Long-term Impacts of the Russia-Ukraine Conflict on the Black Sea in 2022-2024 on Maritime Environmental Change: An Ecological Analysis

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ABSTRACT

The Black Sea conflict is a geopolitical and military conflict that is still ongoing today. It involves strategic rivalries between Russia, Ukraine, and some NATO countries (especially after Russia invaded Ukraine again in 2022). This research was conducted to analyze the long-term impacts on the Black Sea ecosystem itself arising from the conflict. Using a literature review as well as analyzing secondary data from environmental reports and academic literature, this research revealed that prolonged conflict can also accelerate the degradation of marine ecosystems. Military activities such as underwater exploitation, combat ship movements, and airstrikes have caused negative impacts in the form of marine pollution, damage to coral ecosystems, and a decline in the number of marine species in the region. In addition, unstable geopolitical conditions have worsened the collective marine resource management system among countries bordering the Black Sea, which in turn hinders transboundary conservation measures. The research concludes that conflicts in the Black Sea region not only affect the security sector and political dynamics, but also bring serious threats to ecosystems that have the potential to damage environmental balance at the regional level. Thus, this research encourages the importance of implementing environment-based diplomacy and strengthening cooperation between countries in the marine sector as a strategic effort to reduce the long-term damage caused by ongoing conflicts.

Keywords: *Black Sea, conflict, ecosystem, degradation, long-term.*

INTRODUCTION

The Black Sea has been a well-known geopolitical battlefield, as well as, an important shipping route. Its location links Eastern Europe with import-dependent regions such as North Africa, the Middle East, and parts of Asia. Along its north coast, Russia and Ukraine are in that strategic place where they bring huge amounts of farm produce such as wheat, maize, and sunflower oil (Kideys, 2002). By 2021, the two countries combined closer to a third of all world wheat shipments, demonstrating the importance of sustained maritime commerce in this basin to the international food security system. Any interference with shipping routes in the Black Sea thus is directly and immediately impactful on already weak international food systems (Sudirman, 2025).

Alongside its economic and political importance, the Black Sea represents a distinctive ecological system marked by both richness and fragility. The sea covers approximately 178, 000 square miles with an average depth of over 4,000 feet which supports various habitats including wetlands, estuaries, and lagoons. But in all it is only its upper layers which are oxygenated, and virtually all its volume is that which is permanently anoxic,

making it the largest oxygen-deprived body in the sea. Such a state of nature makes the environment particularly susceptible to external forces. Previously its fisheries were rich with sturgeon, anchovy and turbot, however, due to overfishing, pollution and loss of habitat the stocks dwindled in number over time (Black Sea Ecosystem | Research Starters | EBSCO Research, 2025).

The history of the last few decades demonstrates the vulnerability of the Black Sea to human activity. In the 1970s and 1980s, the large inflows of nutrients of major rivers caused mass eutrophication, algal proliferation and hypoxia and caused the mass death of benthic organisms (Buburuz et al., 2024). The unintentional arrival of the comb jelly Mnemiopsis leidyi further destabilized the ecosystem by voraciously feeding on zooplankton and fish larvae, causing the anchovy populations to collapse and causing big losses in fisheries. Despite indications of improvement in the mid-1990s, with the aid of reduced nutrient inflows and the introduction of the predatory ctenophor Beroe ovata, the Black Sea has since been ecologically sensitive and still faces the ongoing stresses of pollution, invasive species and climate change (Mavrič et al., 2025).

The outbreak of the Russia–Ukraine conflict in 2022 has added another layer of disturbance to this already stressed sea. Naval blockages, drifting sea mines, the rerouting of shipping routes, interfered with maritime logistics and introduced additional oil spill and chemical contamination threat. In 2023 in the destruction of the Kakhovka Dam the subsequent releases of sediments, nutrients and possible toxins into the basin changed the water chemistry, and nutrient cycling. Stiffened shipping on the western shores increased emissions and added further pressure to coastal habitats. A large oil spill in the Kerch Strait in late 2024 was yet another indication that conflict-related activities can increase already existing ecological dangers (Lisovets et al., 2025).

Based on this, it is vital to analyze the long-term effects of the Russia-Ukraine conflict on the Black Sea in 2022-2024. The war has not just revealed how vulnerable world food exchange is, but has also served as an environmental test on a semi-closed sea with low resilience. A clear explanation on the physical, chemical and biological transformations at this time offers a good insight into the way that armed conflict goes through ecological systems. This kind of analysis will be vital in advising conservation efforts, regional collaboration, and sustainable maritime governance in the coming years.

METHODS

This research employed a qualitative descriptive approach, focusing on the analysis of secondary data to understand the environmental impact of prolonged conflict on marine ecosystems. The study was conducted through a literature review, drawing from academic journals, environmental reports, and institutional publications that discuss the ecological consequences of the Russia–Ukraine war, particularly in the Black Sea region.

The primary sources of data included peer-reviewed articles, government and NGO environmental assessments, and reports from marine research institutions. One of the key references used was the Turkish Marine Research Foundation, which provided detailed documentation on the increase in dolphin mortality and the degradation of

marine biodiversity due to sonar disruption, pollution, and war-related activities.

These sources were selected based on relevance, credibility, and the depth of ecological data they offered. Data collection was carried out by systematically identifying, reviewing, and synthesizing findings from published materials between 2022 and 2024. The focus was placed on indicators of water quality deterioration, biodiversity loss, and habitat destruction. Reports detailing oil spills, acoustic pollution, and marine mammal strandings were examined to construct a comprehensive picture of the environmental damage.

The data analysis technique used in this study was content analysis. Key themes and patterns were extracted from the literature to identify causal relationships and long-term ecological implications. The findings were then interpreted to highlight how armed conflict exacerbates marine degradation, disrupts conservation efforts, and threatens the sustainability of marine life in the Black Sea.

RESULT AND DISCUSSION

Changes in Water Quality and Pollution - Biodiversity Loss and Marine Habitat Destruction

The armed conflict between Russia and Ukraine has not only caused widespread humanitarian and geopolitical impacts, but also brought significant ecological consequences to the Black Sea ecosystem. As a semi-enclosed body of water that is sensitive to environmental changes, the Black Sea is experiencing additional pressure due to military activities, infrastructure damage, and chemical pollution. Drastic changes in water quality, increased pollution, and damage to marine habitats have accelerated the loss of biodiversity and threatened long-term ecological stability. This subsection will examine in depth how the conflict has affected the physical and biological conditions of the Black Sea, as well as the potential resilience of the ecosystem amid geopolitical uncertainty. (H Renolafitri A, 2022.

The mass deaths of dolphins along the coasts of Turkey, Bulgaria, and Ukraine are a clear indicator of ongoing ecosystem damage. According to reports from the Turkish Marine Research Foundation and various local researchers, the number of dolphins dying and washing up on the shores of the Black Sea has increased dramatically since the start of the conflict. It is estimated that more than 5,000 dolphins have died during this period of war, and the actual number is likely to be much higher as around 95% of dolphin carcasses sink to the bottom of the sea and go undetected. Many of which show no physical injuries, suggesting that the main cause of death is not direct physical trauma, but rather internal system disruption due to pollution and underwater noise. Some individuals were even found with burns, presumably from sea mine explosions, indicating that this conflict has penetrated the boundaries of ecosystems that should be protected. (Setiawan, 2022).

The long-term impact of this phenomenon is very complex and multi-layered. The drastic decline in dolphin populations has the potential to disrupt the food chain balance in the Black Sea. As apex predators, dolphins play an important role in controlling small

fish populations and maintaining stable ecosystem dynamics. Their loss could lead to an explosion in the population of certain species, which would ultimately disrupt the overall structure of the marine community. In addition, the habitat damage caused by pollution and military activities will take years to recover, even after the conflict ends. The regeneration process of marine ecosystems cannot happen instantly, especially if key species such as dolphins have experienced a significant population decline.

Furthermore, this damage also hinders cross-border conservation efforts that have been carried out to preserve the Black Sea. Geopolitical tensions make international cooperation difficult, so that the restoration of the marine ecosystem is not only an ecological challenge, but also a diplomatic one. In the long term, without serious intervention, the Black Sea risks losing much of its biodiversity, making it a clear example of how human conflict can damage life systems far beyond the war zone.

In addition, the grounding of the Russian tanker Volgoneft 239 in the Black Sea due to a severe storm has exacerbated ecological conditions that were already under pressure from military conflict. The ship was carrying a cargo of low-grade fuel oil (mazut), and together with the Volgoneft 212, which broke in two in the same storm, the total spill reached around 9,200 tons of mazut. Of this amount, about 3,700 tons spilled directly into the sea, massively polluting the waters and coastline. According to reports from Greenpeace Ukraine and local media, more than 60 kilometers of coastline were polluted, including the Anapa and Novorossiysk areas. (Nugrahani, 2024).

Thick black waves carrying oil washed up on the shore, and seabirds were found dead, their bodies covered in oil, unable to fly or regulate their body temperature. The layer of oil that sticks to the seabed, coral reefs, and sediments disrupts important biological processes in the marine food chain. Small organisms such as plankton, which form the foundation of the ecosystem, are exposed to toxins and experience a decline in population. This has an impact on larger predators, including commercial fish, seabirds, and mammals such as dolphins and seals. Many of them die because their bodies are coated in oil or because they ingest toxic residues that accumulate in their body tissues. The reproductive process is also disrupted, especially in the early stages of life such as eggs and larvae, which are highly vulnerable to heavy pollutants such as fuel oil.

Furthermore, toxic compounds from mazut do not stop at one trophic level. They continue to move from one organism to another through a process of bioaccumulation, eventually reaching humans as the final consumers in the food chain. Consumption of contaminated seafood can cause serious health problems, ranging from skin irritation and respiratory disorders to the risk of cancer due to exposure to carcinogens contained in heavy oil.

The damage caused is not only ecological, but also social and economic. Polluted coastlines are difficult to restore, as oil can seep into sand and mud, persisting for years and continuing to release toxins into the surrounding environment. Coastal communities that depend on the sea for their livelihoods experience a decline in catches, disruption of marine tourism activities, and loss of income. In the long term, oil spills like this leave behind a legacy of pollution that is not easily removed, requiring

complex and sustained restoration efforts.

Maritime Activities and Ecological Pressure Long-term Ecological Shifts and Regional Implications

The Black Sea has long been a busy maritime area, with commercial shipping routes, coastal fishing, and naval activities overlapping in a relatively narrow basin. The conflict that occurred in 2022-2024 changed the pattern of daily activities in the sea. First, merchant ship traffic and port activities were often disrupted due to temporary closures, route changes, and stricter security checks. This situation forced some ships to travel longer distances, resulting in longer travel times, while the remaining routes became congested and prone to accidents and pollution.

Second, military operations in the area, such as mine laying, the use of explosives, and mine clearance efforts, caused major physical and acoustic disturbances. Underwater explosions, waves from warship propellers, and clearance activities damaged the seabed, stirred up sediment, and reduced the amount of light entering the water. This process ultimately damages the habitat of seabed organisms. Third, fishing activities have also changed. Some fishing vessels have chosen to retreat from areas considered dangerous, while others have shifted to shallow waters or previously underutilized areas. In a situation of weak surveillance, illegal fishing activities have also increased. All these changes have spread fishing pressure to new locations and affected the balance of the marine food chain. Changes in maritime activity during the conflict have had not only an immediate impact but also a long-term one. This has the potential to alter the flow of energy and biomass movement in the Black Sea ecosystem, which could lead to further ecological pressure in the future (Renolafitri & Yolandika, 2023).

The ecological impact of the conflict in the Black Sea needs to be viewed in the context of its history of vulnerability. In the 1960s–1990s, overfishing and the influx of nutrients from land triggered major shifts in the ecosystem. Opportunistic species such as jellyfish became dominant, the food chain was disrupted, and recovery was very slow (Akoglu, 2023). A similar situation risks repeating itself due to new pressures since 2022. The decline of apex predators, the influx of pollutants from damaged infrastructure, and explosions and military activities that damage the seabed increase the potential for sudden changes in the ecosystem structure. Akoglu (2023) shows in his research that such shifts are characterized by decreased energy efficiency, reduced diversity, and the dominance of fast-growing species. If these conditions recur, the Black Sea could face a simpler food web, less productive for fisheries, and be vulnerable to sudden population explosions. Therefore, the ecological pressures of conflict cannot be viewed as temporary but rather as having a long-term impact on ecosystems and coastal communities, making regional cooperation essential to prevent a greater ecological crisis.

The adverse consequences are serious and long-lasting. The military activities and ships that have been damaged by oil spills have contaminated vast parts of the ocean, including this sea. The Kakhovka Dam failure caused the discharge of billions of cubic meters of freshwater and mixes industrial waste, heavy metals, fertilizers, and

landmines to the Dnipro-Bug estuary and to northern Black Sea. Mass deaths of fish, destroyed mussel beds and disturbed coastal habitats were the result of this sudden flood. The marine species were quickly displaced by freshwater species in most regions, and the system was further stressed by nutrient overload, which caused deadly algal blooms (Kvach et al., 2025). There are also the positive though not longlasting effects. Due to the war that has minimized tourism, fishing, and shipping, most coastal regions have been able to take the opportunity to heal under the influence of humans. Beaches have been closed, trawling has ceased and recreational activity has decreased, and a few communities of plants and animals have recovered. But these benefits can vanish as pollution and destruction of habitat proceed (Wija Anarki Andi Cella & Seniwati Seniwati, 2024).

In the long run, the war is bound to create a legacy of pollution. Heavy metals and oil residues will remain in sediments, and unblasted mines and munitions will contaminate toxins decades later. Habitats that are not consistent, such as anchovies and mussels, may suffer decline as primary commercial species. Meanwhile, invasive species are exploiting emerging ecological niches, and propagating faster in disturbed waters (Wirtu & Abdela, 2025). These ecological changes are not specific to Ukraine as a region. Romania, Bulgaria, and Turkiye are impacted by the pollution of rivers and floating drifting sea mines, and the deterioration of fisheries and coastal economies through the loss of biodiversity along the Black Sea. This demonstrates that the ecological costs of the conflict are cross-national and require international collaboration.

Even after the devastation, there are signs of resilience in the Black Sea. Most of the native species are broadly tolerant to the environment and this could aid ecosystems to change with time. However, it will need active monitoring, cleanup of the pollutants, and a collective conservation program involving all the Black Sea states to recover. Otherwise, the sea can further slide towards the path of ecological disaster, and food security, tourism, and stability of the region will be affected.

Emerging Issues and Unexpected Findings

The war has not only exacerbated age-old ecological problems in the Black Sea, but has also raised new and unexpected ones. A paradox of temporary recovery of the environment is one interesting observation. With a decline in shipping, trawling and tourism, many coastal systems experienced a release from human pressure. Seashores that were closed for security reasons enabled vegetation to recover, seabirds to recover and fish populations to stabilize in some regions.

Another new problem is the environmental consequences of the demolition of the Kakhovka Reservoir, which was even worse than expected. Aside from killing the fish and mussels, the large influx of polluted freshwater also contributed to dramatic changes in species composition. Briefly the freshwater species momentarily outcompeted brackish-adapted species in near-coastal reaches that were once more saline than they are now. That means the war has added to the pressure in some parts of the ecosystem somewhere closer toward what it used to be like, a result that contradicts the assumption of a oneway street with habitat change.

Equally unexpected has been the spread of invasive species during wartime. Floods and disturbed habitats produced new ecological niches, which allowed species such as the Chinese sleeper fish and Atlantic blue crab to spread quickly. These invasions, along with the epidemic-induced decline of indigenous populations, might irreversibly affect biodiversity and food webs in the northern Black Sea. The war also serves as a reminder that environmental risks do not respect borders. Oil leaks, floating naval mines and river-borne contaminants are already making their way to the waters of Romania, Bulgaria and Turkiye, highlighting that the environmental destruction is not confined to Ukrainian land. This underscores the importance of regional cooperation in monitoring, cleanup and biodiversity conservation.

CONCLUSION

The Russia–Ukraine conflict of 2022–2024 has left a measurable and enduring imprint on the environment of the Black Sea. The analysis shows that wartime actions from infrastructure collapse and fuel releases to underwater detonations and altered shipping patterns, have intensified preexisting stresses, shifted species assemblages, and created pollution legacies that will persist beyond active hostilities. Empirical signals include declines in higher-trophic species, localized habitat loss, and the expansion of opportunistic and non-native organisms; together these changes point to a system with reduced resilience and heightened vulnerability to future shocks. While the analytical approach used here provides a useful initial picture, it has clear limitations. Field observations and incident reports provided essential evidence, yet uneven spatial coverage, limited baseline data, and detection biases, for example, carcass sinkage and underreported contamination, weakened inference about regional rates and trajectories of change. Remote sensing and opportunistic sampling compensated in part, but the study lacked consistently applied, long-term time series and integrative socio-ecological metrics that would allow robust attribution and forecasting.

Refinement of the methodology, including the combination of sediment and biota contaminant analyses, eDNA surveys, telemetry for key species, and harmonized monitoring protocols across coastal states, would reduce uncertainty and improve causal interpretation. Future research should prioritize continuous, cross-border monitoring and interdisciplinary frameworks that connect ecological indicators with human livelihoods and maritime governance. Comparative studies with other semi-enclosed seas affected by conflict can reveal common pathways and recovery options. Action-oriented experiments on habitat remediation, coupled with social science work on fisheries adaptation and risk governance, will make findings policy-relevant. Above all, rebuilding repositories of shared environmental data and establishing joint response mechanisms among Black Sea littoral nations are essential steps to limit long-term damage and to guide effective restoration.

REFERENCES

Buburuz, M. B. (2024). Pressures, threats and impacts on life in the Black Sea. *PARTNERSHIP WITH NATURE.*

Kideys, A. E. (2002). Fall and Rise of the Black Sea Ecosystem. *Science, 297(5586)*, 1482–1484. https://doi.org/10.1126/science.1073002

Kvach, Y. S. (2025). Biodiversity effects of the Russia–Ukraine War and the Kakhovka Dam destruction: Ecological consequences and predictions for marine, estuarine, and freshwater communities in the northern Black Sea. *Ecological Processes*, 4(1), 22. https://doi.org/10.1186/s13717-025-00577-1

Lisovets, O. P. (2025). Hemeroby reveals the dynamics of vegetation cover following the destruction of the Kakhovka Reservoir. *PeerJ*, 13, e19607. https://doi.org/10.7717/peerj.19607
Mavrič, B. I. (2025). Feeding Habits of the Invasive Ctenophore Mnemiopsis leidyi in the Gulf of Trieste (Adriatic Sea). *Water, 17(4)*, 470. https://doi.org/10.3390/w17040470

Naturaleza, I. (n.d.). *Lumba-lumba yang terancam punah: Penyebab dan lainnya.* Retrieved from id.postposmo.com: https://id.postposmo.com/lumba-lumba-yang-terancam-punah/

Renolafitri, H. &. (2022). Impact of the Russia-Ukraine war on the environmental, social, and economic conditions of the Black Sea. *Economic, Management, and Social Sciences Journal (ECOMANS)*, 1(1), 123-130. https://doi.org/10.56787/ecomans.v1i1.4

Research., B. S. (n.d.). *Black Sea Ecosystem | Research Starters | EBSCO Research.* Retrieved from EBSCO: https://www.ebsco.com/research-starters/science/black-sea-ecosystem

Seniwati., W. A. (2024). The Impact of the war Between Russia and Ukraine on Trade Routes in the Black Sea. *Konsensus : Jurnal Ilmu Pertahanan, Hukum Dan Ilmu Komunikasi,1(6)*, 118-129. https://doi.org/10.62383/konsensus.v1i6.472

Setiawan, T. (2022, August 23). *Invasi Rusia ke Ukraina bunuh lebih 5.000 lumba-lumba Laut Hitam.* Retrieved from jernih.co: https://jernih.co/crispy/invasi-rusia-ke-ukraina-bunuh-lebih-5-000-lumba-lumba-laut-hitam/

Sudirman, R. D. (2025). BLACK SEA GRAIN INITIATIVE SEBAGAI INSTRUMEN STABILITAS GLOBAL: KETAHANAN PANGAN DAN GEOPOLITIK PASCA INVASI RUSIA. 9(4).

Wirtu, Y. D. (2025). Impact of war on the environment: Ecocide. *Frontiers in Environmental Science*, 13, 1539520. https://doi.org/10.3389/fenvs.2025.1539520

Wulan Nugrahani, A. (2024, December 24). *Tumpahan minyak dari kapal tanker di Rusia cemari Laut Hitam.* . Retrieved from Tribunnews: https://www.tribunnews.com/internasional/2024/12/24/tumpahan-minyak-dari-kapal-tanker-di-rusia-cemarilaut-hitam