS: AN INTERIM UPDATE ON DAMAGES FROM THE FULL-SCALE INVASION

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ABSTRACT

The Russian Federation's full-scale invasion of Ukraine has become a humanitarian and political crisis. Since the very start of the invasion, it has also been an ecological disaster, with Russian troops utilising protected areas both in an attempt to access strategic Ukrainian settlements, but also as locations in which to conduct active warfare. The frontline has now crossed and retreated from many protected areas, many are still occupied and many are still the sites of active hostilities. This study found the most common damages to protected areas are: physical destruction of habitats and wildlife and wildlife behavioural changes from explosions; chemical and physical pollution from explosive materials; fires caused by shelling; damages to soil and plant cover from heavy military vehicles, equipment and defence infrastructure; and military exploitation of natural resources. Given the occupation, combat and mining with explosives, it will be years before Ukraine can account for the full extent of damage to its protected area system. This paper provides an interim assessment of the damages to protected areas so far and urges the conservation and policy communities to monitor the situation moving forward.

Key Words: conflict, war, ecology, impacts, Russia, Europe

INTRODUCTION

The Russian Federation launched the full-scale invasion (FSI) of Ukraine on 24 February 2022. Shortly after the FSI began, it became clear that this war would have significant environmental impacts (Weir, 2022). Ukrainian authorities have valued the ever-rising bill of environmental damage to the country at over US$ 46 billion (Zhao & Anthony, 2023). This includes impacts on air quality, forests and other ecosystems, soils and water, pollution from the use of weapons and military equipment and contamination from the shelling of thousands of facilities holding toxic and hazardous materials.

Ukraine's Ministry of Environmental Protection and Natural Resources (MEPNR) estimates that the first twelve months of the FSI alone generated an additional 109 million tonnes of CO_2 equivalent from missile explosions, ammunition, forest fires, burning of oil depots and settlements (de Klerk et al., 2023). There are also the future emissions that will occur during post-war reconstruction of Ukraine.

In addition to the climate costs, war and conflict can directly lead to environmental destruction. War affects all components of nature, for example, interference in the functioning of river ecosystems due to the destruction of dams, explosions in water, chemical pollution, destruction of treatment facilities, lack of access to water, air pollution by combustion products and toxic gases, destruction of soil cover and microrelief, destruction of plant and animal life due to explosions, detonations from mines, fires and flooding. Induced impacts from war can occur from a reduction in funding of environmental protection and an increase in unsustainable exploitation of natural resources and environmental crimes (Arias et al., 2020; Daskin & Pringle, 2018; Glew & Hudson, 2007; Hanson et al., 2009; Rüttinger et al., 2022).

Ukraine, whilst one of the largest countries in Europe, occupies less than six per cent of the continent's area, yet it is home to a disproportionately high 35 per cent of the continent's biodiversity (Convention on Biological Diversity, n.d.). Ukraine's 70,000 species include many

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rare, relict and endemic species, all reliant on Ukraine's network of mountain, forest, steppe, wetlands and coastal ecosystems. Ukraine also has 142 Key Biodiversity Areas (KBAs) covering 3,026,800 ha (KBA Global Dataset, 2023). Numerous migration routes and wildlife corridors connect these ecosystems, including 63,000 rivers totalling 206,000 km in length and 1.3 million ha of river and riparian protected areas (PAs; Convention on Biological Diversity, n.d.). Ukraine's wetlands extend across 4.5 million ha (Convention on Biological Diversity, n.d.) including 50 Ramsar sites of over 930,000 ha (Convention on Wetlands Secretariat, 2023). Finally, the country also has eight UNESCO biosphere reserves, four of which are cross-border sites (UNESCO, 2023).

Ukraine's Nature Reserve Fund (NRF; the MEPNR's system of PAs) lists 8,889 protected sites covering 4.6 million ha, around seven per cent of the country, including marine PAs (MEPNR, 2023a). The Emerald Network (EN) of Areas of Special Conservation Interest was created to preserve species and habitats across the European continent. Ukraine has 377 official EN sites covering an area of 8,098,200 ha and a further 162 proposed EN sites (Ukraine War Environmental Consequences Work Group, 2023). Upon joining the European Union (EU), Ukraine's EN will constitute a basis of the EU's Natura 2000 conservation network. Of particular importance at the European-level are Ukraine's steppe habitat sites; Ukraine has the largest total area of steppe habitat among countries that have ratified the Bern Convention (Ukraine War Environmental Consequences Work Group, 2023). Much of this fragile steppe habitat is situated in or near conflict zones in the south and south-east of the country.

This study aims to provide an interim update on the state of Ukraine's PAs since the start of the FSI in February 2022 and focuses on the damages to nature in these PAs. This war has also damaged the conservation sector of Ukraine; through the displacement, recruitment and even death of conservation staff and the looting and destruction of administrative buildings, vehicles and equipment. Nature protection and management is now impossible in many areas due to mining of territories with explosives, occupation of PAs, and the dangers posed by constant shelling and Russian Federation troops that may have broken through frontlines. It is recommended that further research is conducted to account for these forms of damage.

METHODOLOGY

The World Database of Protected Areas (WDPA) lists a total of 5,622 protected areas registered in Ukraine, these are not entirely aligned with Ukraine's NRF which lists 8,889 sites (MEPNR, 2023a). The Ukrainian PA system is complex and national categories do not overlap perfectly with the WDPA management category system. There are 11 NRF categories of national and local importance. Of these, four are artificial, botanical gardens for example, the remaining seven are natural areas, these include Nature Reserves (NR), Biosphere Reserves (BR), National Nature Parks (NNP), Regional Landscape Parks, Reservations, Nature Monuments, and Reserve Stows (landscapes with scientific, conservation and aesthetic values set aside to preserve natural processes, the management of which corresponds with category Ia; MEPNR, 2012).

NRs, BRs and NNPs are considered the categories of the highest national and international importance for nature. NRs are established to preserve the natural state of a landscape for research use, and economic uses are not permitted. In theory, NRs correspond to the WDPA management category Ia or Ib but in reality, NR management often appears more aligned with category IV. Like the UNESCO Biosphere Reserve programme, BRs preserve the natural state of all present ecosystems and function as models for people living in harmony with nature. BRs in Ukraine, like elsewhere, can contain a number of different management category types across the core, buffer and transition zones. NNPs are created for the conservation, restoration and effective use of nature complexes with special natural, recreational, historical, cultural, scientific, educational and aesthetic values (MEPNR, 2012). NNPs often meet the management requirements of category II PAs, however, many NNPs do not have strict management regimes and may align better with other categories (MEPNR, 2012).

To focus our analysis on the most significant of the NRF's PAs for nature conservation, we selected NNPs, BR and NRs that have come into contact with combat zones since the start of the FSI (Live UA Map, 2023). This generated a final list of 21 PAs. As the NRF names do not always match the WDPA names of PAs, WDPA identification numbers are noted in parentheses at first mention to streamline future research (see Table 1).

Whilst there are calls within the field of conflict conservation to improve scientific rigour through employing more quantitative and systematic analyses, on a practical level, this is often extremely challenging (Glew & Hudson, 2007). For example, 14 of the 21 PAs analysed remain, at least partially, occupied and are therefore particularly challenging to gather data on in any kind of systematic way. At least 16 of the PAs have been subjected to mining with explosives, rendering ecological field assessments dangerous. These ground conditions make systematic collection of comparable primary or even secondary data across all PAs difficult.

However, where possible, field trips were made to territories that are liberated and now back under Ukrainian control. Coauthors and their colleagues exercised caution in collecting field data and consulted high-risk advisors and military personnel where possible in order to avoid explosives and harmful chemicals. Damages were photographed, descriptions were compiled, soil samples were taken from explosion craters in accordance with the methodology developed jointly by ecologist Kateryna Polianska (co-author) from non-profit *Environment People Law* (EPL) and scientists from the University of Bern. Remote methods used include reviewing satellite imagery and available maps on conflict and contamination by explosive objects. Primary field research was conducted by the NGO *Ukrainian Nature Conservation Group* (UNCG) and EPL.

A systematic literature review was also conducted to increase information particularly on PAs that could not be accessed directly. This assessment has drawn on data from as many sources as possible including: the MEPNR's weekly updates on environmental damages from the war, data from the State Emergency Service of Ukraine, reports from the Ukraine War Environmental Consequences Working Group, published investigations, news from the press, reports from national and international meetings, published interviews and personal communications with employees of the NRF and those that have visited PAs on or near the frontline (Ecodozor, 2023). To avoid using misinformation, where field visits were not possible, caution was exercised by triangulating data to ensure reliability. This involved cross-comparing media and NGO reports, reports from the MEPNR and personal communications with contacts in or near those PAs.

To support a semi-quantitative assessment across the 21 PAs, reports on damages were classified into seven forms:

- Fires
- Pollution from explosive materials (including mining)
- Direct damages from shelling, missiles or active combat
- Disruption from heavy military vehicles and equipment
- Disruption from the building of combat and defence infrastructure
- Pollution from chemicals
- Other (for example, logging, hunting and other waste pollution)

Not all impacts could be comparatively and quantifiably assessed across all PAs, where possible we have provided comparable statistics and maps. However, much information is still missing. Case studies on PAs where the most information could be gathered have been provided as supplementary online material.

RESULTS AND DISCUSSION

In total, we analysed 21 PAs. These include 16 NNPs, two NRs and three BRs (Table 1 and Figure 1).

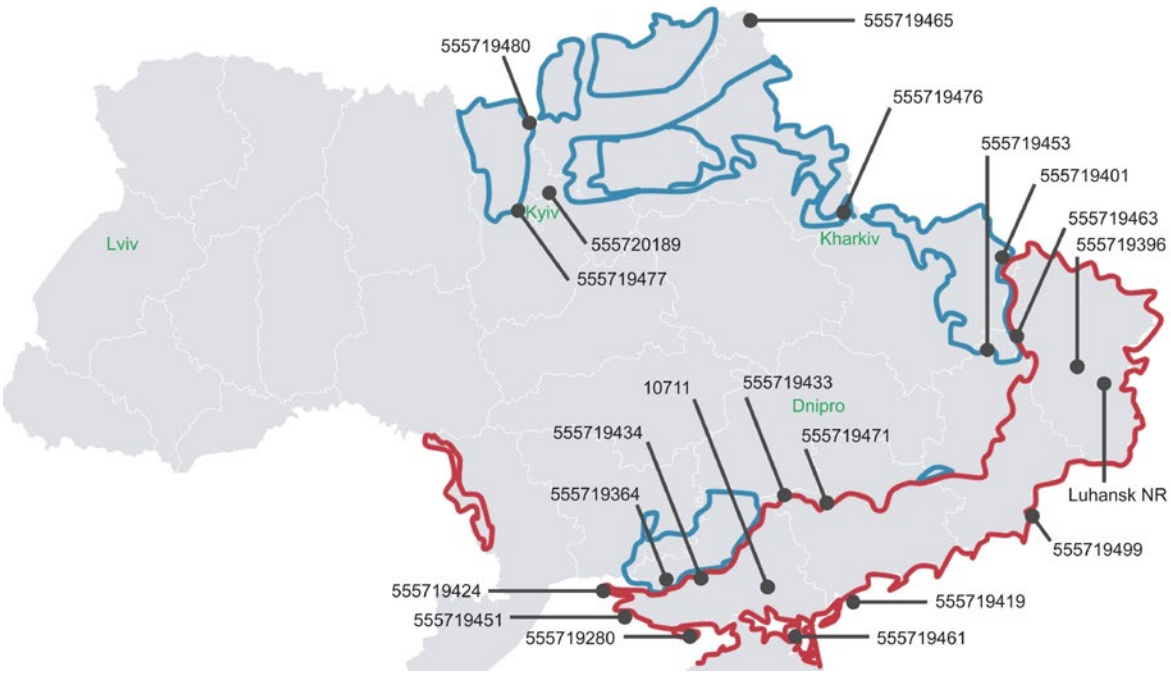

Figure 1. Locations of the 21 Protected areas assessed (numbering refers to WDPA IDs, see Table 1) in relation to the occupied (red) and liberated (blue) territories of Ukraine (based on the Live UA Map, accessed 23 August 2023).

Table 1. All protected areas analysed with major defining features

Protected area full name	WDPA ID number	WCPA category	Other overlapping designations	Area (ha)	Ecosystems present
Azovo-Syvaskyi NNP	555719461	Not reported	EN, Ramsar, KBA	51,983	Terrestrial and inland waters
Dzharylhatskyi NNP	555719280	Not reported		10,018	Marine
Oleshkivski Sands NNP	555719434	Not reported	EN	46,259	Terrestrial and inland waters
Pryazovskyi NNP	555719419	Not reported	EN, Ramsar, KBA	7,790	Marine
Velykyi Luh NNP	555719471	Not reported	EN, Ramsar	16,755	Terrestrial and inland waters
Meotyda NNP	555719499	Not reported	EN, Ramsar, KBA	22,199	Marine
Biloberezhzhia Sviatoslava NNP	555719424	Not reported	EN, Ramsar, KBA	35,242	Marine
Dvorichanskyi NNP	555719401	Not reported	EN	3,433	Terrestrial and inland waters
Kreminsky Lisy NNP	555719396	Not reported	EN, KBA	18,240	Terrestrial and inland waters
Holosiivskyi NNP	555719477	Not reported	EN	11,080	Terrestrial and inland waters
Zalissia NNP	555720189	Not reported		20,621	Terrestrial and inland waters
Sviati Hory NNP	555719463	Not reported		43,437	Terrestrial and inland waters
Hetmanskyi NNP	555719476	Not reported	EN	23,473	Terrestrial and inland waters
Desniansko-Starogutskyi NNP	555719465	Not reported	EN, Ramsar, UNESCO BR	16,223	Terrestrial and inland waters
Nyzhnodniprovskyi NNP	555719364	Not reported	EN, Ramsar	52,386	Terrestrial and inland waters
Kamianska Sich NNP	555719433	Not reported	KBA	218,119	Terrestrial and inland waters
Luhansk NR	Unavailable		EN		
Ukrainskyi Stepovyi NR	555719453	Not reported		3,355	Terrestrial and inland waters
Black Sea Biosphere Reserve	555719451	Not reported	EN	115,873	Marine
Askania-Nova Biosphere Reserve	10711	Not applicable	EN, Ramsar, UNESCO BR, KBA	33,307	Terrestrial and inland waters
Chornobylskyi Radiation and Environmental Biosphere Reserve	555719480	Not reported	EN, UNESCO BR, KBA	227,381	Terrestrial and inland waters

A note on interpretation

Of the 21 PAs analysed, 14 remain at least partially occupied by the Russian Federation, therefore retrieving reliable information about the conditions of these PAs is not only difficult, but it can put the lives of informants in danger. A further five PAs assessed have been fully liberated since the start of the FSI, the remaining two PAs were never occupied but have been damaged by active hostilities, these PAs are in varied states of damage, assessment and reporting. Data from these individual examples, along with reports from occupied PAs, can provide some interim indication of the damages so far sustained to Ukraine's PA estate. Thus all figures, photos and descriptions in the results and discussion below should be interpreted as the minimum positive confirmation of damage.

Damages will be revealed slowly, upon the liberation and de-mining of territories, the ceasing of hostilities, and once Ukrainian authorities and civil society organisations have the resources and time to safely conduct assessments. However, it is likely that the full extent of damages in Ukraine may never be accurately quantified.

Overarching information on impacts to protected areas

Preliminary assessments have been conducted on damages sustained by PAs from explosions, the movements of heavy military vehicles and equipment, the construction of military infrastructure (for example, fortifications and dugouts), fires as a result of shelling and missiles, chemical contamination of soils from explosives and other forms of pollution, waste and exploitation of natural resources. The following areas have overlapped with active hostilities and need to be assessed extensively and systematically for damages when safe to do so (Drapaliuk et al., 2023; Petrovych, 2023; Shumy et al., 2023):

- Almost 36 per cent of the total area of Ukraine's EN sites; 2.9 million ha, impacting 160 of Ukraine's 377 EN sites;
- Almost 67 per cent of the total area of Ukraine's Ramsar sites; almost 620,000 ha, impacting 16 of Ukraine's 50 Ramsar sites;
- Almost 30 per cent of the total area of Ukraine's PAs of national or local importance; 1.24 million ha, impacting 900 PAs in total.

Direct damage from shelling, missiles or active combat was the most frequently reported impact for the PAs we assessed (Table 2). Unfortunately, reports on chemical contamination remain highly localised leaving large gaps in between and a scarcity of positive confirmation. This is for a number of reasons including limited laboratory equipment and a lack of safe access to some explosion craters due to unexploded ordnance. However, soil samples were taken from explosion craters, as well as from burned equipment by our team in different PAs. These are discussed later in the paper.

Conditions of occupied protected areas

Of the PAs assessed, ten are currently fully occupied by the Russian Federation, four remain partially occupied, five have been liberated and two have not been occupied since the start of the FSI. Of the occupied PAs, the development of infrastructure and exploitation of natural resources were more frequently reported as damages to nature, for example, Pryazovskyi NNP (ID:555719419) where fortification, trenches, training grounds for heavy artillery in a strict protection zone and a shooting range have reportedly been established and industrial fishing is extracting 4.5–9 tonnes per day to feed the Russian Federation military (Petrovych, 2023). Reports on the management of occupied PAs by Russian Federation-appointed personnel are concerning, for example, staged military exercises on Meotyda NNP (ID: 555719499) Ramsar site, which reportedly included the shooting of important bird colonies for target practice (see supplementary online material for case studies).

Impacts from explosive munitions and active hostilities

Whilst the exact number of munitions being used in the current war is unknown due to operational security protocols, it has been reported that the Russian Federation is firing around 60,000 artillery shells in Ukraine on a daily basis (Khurshudyan & Sonne, 2022) and Ukraine is firing an average of 7,700 shells per day (Khurshudyan & Hrabchuk, 2023). The immediate physical impact of explosives on ecosystems is highly destructive, causing tree, plant and animal deaths and mass soil erosion (Vasyliuk, 2023).

Eighteen of the PAs reported damage from active hostilities. For example, shelling has damaged Europe's largest steppe habitat in Askania-Nova Biosphere Reserve (ID:10711; KBA); 80 per cent of Sviati Hory NNP's forests (ID:555719463; Petrovych, 2023); and 2,700 hectares of Desniansko-Starogutskyi NNP (ID:555719465; Petrovych, 2023). Holosiivskyi NNP (ID:555719477) and EN site was visited by our team who assessed first hand the significant damage done to trees and soils from shelling (see photo below). Nyzhnodniprovskyi NNP (ID:555719364), EN and Ramsar site (Petrovych, 2023) and Kamianska Sich NNP (ID:555719433; MEPNR, 2023b) reported the destruction of aquatic ecosystems from explosions inside the water column of seas and inland waters. In

Table 2. Positive confirmation (grey cells) of damages to the protected areas analysed since the start of the FSI

WDPA ID number (if available)	Impacts from explosive munitions and active hostilities	Pollution from explosive objects	Damage from fires	Disruption from heavy military vehicles and war infrastructure	Pollution from chemicals
555719461					
555719280					
555719434					
555719419					
555719471					
555719499					
555719424					
555719401					
555719396					
555719477					
555720189					
555719463					
555719476					
555719465					
555719364					
555719433					
Luhansk NR					
555719453					
555719451					
10711					
555719480					

Biloberezhzhia Sviatoslava NNP (ID:555719424; EN, Ramsar site and KBA), bomb blasts have caused bird deaths and population falls (Petrovych, 2023). Active hostilities such as shelling and artillery fire have also impacted wildlife behaviour as they seek refuge from combat zones (Grigorenko, 2023) and change migratory routes (Drapaliuk et al., 2023).

Military actors often use water as a weapon (Pacific Institute, 2023) as was the case with the Russian Federation attack on the Kakhovka hydropower plant (HPP) on 6 June 2023, the intention being to cause disruptive upstream, downstream and energy impacts (Glanz et al., 2023). The UNCG estimates that this single act of war caused more environmental damage than the combined consequences of all military operations since the beginning of the FSI (UNCG, 2023).

Upstream, the breach drained the Kakhovs'ke reservoir KBA, EN and Ramsar sites; wetlands protected by Kamianska Sich NNP and Velikiy Luh NNP (ID:555719471), causing the death of 28,000 fish (Shumy et al., 2023) and the destruction of wetland breeding grounds of tens of thousands of waterfowl (see supplementary online case studies). The breach flooded 62,000 hectares of land (UNOSAT, 2023), killing 52 people (Reuters, 2023), uprooting numerous landmines, caches of weapons and ammunition, and spilling between 150 and 450 tonnes of engine oil from the power plant's turbines into the Dnipro River (Relief Web, 2023). Nine EN sites were impacted by flooding; 90 per cent of the Nyzhnodniprovskyi NNP and Ramsar site was inundated (Moreland, 2023; Nikolaieva et al., 2023). Agricultural fertilisers, sewage, sediments and military debris were discharged into the north-western Black Sea where Ukraine, Romania and Bulgaria have numerous coastal and marine PAs (UNCG, 2023).

Pollution from explosive objects

Thirty per cent of Ukraine's territory is now potentially mined with explosives, equivalent to an area twice the size of Portugal, making it the most widely mined country in the world (Save the Children, 2023). Mines are buried

The dry basin of Kamianska Sich NNP after the Kakhovka dam explosion © Anastasiia Drapaliuk

in the sands of beaches, hidden in the vegetation of forests and grasslands and floating mines are in rivers, lakes and the Black Sea (Chernysh, 2023; The Maritime Executive, 2023). In addition to actively mined areas, unexploded munitions (missiles, bombs and shells) now litter much of Ukraine's environment. Of the 67,000 or so shells that land on Ukraine each day, the 'fail rate', that is the number of munitions that will not detonate on impact, ranges between two per cent for the modern NATO supplied shells to 30 per cent for older Soviet Union weaponry (confirmed by our team, 2023).

Unexploded munition on a tree, image taken from the road © Kateryna Polyanska

This leaves the country with a significant number of unexploded ordnance (UXO). During the first year of the FSI, Ukraine's State Emergency Service neutralised almost 314,000 explosive devices, including over 2,100 aircraft bombs, and surveyed 77,700 ha for explosives (Drapaliuk et al., 2023). UXO is lethal not only to humans, but also for wildlife which have been blown up, killed, traumatised and wounded by explosions (Polyanska, 2023). UXO also poses a threat to nature conservation by preventing conservation management activities and detering nature tourism (Hatton et al., 2001; Vasyliuk, 2023; see supplementary online case studies).

Sixteen of the PAs reported the presence of UXO. For example, in Desniansko-Starogutskyi NNP (ID:555719465) over 7,300 ha have been mined (Petrovych, 2023); over 3,500 ha of Kamianska Sich NNP (Petrovych, 2023); almost 1,400 ha in Zalissia NNP (ID:555720189; Petrovych, 2023); 1,300 ha of Velykyi Luh NNP (ID:555719471; Petrovych, 2023) and in Sviati Hory NNP only 1.5 per cent of the PA has been assessed as safe from mines so far (Petrovych, 2023; see supplementary online case studies).

Damage from fires

Combat-caused wildfires are usually collateral damage stemming from explosions of artillery, shells, missiles and rockets. Every day tens of thousands of shells explode in Ukraine, each one has the potential to start a fire. In 2022, over 10,000 fires were recorded within 60 km of the frontline, and almost 8,500 fires were recorded in occupied territories (MEPNR, 2023b). Over 100,000 ha of EN sites have burned as a result of active hostilities

The result of a forest fire caused by the invasion in Sviati Hory NNP © Kateryna Polyanska

(Ukraine War Environmental Consequences Work Group, 2023). Thirteen PAs reported damaging fires from hostilities, these include over 31,761 ha of radiation-contaminated forests and 8,695 of grasslands in the Chornobylskyi Radiation and Environmental Biosphere Reserve (ID:555719480; confirmed by our team, 2023).

The Kinburn Peninsular (site of the Black Sea Biosphere Reserve [ID:555719451] and the Biloberezhzhia Sviatoslava NNP) have lost almost 6,000 ha of vegetation (Kasyanov, 2023) in a particularly destructive series of fires, much of which is valuable rare plants and wetland habitat for birds and bats (MEPNR, 2023b; Panchenko, 2023; Petrovych, 2023). The severity of these fires worsened after occupying Russian Federation troops confiscated fire-fighting equipment (Petrovych, 2023; see supplementary online case studies).

Disruption from heavy military vehicles and war infrastructure

Numerous fortifications, barriers, trenches (Africk, 2023), dugouts, new road networks and heavy military vehicles and equipment have caused physical damage to PAs particularly in the east and south of the country. In areas where the frontline has become more static, the use of large-scale, dug-in defensive positions is analogous to the construction of a wall creating a physical barrier for terrestrial species disturbing connectivity corridors between PAs and limiting the potential for natural movement (confirmed by our team, 2023).

Such infrastructure and vehicle use destroys vegetation, disturbs and compacts soils and fragile sand and steppe habitats. Ukraine's smaller mammals are particularly vulnerable to this kind of disturbance (Rusin, 2023). Military vehicles also create habitat openings for invasive species (Pashkevich, 2023) and cause animals stress and injury. For example, military ships and equipment are suspected of causing acoustic injuries to the inner ear and chemical skin burns on cetaceans in the Black and Azov seas (Shumy et al., 2023). Mass dolphin death has been reported in these areas (Kolodezhna, 2022) and scientists are analysing samples from the bodies to provide official results for use in international courts.

Eight PAs reported damage from military vehicles and 11 from the building of combat and defence infrastructure (15 in total). These include Askania-Nova Biosphere Reserve reporting damages to fragile steppe from heavy equipment and vehicles, and trenches and low-flying jets disrupting ungulate grazing (Baturin, 2023; Petrovych, 2023); Pryazovskyi NNP reporting 672 ha of steppe, coast, delta and nesting colonies damaged by vehicles and low altitude helicopter flights, along with the building of fortification, trenches, training grounds and a shooting range for heavy artillery in the PA's strict protection zone (Petrovych, 2023); Dzharylhatskyi NNP (ID:555719280) reporting Russian Federation troops filled the channel between the island and mainland which will increase siltation and eutrophication and disrupt the hydrology of the bay (Petrovych, 2023); the Chornobylskyi Radiation Ecological Biosphere Reserve reporting six ha of fortifications and trenches (confirmed by our team, 2023; see supplementary online case studies).

Pollution from chemicals

Military activities can release dangerous toxins through emissions from fires at civil and industrial infrastructure sites, pollution from damage to water management systems, fuel and lubricant spills, rocket fuel released at unexploded rocket fall sites and abandoned and burnt-out military equipment degrading in ecosystems (Polyanska, 2023). Explosions also release heavy metals such as arsenic, copper and lead into the environment (Barker et al., 2020) which can accumulate in plants and the bodies of animals damaging internal organs and the nervous system (Polyanska, 2023).

Broadscale and systematic chemical analyses of PA soils and water systems are currently impossible given the occupation and extent of explosives pollution. However, Pryazovskyi NNP has reported fuel and other petroleum products in estuary water and soil (Petrovych, 2023), whilst Sviati Hory NNP reported soils contaminated with petroleum products and debris from military equipment (MEPNR, 2023b). Soil samples taken from missile impact sites in Kamianska Sich NNP by our team

revealed excessive concentrations of petroleum products, lead, arsenic and many other chemicals (see supplementary online case studies). Toxins like these can leach into water systems, crops, livestock, wildlife, trees and eventually humans, creating a potentially huge challenge for Ukrainian and global food and water security.

CONCLUSIONS

The damage to nature sustained so far by Ukraine's PA estate, that we know of, has been highly destructive and has the potential to be catastrophic. Indeed, the aftermath of the Kakhovskaya HPP explosion can certainly already be described as catastrophic. The frontline continues to shift, and with it the intensity of impacts to nature conservation areas. Timely monitoring of the damage caused is important. The impacts discussed in this article will not be limited to the 21 sites, instead these PAs should be interpreted as indicative of the conditions of other protected areas and important sites for biodiversity particularly in the south-east of the country.

For deeper analysis and to obtain a more complete picture of damages, the authors propose the careful assessment, recovery and restoration of the roughly three million ha of Ukraine's PAs of local, national and international importance that have come into contact with the war. Assessment should focus on the types and extent of damages in order to plan and budget for restoration costs in post-war recovery. We recognise and stress this is a huge amount of work that should bring together the efforts of conservationists in-country and internationally. Not only is this a vast area to restore but, considering the complex and varied types of damage (physical destruction, burning, chemical and heavy metal pollution and extensive mining), the process of recovery will require concerted and coordinated effort, innovation and cooperation from a variety of skillsets and expertise. For example, de-mining vast areas in an environmentally friendly way, re-designing safe ecotourism, any planning of peace parks (as per the definition in Vasilijević et al., 2015), or exploring the emerging concept of defensive rewilding (Schmidt, 2023) will all require specialist knowledge.

The repercussions for Ukraine's biodiversity and ecosystem services will be felt not just by Ukraine but by Europe and the world more broadly. It is important that conservationists and international policy makers acknowledge this war not only as a humanitarian disaster with local, regional and global effects, but also as an environmental disaster with climate, ecosystem and biodiversity effects impacting multiple geopolitical levels. Global environmental mapping and accounting systems such as WDPA, UNESCO, Ramsar, Emerald Network, KBA and Global Safety Net must also remain conscious that this is an active invasion and war for territory. As independent and neutral entities they should maintain Ukraine's official ownership of such areas until the war is over.

As a signatory to the Global Biodiversity Framework (GBF), Ukraine is committed to protecting and conserving at least 30 per cent of its terrestrial, inland water, and coastal and marine ecosystems and restoring at least 30 per cent of its degraded terrestrial, inland water, and coastal and marine ecosystems by 2030. While Ukraine's protected and conserved area estate needs to be expanded significantly to meet this target, the Russian Federation's FSI is severely hindering Ukraine's ability to effectively protect its current PA estate. Meanwhile the war has also significantly increased the extent of degraded ecosystems and further reduced their capacity to support biodiversity and ecosystem services.

This all amounts to a widening of the gap between Ukraine's current biodiversity conservation and its 2030 targets. Under Ukraine's Criminal Code, such complex, long-term and large-scale negative impacts on wildlife fall under the definition of ecocide (Polyanska, 2023). As another signatory to the GBF and other multilateral environmental agreements (MEAs), the Russian Federation could be held responsible for compromising the achievement of nature conservation goals in Ukraine, along with the goals of countries connected to and impacted by Ukraine's biodiversity. In the international legal proceedings that may follow the end of the FSI, and during the meetings of the Parties of the MEAs, the Russian Federation could be called on to take political and fiscal responsibility for this biodiversity loss and nature restoration.

Lastly, the authors acknowledge the limitations of this study and offer suggestions for future research and policy discussion. Ukraine's ecosystems will be damaged through other effects of the war, for example, the need to create special landfills for the disposal of a growing amount of rubble and military waste and the rebuilding of the irrigation system in the south of Ukraine in order to preserve agricultural land. Other damages will have been incurred through Ukraine's efforts to fight this war, such as the redirecting of financial and human resources away from conservation, the use of natural resources in the war, changes in institutional dynamics, loss of human capital and in-situ networks of environmental protection organisations that have been disbanded. Further research could focus on these impacts to provide a more holistic picture of what will be needed for post-war recovery.

During our research, we also found numerous examples of protected area management and ranger staff becoming internally displaced people or refugees, or joining the military to fight and leaving behind their positions in conservation. In some cases, staff were lost in active combat or executed as government staff by invading troops. Protected area vehicles and equipment have been destroyed or stolen, many administrative and research facilities have been looted or razed. Rebuilding Ukraine's conservation sector will require significant effort and investment that needs to be quantified.

There is also an urgent need to map out a post-war biodiversity recovery plan to get Ukraine's GBF and other MEA goals back on track. In accordance with European integration processes, the basis of this plan should be the European Union's Biodiversity Conservation Strategy, in particular drawing on the EU's future Nature Restoration Law (European Commission, 2020).

SUPPLEMENTARY ONLINE MATERIAL

Online case studies

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RESUMEN

La invasión a gran escala de Ucrania por parte de la Federación Rusa se ha convertido en una crisis humanitaria y política. Desde el comienzo de la invasión, también ha sido un desastre ecológico, ya que las tropas rusas han utilizado zonas protegidas tanto para intentar acceder a asentamientos estratégicos ucranianos como para llevar a cabo una guerra activa. La línea del frente ya ha cruzado y se ha retirado de muchas zonas protegidas, muchas siguen ocupadas y muchas siguen siendo escenario de hostilidades activas. Según este estudio, los daños más comunes en las zonas protegidas son: la destrucción física de los hábitats y la fauna y los cambios de comportamiento de la fauna a causa de las explosiones; la contaminación química y física provocada por los materiales explosivos; los incendios causados por los bombardeos; los daños en el suelo y la cubierta vegetal provocados por los vehículos militares pesados, los equipos y las infraestructuras de defensa; y la explotación militar de los recursos naturales. Dada la ocupación, los combates y la explotación con explosivos, pasarán años antes de que Ucrania pueda contabilizar el alcance total de los daños sufridos por su sistema de zonas protegidas. Este documento ofrece una evaluación provisional de los daños sufridos por las áreas protegidas hasta la fecha e insta a las comunidades conservacionistas y políticas a seguir de cerca la situación en el futuro.

RÉSUMÉ

L'invasion massive de l'Ukraine par la Fédération de Russie est devenue une crise humanitaire et politique. Depuis le début de l'invasion, c'est également un désastre écologique, les troupes russes utilisant les zones protégées à la fois pour tenter d'accéder aux implantations stratégiques ukrainiennes, mais aussi pour y mener une guerre active. La ligne de front a maintenant traversé et s'est retirée de nombreuses zones protégées, beaucoup sont encore occupées et beaucoup sont encore le théâtre d'hostilités actives. Cette étude a révélé que les dommages les plus courants causés aux zones protégées sont : la destruction physique des habitats et de la faune et les changements de comportement de la faune dus aux explosions ; la pollution chimique et physique due aux matières explosives ; les incendies causés par les bombardements ; les dommages causés au sol et à la couverture végétale par les véhicules militaires lourds, l'équipement et l'infrastructure de défense ; et l'exploitation militaire des ressources naturelles. Compte tenu de l'occupation, des combats et de l'exploitation minière à l'aide d'explosifs, il faudra des années avant que l'Ukraine puisse rendre compte de l'étendue totale des dommages subis par son système de zones protégées. Le présent document fournit une évaluation provisoire des dommages subis par les zones protégées jusqu'à présent et invite instamment les milieux de la conservation et de la politique à surveiller la situation à l'avenir.