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Impact of Military Expenditure on Biodiversity Loss: Worldwide Evidence

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The potential impact of military operations, whether occurring in times of armed conflict or during periods of peace, has been recognised as a potential factor in environmental deterioration. This study investigates the correlation between military spending and the decrease in biodiversity within a dataset comprising 112 countries. The utilisation of the quantity of endangered species functions as a proxy indicator for the diminishment of biodiversity. In addition to the allocation of funds towards military expenditures, the current study incorporates various control variables such as income, population size, and the quality of governance. We employed a combination of static and dynamic panel data estimation methodologies to estimate our model. The Fixed Effects model is commonly favoured over alternative models, including Pooled Ordinary Least Squares, Random Effects, Difference-GMM, and System-GMM. Based on the results of our research, the Fixed Effects model demonstrates an inverse correlation between military expenditure and the depletion of biodiversity. A 1% increase in military expenditure, as a proportion of the Gross Domestic Product (GDP), is associated with a subsequent increase of 0.24% in the depletion of biodiversity. Contrarily, a rise of 1% in both income and population yields a reduction in biodiversity of 0.75% and 2.31%, respectively. On the contrary, a marginal increase of 1% in the government efficiency index is associated with a corresponding decrease in the rate of biodiversity loss by 0.22%. Based on the findings of our research, it is advisable for governments to contemplate the use of militarism as a policy instrument in order to safeguard environmental preservation. The integration of environmental factors into military policies and overarching frameworks necessitates cooperative endeavours involving local governments and international organisations. To address the issue of reliance on limited resources, it is crucial to embrace an environmentally conscious approach when designing and manufacturing defensive equipment. Furthermore, the adoption of strategies aimed at limiting armed conflicts and interstate disputes, coupled with the efficient coordination of military campaigns and their scale, has the potential to alleviate the negative consequences for biodiversity arising from militaristic activities.

Keywords: Biodiversity Loss, Threatened Species, Military Expenditure, Static and Dynamic Panel, Worldwide Evidence

Introduction

The task of effectively managing the diverse and abundant natural resources present in our global environment is increasingly intricate and challenging. The degradation of worldwide ecosystems and the escalating pace of species extinction are outcomes of environmental challenges, particularly those that surpass political boundaries, such as the depletion of biodiversity. Biodiversity, also known as biological diversity, is defined as the assortment of differences exhibited among living organisms that arise from diverse sources. This includes terrestrial, marine, and other aquatic ecosystems, as well as the interconnected ecological systems they comprise. This encompasses the variability observed within populations of a given species, as well as the differences observed between various species, and the variations observed across different ecosystems. Biodiversity plays a crucial role as the fundamental underpinning for all life forms on Earth. Backhaus, Snape, and Lazorchak (2012) argue that the implementation of an "insurance policy" involves mitigating the likelihood of significant changes occurring in ecosystems, which are of paramount importance in the advancement of human development. The intrinsic worth of biodiversity is widely acknowledged, and it serves a vital function in supporting human survival through the provision of fundamental resources, including nourishment, healthcare, and housing. The available resources encompass a diverse array of commodities, such as agricultural goods, seafood, timber, pharmaceuticals, and wool, among various others. One additional role of biodiversity is to uphold the integrity, abundance, and resilience of the ecosystem by means of regulating and recycling essential elements, including air, soil, and water, which are vital for human sustenance.

Despite numerous efforts and policy interventions aimed at the conservation of biodiversity, the decline in biodiversity is not a recent occurrence and has consistently constituted a significant and pressing issue that necessitates immediate attention from humanity. This study employed the count of endangered species as a surrogate indicator to assess the decrease in biodiversity, considering that biodiversity encompasses the entirety of living organisms on the planet. According to statistical data, there is a projected increase in the global number of threatened species to 42,108 by the year 2022, in comparison to the recorded figure of 16,306 in 2007 (refer to Figure 1). The findings of the analysis on endangered species categorization indicate that plants demonstrate the greatest degree of susceptibility, followed by vertebrates, invertebrates, fungi, and protists (IUCN, 2022).

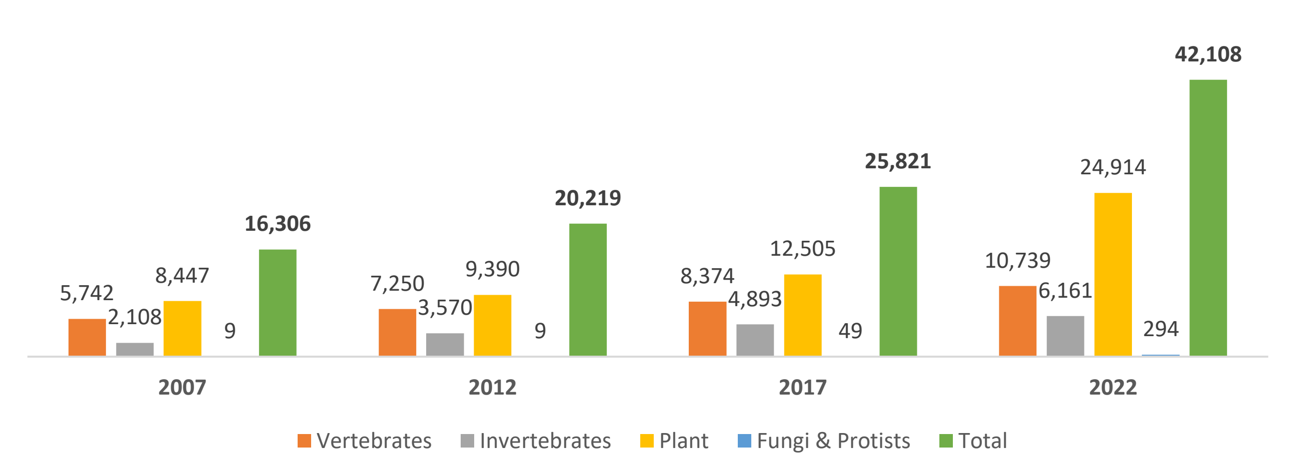

Figure 1: Global number of threatened species by groups.
Source: IUCN, 2022

The decline in biodiversity and its associated environmental threats have been attributed, in part, to the operational activities of the military sector. According to Hanson et al. (2009), areas exhibiting substantial biodiversity, commonly known as biodiversity hotspots, were identified as the setting for more than 90% of significant armed conflicts that transpired from 1950 to 2000. Moreover, it was noted that a majority exceeding 80% of these conflicts occurred within the confines of these designated areas of heightened tension. Within this specific time frame, a minority of the 34 designated hotspots, specifically less than one-third, were granted exemption from significant acts of violence. However, the majority of these locations witnessed repeated occurrences of violent events. Unfortunately, this propensity has persisted over the course of the past five decades. The notable disturbances exert a substantial influence on the topography, leading to heightened difficulties in the restoration of its initial state prior to the disruptions.

Generally, Militarism has maintained a consistent level of importance throughout historical periods. However, it is noteworthy that the environmental consequences resulting from militarised activities have experienced an increase following the culmination of World War II (Gokmenoglu, Taspinar, & Rahman, 2021). The phenomenon of governments giving higher priority to militarization during periods of conflict was further exacerbated by the escalating global arms race, thereby exacerbating the issue and transforming it into a contentious competition among nations. Concurrently, the military domain has experienced substantial structural changes as a result of technological advancements in both military operations and logistics. As a result, the advancement of increasingly complex and expensive armaments necessitates a rise in the demand for additional fossil fuel utilisation, thereby rendering military operations more reliant on resources (Kentor, Jorgenson, & Kick, 2012).

According to Singer and Keating (1999), the phenomenon of militarization has been found to have adverse consequences for the environment. These include the depletion of natural resources, deforestation, and the introduction of radioactive and hazardous materials, thereby leading to pollution. An additional attribute of the correlation between military activities and environmental challenges is the broadened scope of negative consequences resulting from military operations, which surpass instances of armed conflicts or wars. Despite the absence of armed conflict, the military sector continues to exert a substantial impact on environmental pollution through its regular operations (Jorgenson, 2005; Smith, Hooks, & Lengefeld, 2014; York, 2014). The integrity of biodiversity in terms of its structure and function, which play a crucial role in sustaining numerous plant and animal species, has been adversely affected by a range of factors. These include the advancement of novel military technologies, the demand for resources to sustain military equipment and facilitate weapon testing, as well as the movement of soldiers and weaponry.

In light of these circumstances, it is imperative to determine the quantity of endangered species that are in jeopardy, with the purpose of assessing the potential extent of biodiversity decline arising from military activities. The subject matter has garnered increased attention, notwithstanding the limited scientific evidence currently accessible within this specific field of research. To the best of our current knowledge, previous scholarly investigations have not explored the relationship between military spending and the population of endangered species. Prior research has predominantly concentrated on various environmental indicators, such as carbon emissions and ecological footprints. Furthermore, recent studies have indicated that employing the count of endangered species as a surrogate indicator for measuring the decline in biodiversity could yield a more precise evaluation of the ecological consequences, particularly in the context of expansive military installations and activities that contribute to the reduction of biodiversity.

The primary aim of this study is to investigate the influence of military spending on the reduction of biodiversity within the global economic framework. This study employs two methodologies: static panel data methods and dynamic panel data approaches. The static panel data methodologies encompass three main models: Pooled Ordinary Least Squares (POLS), Random Effect (RE), and Fixed Effect (FE) models. In contrast, the examination of the dynamic approach involved the utilisation of both Difference-Generalized Method of Moments (D-GMM) and System-GMM techniques. To accomplish this aim, we utilised a panel data set comprising 112 countries across the time period from 2013 to 2020 to evaluate the influence of military expenditure on the occurrence of biodiversity decline. This study incorporates supplementary explanatory variables, namely income, population, and governance indicators. This study additionally integrates a thorough evaluation of resilience by employing multiple governance metrics.

Similarly, the anticipated results of the macro-level cross-national study are projected to yield significant policy implications regarding the notion of human security, encompassing aspects beyond the realm of state border safeguarding. This study will offer substantial value to environmental practitioners and policymakers engaged in the formulation of environmental laws and policies that incorporate the element of militarization, despite its intrinsically unproductive nature. The subsequent sections of this piece are structured in the following manner: The following section conducts a comprehensive examination of the current body of literature regarding militarism and its implications for the environment. Section 3 delves into the empirical model and methodology employed in this study. Following that, the findings obtained from the study are presented in Section 4. Section 5 of this study presents a comprehensive overview of our analysis and puts forth policy recommendations that are derived from the findings.

Literature Review

The adoption of a human security perspective can help with the analysis and resolution of modern challenges that people and communities are facing in the twenty-first century, such as global environmental change. A significant aspect within the domain of international relations theory pertains to the identification and analysis of national security. The core foundation of international philosophy is grounded in the notion of inter-national connections (Wolfers, 1962). Military strategy is a further notable understanding of security within the field of international relations theory, with the realist viewpoint having a strong influence. The domain of security studies has exhibited a strong correlation with advancements in military technology, encompassing the evolution of offensive and defensive armaments.

Scholarly literature has established a correlation between military strategy and deterrence theory and arms control (Brodie & Dunn, 1946). The emergence of the concept of deterrence can be attributed to the strategic response aimed at predicting and preventing a potential large-scale nuclear conflict between the United States and the Soviet Union, following the development and deployment of nuclear weapons. Buzan (1983, 1991) endeavoured to broaden the purview of security by incorporating non-military variables. Similarly, Haq (1995) posited that the prioritisation of individuals should be emphasised in the pursuit of security, rather than solely relying on a nation's military capabilities or security measures. Furthermore, following the culmination of the Cold War, scholarly analyses of security underwent a significant shift away from the traditional emphasis on national security, predominantly influenced by neo-realist viewpoints (Mearsheimer, 2001; Walt, 1998; Waltz, 2010). Consequently, a more expansive understanding of security emerged, encompassing dimensions that extend beyond the boundaries of the nation-state. Following the disintegration of the Soviet Union, there emerged a notable redirection of attention towards alternative security challenges that had hitherto been disregarded. The aforementioned transition was accompanied by endeavours to diverge from the dominant security orthodoxy, which predominantly revolved around the notion of conflict between major global powers (Hampson & Daudelin, 2002; Tadjbakhsh & Chenoy, 2007).

The concept of environmental security is complex and can be interpreted in various ways. Realism, the dominant theoretical framework in the field of security studies, conventionally places the state at the core of analysis and argues that security is achieved through the application of military force or the prevention of potential threats. From a realist standpoint, environmental issues are commonly classified as "low" politics, in contrast to "high" politics that predominantly revolve around security concerns. Realist scholars frequently construct a hierarchical categorization of threats, distinguishing between those that can be legitimately incorporated into the security agenda and those that cannot (Krause & Williams, 1996; Rothschild, 1995).

The perspectives of constructivists and poststructuralists, who argue that hazards are socially constructed, have presented a challenge to the limited realism viewpoint. Barry Buzan, Ole Waever, and Jaap de Wilde, three renowned academics who led the Copenhagen School, developed a remarkably inventive and intellectually challenging conceptual framework to understand the social construction of security concerns (Buzan, Wæver, & De Wilde, 1998). Furthermore, the cautionary message conveyed by this study regarding the potential risks of framing environmental issues from a security perspective has exerted a substantial impact on political and intellectual discourse. In accordance with the theoretical framework of securitization, it can be argued that there are presently no imminent and concrete threats. If a political community effectively redefines a specific issue as a matter of security through a speech act that alters the way the issue is approached, a wide range of issues may be perceived as security concerns. The concept of security is commonly understood as a social phenomenon rather than being purely theoretical or static in nature. A novel approach to analysing discourse on environmental security entails investigating the manner in which security concerns are constructed through discourse.

According to Brandão (2014), the critical perspective presents an alternative method for tackling environmental concerns. This perspective places emphasis on the necessity of ensuring the security of the environment, rather than framing it solely within the context of securitization. From this particular standpoint, the environment assumes a pivotal role of utmost importance, surpassing the state as the primary focal point. Furthermore, the environment is understood in the context of its human inhabitants. The critical perspective advocates for a departure from security frameworks that prioritise militaristic approaches in favour of a strategy that prioritises addressing the root causes of environmental degradation. Within this particular context, the incorporation of environmental security is encompassed within the wider framework of human security. In the words of Elliott (2004), the prioritisation of preserving surrounding ecosystems is crucial for ensuring environmental security, as the well-being of humans is intricately interconnected with these ecosystems.

Previous empirical studies have demonstrated a positive correlation between increased militarism and its impact on the environment. Carbon emissions are frequently employed as a primary environmental indicator for evaluating the effects being examined. According to a study by Jorgenson and Clark (2016), there is a positive correlation between rising military spending and higher levels of carbon emissions in both OECD and non-OECD nations. The research employs a sample of 81 countries, covering the time frame from 1990 to 2010. In order to analyse the environmental model, the Prais-Winsten regression model is employed, incorporating panel-corrected standard errors (PCSE). The findings of this study indicate that a slight augmentation of 1% in military spending as a proportion of the total Gross Domestic Product (GDP) results in a corresponding increase in emissions of 0.068% and 0.250% for non-Organisation for Economic Cooperation and Development (OECD) and OECD nations, respectively.

Through a thorough panel analysis, the research by Afia and Harbi (2018) revealed a notable correlation between the militarization process and carbon emissions. The result is obtained from a dataset comprising 120 countries across the time period from 1981 to 2015. The present study employed a multivariate cointegration technique to examine the direct and indirect impacts of military expenditure on carbon emissions. This study operationalizes the notion of direct impact as the degree of influence that military expenditure exerts on carbon emissions. In contrast, the concept of indirect impact is defined and measured as the resultant outcome arising from the combined influence of military expenditures on income and income on carbon emissions. The available empirical evidence suggests that there is a discernible positive relationship between military expenditure and carbon emissions per capita. This implies that both direct and indirect effects of military expenditures have an influence on overall environmental sustainability.

Bradford and Stoner (2017) conducted a study wherein they observed a significant and positive correlation between military expenditure levels and per capita carbon emissions. The results obtained from the analysis of panel data indicate that the initial relationship displayed a relatively weaker and more varied pattern. However, over time, there has been an observed trend of increasing strength in the relationship. This analysis provides additional evidence to support the notion that the degree of economic development within a country plays a moderating role in the correlation between military spending and carbon emissions per person. More developed nations exhibit significantly larger net effects stemming from their military expenditures. However, the existing data suggest that the temporal consistency observed in the correlation between military expenditure and carbon emissions is a relatively recent occurrence, as there was a less pronounced connection between these two factors prior to the 1990s.

Furthermore, Bildirici (2017a) research showed a link between military spending and carbon emissions in the G-7 nations. The analysis in question was carried out over a span of thirty years, specifically from 1985 to 2015. The methodology employed for this analysis was the panel autoregressive distributed lag (PARDL) approach. The results of this study suggest that there are significant connections, both in the short-term and long-term, between military spending and carbon emissions. The findings of the causality analysis demonstrate the presence of a distinct causal link between carbon emissions and military expenditure. The study additionally demonstrated that for the purpose of efficiently mitigating carbon emissions, it is crucial for the G7 countries to abandon militaristic practices, thereby decreasing energy consumption per unit. The United States also demonstrates environmental repercussions stemming from its military activities. Bildirici (2017b) conducted a study that investigated the long-term trends and underlying determinants of carbon emissions, militarism, economic growth, and energy consumption from 1960 to 2013. The bound test approach for cointegration was utilised to determine the presence of a relationship, both in the short-term and long-term, between the variables being examined. The present analysis has unveiled a significant and robust positive correlation, suggesting a strong association between carbon emissions and militarization. The F tests conducted by Rao yielded evidence supporting the presence of unidirectional causality in cases where there is no feedback loop connecting militarism to carbon emissions, energy consumption to carbon emissions, and militarization to energy consumption. The research findings demonstrate that there is a significant relationship between militarism and energy consumption, which collectively explain 26% and 60% of the observed variations in carbon emissions, as evidenced by the forecast-error analysis. In an independent study conducted in the United States, Bildirici (2017c) investigated the correlation between militarism and carbon emissions. The study utilised a dataset covering the period from 1984 to 2015 and employed several estimation techniques, including ARDL, Dynamic OLS (DOLS), Canonical Cointegration Regression (CCR), and Fully Modified OLS (FMOLS). The results of the study revealed that the presence of militarism had a detrimental effect on carbon emissions.

The levels of carbon emissions, nitrous oxide, and methane in African countries show the detrimental effects of militarism on environmental welfare. Domguia and Poumie (2019) conducted a study that investigated the correlation between military expenditure and environmental degradation in a sample of 54 African countries from 1980 to 2016. Based on the results derived from the Generalised Method of Moment (GMM), it can be inferred that all the environmental indicators demonstrate statistical significance at a significance level of 1%. The capacity of these nations to efficiently curtail or diminish military outlays is pivotal for the preservation of an environmentally sustainable state.

Similarly, the allocation of financial resources towards military endeavours has led to a significant increase in carbon emissions among affluent Mediterranean countries, such as Greece, France, Italy, and Spain. Erdogan, Gedikli, Çevik, and Öncü (2022) employed the Global Vector Autoregression methodology to conduct their analysis, utilising annual data from 1965 to 2019. The nations were chosen solely based on their comparatively high levels of carbon and greenhouse gas emissions. Furthermore, it is noteworthy that France and Italy demonstrate a significant commitment to their military expenditures by allocating the highest financial resources among all countries. This study further highlights the importance of approaching the topic with appropriate gravity, as the increasing levels of military spending appear to have a significantly adverse effect on the environment. In contrast, a positive correlation between military expenditure and carbon emissions was discovered by Zandi, Haseeb, and Zainal Abidin (2019) in a separate panel study conducted on six ASEAN countries. The data spanning from 1995 to 2017 is subjected to analysis using the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methodologies. The analysis of both methodologies reveals a discernible correlation between military expenditure per unit and fluctuations in carbon emissions, indicating a positive relationship. The observed relationship between an increase in military expenditure per unit and alterations in carbon emissions is demonstrated by the corresponding methodologies, indicating changes of approximately 0.33 units and 0.38 units, respectively.

In the specific context of Pakistan, the existing body of research investigating the ecological footprint as a metric for assessing the environmental ramifications of militarism has been relatively scarce. The increase in military spending has led to a proportional increase in energy consumption, thereby contributing to a substantial environmental impact. Ahmed et al. (2020) conducted a study that examined a dataset covering the period from 1971 to 2016. The researchers employed bootstrap causality and cointegration test techniques in their analysis. The study's findings are supported by the observation that the Pakistani military heavily depends on fossil fuels and operates across a substantial geographical area. The present study, conducted by Gokmenoglu, Taspinar, and Rahman (2021), investigates the correlation between military expenditure and carbon emissions within the context of Turkey. The researchers employ the Fully Modified Ordinary Least Squares (FMOLS) estimator and the Toda and Yamamoto (1995) causality test to examine the dataset covering the time period from 1960 to 2014. The analysis unveiled a significant positive correlation between military expenditure and the exacerbation of environmental degradation.

In a recent empirical study by Eregha, Vo, and Nathaniel (2022), the researchers looked at the relationship between military spending and the ecological footprint using the bootstrap causality test and the Maki (2012) cointegration test while also taking various structural breakdowns into account. The study's findings demonstrated a positive correlation, suggesting that there is a tendency for military expenditures to increase the ecological footprint. Moreover, it is important to acknowledge that energy consumption and economic growth have a detrimental effect on the environment. Nevertheless, it is important to note that the advancement of financial systems can potentially yield beneficial outcomes for environmental welfare through the reduction of ecological impact. The study's findings suggest a unidirectional causal link from military expenditure to ecological impact while demonstrating a bidirectional causal relationship between military expenditure and economic growth.

However, despite the growing prominence of this topic, the use of empirical data to examine the relationship between militarization and the reduction of biodiversity has yet to be acknowledged. The existing research in this particular domain primarily focuses on carbon emissions, while relatively less emphasis has been placed on the issue of biodiversity loss. Understanding the correlation between militarization and the decrease in biodiversity presents difficulties in the absence of reliable and sufficient data. Hence, additional investigation is necessary in diverse contexts to examine the influence of militarization on the population of endangered species. The foremost concern linked to the decline in biodiversity pertains to its potential consequences for forthcoming generations, who could encounter difficulties concerning the depletion of natural resources and compromised well-being of ecosystems.

The central concern of modern society revolves around the recognition that, despite our present access to economic prosperity, future generations will inevitably encounter the limitations imposed by finite natural resources and a progressively deteriorating ecosystem. The preservation of the Earth's ability to sustain itself as an ecosystem that provides fair opportunities for survival to all cohabiting species is of utmost significance.

3. Data and Methodology

The model proposed in this study is founded upon the works of Domguia and Poumie (2019) as well as Erdogan, Gedikli, Çevik, and Öncü (2022). The assessment of the environmental impact of increasing militarism incorporates the count of endangered species, along with additional explanatory factors that have been incorporated to enhance the model. The model is defined in the following manner:

biodiversity loss = f (military, income, population, governance) (1)

All variables are converted to natural logarithms (ln). The estimated stochastic model can therefore be illustrated as follows:

$$\ln \text{biodiversityloss}_{it} = \pi_0 + \pi_1 \ln \text{military}_{it} + \pi_2 \ln \text{income}_{it} + \pi_3 \ln \text{population}_{it} + \pi_4 \ln \text{governance}_{it} + \varepsilon_{it} \quad (2)$$

Biodiversity loss, denoted as $\text{biodiversityloss}_{it}$, refers to the quantification of species that face threats within country i during time t. This serves as a proxy for measuring the extent of biodiversity decline. Military expenditure in country i during time t is represented by military_{it}, indicating the financial resources allocated towards military activities. income_{it} corresponds to the real GDP per capita of country i during time t, serving as a proxy for gauging economic development. population_{it} represents the total population of country i during time t, serving as a proxy for assessing demographic changes. Lastly, governance_{it} denotes the quality of governance in country i during time t, serving as a proxy for evaluating institutional quality. The parameters π_1 , π_2 , π_3 and π_4 are used to denote the coefficients or elasticities associated with the independent variables, while π_0 is the intercept and ε represents the error term.

There are multiple methodologies that can be employed to quantify the impact on the environment. Nevertheless, scholarly inquiries in this particular domain have primarily focused on assessing the environmental impact of military spending through the analysis of carbon emissions and ecological footprints. Deforestation, water pollution, and air pollution are among the supplementary environmental indicators that have been extensively studied (Ahmed, Shahbaz, Qasim, & Long, 2015; Arshad, Robaina, Shahbaz, & Veloso, 2020; Din, Habibullah, & Choo, 2014; Gedik & Mugan-Ertugral, 2019; Habibullah, Din, Choo, & Tan, 2019; Saenz-de-Miera & Rosselló, 2014; Tan, Yiew, & Habibullah, 2022). The preceding study has demonstrated that employing the quantity of endangered species as a substitute for measuring the decline in biodiversity can be a substantial indicator for evaluating the ecological consequences arising from military activities, encompassing land utilisation, contamination, and forest depletion. Threatened species encompass taxa that are classified as severely endangered, endangered, or vulnerable. A negative correlation can be observed between the number of endangered species and the level of species richness. Therefore, it can be deduced that the expected trend of this variable will be positive.

In the realm of academic research, it is customary to evaluate the level of militarization through the quantification of military expenditure as the focal variable. This refers to the comprehensive scope of current and future financial expenditures related to the military. It includes expenses associated with personnel engaged in peacekeeping activities, defence ministries, and other government entities involved in defence-related initiatives. Additionally, it encompasses paramilitary forces equipped with the necessary training and resources for military operations, as well as activities pertaining to military operations in space. The expenses encompassed within this framework consist of operating and maintenance costs, procurement expenditures, investments in military research and development, and military assistance provided by the donor country in the form of its own military outlays. The variable in question encompasses a broad range of individuals, including both military and civilian personnel, along with their associated retirement benefits and social services. This can be observed by referring to the World Bank indicator MS.MIL.XPND.GD.ZS. In line with prior investigations conducted by Zandi, Haseeb, and Zainal Abidin (2019), Gokmenoglu, Taspinar, and Rahman (2021), and Erdogan, Gedikli, Çevik, and Öncü (2022), the current study proposes that an escalation in military expenditure is anticipated to exert an adverse impact on environmental performance, as assessed by the quantification of endangered species.

This study additionally investigates the impact of additional explanatory factors, such as wealth and population, on the estimation of environmental outcomes. Previous research has underscored the potential ramifications of economic development and the expansion of the human population on the degradation and transformation of ecosystems and biodiversity, driven by the objective of generating tangible goods and services (Asafu-Adjaye, 2003; Cafaro, Hansson, & Götmark, 2022). The factors mentioned above have exerted considerable pressure on the Earth's carrying capacity, resulting in the depletion of finite resources, deforestation, environmental pollution, and land degradation. The global annual extraction of both renewable and non-renewable resources has surpassed 60 billion metric tonnes, demonstrating a steady growth rate of around 100% per year since 1980. As a result, there has been a rise in the extinction of various species. As a result, it is expected that these variables will exhibit a positive trend.

On the other hand, there is a positive correlation between higher institutional quality or effective governance and enhanced service delivery. This association is regarded as a favourable outcome of good governance as it aids in the reduction of environmental impact. Essentially, it functions as a primary driver for the conservation of the environment by addressing conflicts within and between nations regarding the exploitation of natural resources, thereby fostering the development of assurance and reliance across various spheres. The presence of strong resource management practices within an institution is commonly associated with improved institutional quality, creating a favourable environment that offers substantial benefits for individuals (Din, Habibullah, & Choo, 2014; Habibullah, Din, Chong, & Radam, 2016; Habibullah, Din, Tan, & Zahid, 2022). A nation's susceptibility to environmental concerns can be heightened by inadequate governance and the presence of illegitimate institutions that lack the capacity to enforce compliance with contracts and operational regulations. Therefore, it is expected that the indicator for this variable would exhibit a negative sign.

The dataset utilised in this study comprises longitudinal panel data encompassing the time period from 2013 to 2020. The study includes a comprehensive sample size of 112 nations, representing diverse countries. The data is collected from various sources, including the IUCN Red List, which is used to assess the population status of species that are vulnerable. Additionally, the World Bank's World Development Indicators (WDI) database is used to analyse military expenditure, income levels, and population figures. Furthermore, the World Bank's World Governance Indicators database is employed to evaluate the governance index. Table 1 presents a succinct summary of the factors being examined, while Table 2 lists the 112 countries that have been incorporated in the study. The countries included in this research were chosen based on the availability of data.

Table 1: Summary of variables.

Variables	Measurement	Sources	Expected sign
Biodiversity loss	Number of threatened species by taxonomic groups (mammals, birds, reptiles, fishes, and plants)	IUCN	-
Military	Military expenditure (% of general government expenditure)	WDI	Positive
Income	Real GDP per capita (constant 2015 US$)	WDI	Positive
Population	Total population	WDI	Positive
Governance	Governance indicators are voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption	WGI	Negative

Note: IUCN - The International Union for Conservation of Nature, WDI is for World Development Indicator, WGI – Worldwide Governance Indicator.

Table 2: List of 112 countries included in this study.

Afghanistan	Colombia	Ireland	Montenegro	South Africa
Albania	Congo, Dem. Rep.	Israel	Morocco	Spain
Algeria	Cote d'Ivoire	Jamaica	Mozambique	Sri Lanka
Angola	Croatia	Japan	Nepal	Sweden
Argentina	Cyprus	Jordan	Netherlands	Tanzania
Armenia	Czech Rep	Kazakhstan	New Zealand	Thailand
Australia	Denmark	Kenya	Nicaragua	Timor-Leste
Austria	Dominican Rep	Korea, Rep.	Nigeria	Trinidad & Tobago
Azerbaijan	Ecuador	Kuwait	Norway	Tunisia
Bangladesh	Egypt, Arab Rep.	Kyrgyz Rep	Oman	Turkey
Belarus	El Salvador	Latvia	Pakistan	Uganda
Belgium	Eswatini	Lebanon	Papua New Guinea	Ukraine
Bolivia	Fiji	Lesotho	Paraguay	United Kingdom
Bosnia & Herzegovina	Finland	Liberia	Peru	United States
Botswana	Georgia	Lithuania	Philippines	Uruguay
Brazil	Germany	Luxembourg	Poland	Zambia
Brunei Darussalam	Ghana	Madagascar	Portugal	
Bulgaria	Guatemala	Malaysia	Romania	
Cambodia	Guyana	Mali	Rwanda	
Cameroon	Honduras	Malta	Saudi Arabia	
Central African Rep	Hungary	Mauritius	Senegal	
Chad	India	Mexico	Singapore	
Chile	Indonesia	Moldova	Slovak Republic	
China	Iraq	Mongolia	Slovenia	

To achieve the objective of our study, we have chosen to employ panel data analysis. The investigation commences by employing a static panel that encompasses the variables of political science (POLS), renewable energy (RE), and foreign exchange (FE). According to the POLS estimation, it is postulated that the intercept and slope coefficients within the biodiversity loss model exhibit constancy across various countries and time periods. The assumption is made that the error term consists of a sequence of disturbances that exhibit identical and independent distributions and do not exhibit correlation with the explanatory variables. Nevertheless, it is crucial to acknowledge that this assumption could potentially impose specific limitations and potentially introduce bias related to heterogeneity. In light of the diverse composition of economic data, it is imperative to incorporate distinct intercepts in the regression analysis of the biodiversity loss model. In contrast, the random effects (RE) and fixed effects (FE) models propose that each nation possesses distinct intercepts while maintaining a homogeneous slope. The model of biodiversity loss can be decomposed into two distinct and independent components, namely the error term.

$$\ln \text{biodiversityloss}_{it} = \pi_0 + \pi_1 \ln \text{military}_{it} + \pi_2 \ln \text{income}_{it} + \pi_3 \ln \text{population}_{it} + \pi_4 \ln \text{governance}_{it} + \lambda_i + \mu_{it} \quad (3)$$

The regression model incorporates the time-invariant, individual-specific impact in order to accommodate individual-specific factors that have not been explicitly accounted for. The random effects (RE) model posits that the individual-specific effect (λ_i) is a stochastic variable that is assumed to be independent of the explanatory variables. This facilitates the incorporation of time-invariant variables as explanatory factors in the model. In contrast, the fixed effects model maintains a constant individual-specific effect and allows for potential correlation with the independent variables. The fixed effects (FE) model is frequently preferred in comparison to the random effects (RE) model. A notable constraint of the random effects (RE) model is the underlying assumption that the level-1 independent variables, which exhibit temporal variation in time-series cross-section and panel data, are not correlated with the random effects term. The plausibility of the condition may be subject to scrutiny due to the existence of unobserved heterogeneity, which is inherently correlated with the independent variables. The observed correlation can be attributed to the inherent variability of a level-1 variable, which manifests both within individual clusters and across different clusters.

However, further experimentation is necessary to determine the most suitable static techniques among the options. Once the estimations for the POLS and RE tests have been made, it becomes imperative to perform the Breuch-Pagan LM (BPLM) test (Breusch & Pagan, 1980) in order to select one of the models. If the null hypothesis is rejected, the decision to choose between the random effects (RE) or fixed effects (FE) model is made based on the application of the Hausman (1978) test.

Endogeneity concerns can occasionally emerge in the context of static panel data analysis, specifically when one of the independent variables in the biodiversity model demonstrates correlation with the error term. The failure to adequately address this matter may lead to inaccurate deductions and potentially misleading outcomes. To mitigate the issue of endogeneity, the present study employs the System Generalised Method of Moments (GMM) approach, originally introduced by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998, 2000). In contrast to a static panel, the incorporation of the lagged dependent variable as an explanatory variable function as an instrumental variable to mitigate the issue of endogeneity. The dynamic model within the biodiversity model is obtained through the utilisation of Equation (3) while incorporating a one-lagged period of the dependent variable.

$$\ln \text{biodiversityloss}_{it} = \pi_0 + \pi_1 \ln \text{biodiversityloss}_{it-1} + \pi_2 \ln \text{military}_{it} + \pi_3 \ln \text{income}_{it} + \pi_4 \ln \text{population}_{it} + \pi_5 \ln \text{governance}_{it} + \lambda_i + \mu_{it} \quad (4)$$

The problem of endogeneity is tackled by the GMM method through the utilisation of two distinct transformations: the first-difference transformation, commonly referred to as one-step GMM, and the second-order transformation, known as two-step GMM. The transformation techniques mentioned above fall into two distinct categories of GMM approaches, specifically difference-GMM (D-GMM) and system-GMM (S-GMM). One of the limitations of the Dynamic Generalised Method of Moments (D-GMM) is that its estimation is dependent on moment conditions that are derived from the estimated initial difference of the error component.

On the other hand, the generalised method of moments (GMM) in the system is a more complex methodology as it integrates two separate sets of moment conditions, encompassing both lagged variables in their original form as well as their differences. The utilisation of this approach holds promise for enhancing efficiency through the integration of additional tools or instruments into the model. The validity of these additional instruments can be assessed using the Sargan over-identifying restriction tests (Arellano & Bond, 1991). Furthermore, empirical evidence has demonstrated that the utilisation of two-step difference generalised method of moments (GMM) standard errors is linked to the concern of downward bias. In contrast, the GMM approach method proposed by Blundell and Bond (1998) and Bond (2002) offers a viable solution to the problems of autocorrelation and heteroskedasticity. This approach effectively mitigates these issues, resulting in dependable coefficient estimates and enhanced accuracy in autocorrelation testing.

Empirical Findings

The principal objective of this study is to evaluate the ecological ramifications linked to military spending, with a specific emphasis on the population of endangered species. Table 3 provides a comprehensive summary of the main characteristics of the variables incorporated in the study, employing descriptive statistics. The data clearly demonstrates that the variable representing biodiversity loss ranges from a minimum value of 9 to a maximum value of 3,483. The focal variable exhibits a mean of 1.875, encompassing a range that extends from a minimum value of 0.146 to a maximum value of 13.326. Furthermore, it is observed that the notable values for income and population are 14,413 and 5.73e+07, respectively. The recorded minimum values for income and population are 364.084 and 404,414, respectively, whereas the maximum values are noted as 108,570 and 1.40e+09. All variables have a positive standard deviation. A greater magnitude of the standard deviation indicates that the data points demonstrate a broader dispersion across a wider range of values. On the other hand, a low standard deviation indicates that the data points exhibit a propensity to aggregate in close proximity to the mean of the dataset.

The results of the correlation matrix are presented in Table 4. The findings of the analysis demonstrate a significant correlation between the decrease in biodiversity and its fundamental determinants, specifically population, income, and governance. Nevertheless, the correlation between the decline in biodiversity and military expenditure does not demonstrate a statistically significant association. The statistical significance of the relationship between the independent variables is moderate overall, except for the association between income and governance, which demonstrates a correlation coefficient of 0.89. Hence, the matter of multicollinearity is regarded as inconsequential. However, it is important to acknowledge that the results obtained from the correlation matrix may not accurately reflect the findings of this study. This limitation arises from the use of variables presented in level data.

Table 3: Descriptive statistics.

Variables	Unit	Obs	Mean	Std. Dev.	Min	Max	Kurtosis	Skewness
Biodiversity loss	number of threatened species	888	306.812	425.088	9	3,483	12.759	2.791
Military expenditure	%	888	1.875	1.621	0.146	13.326	15.498	3.036
Income	constant US$	888	14,413.3	19,009.57	364.084	108,570	7.995	2.122
Population	number of persons	888	5.73e+07	1.68e+08	404,414	1.40e+09	45.120	6.401
Governance	index	888	0.125	0.934	-1.887	2.325	2.245	0.331

Notes: Asterisks ***, **, * denote statistically significant at 1%, 5% and 10% level, respectively. Governance is referred to government effectiveness.

Table 4: Correlation matrix.

Variables	Biodiversity loss	Military expenditure	Income	Population	Governance
Biodiversity loss	1.0000				
Military expenditure	-0.018	1.0000			
Income	-0.115***	0.051	1.0000		
Population	0.582***	0.120***	-0.196***	1.0000	
Governance	-0.064*	-0.001	0.888**	-0.168***	1.0000

Notes: Asterisks ***, **, * denote statistically significant at 1%, 5% and 10% level, respectively.

The examination of the factors influencing the model of biodiversity loss is carried out through the utilisation of both static and dynamic panel methodologies. The coefficients, p-value significance levels, and standard errors for all predictors in each technique are reported. The results for the fixed-effects panel are presented in Table 5. In contrast to other static models, the fixed effects (FE) model exhibits greater effectiveness in elucidating the underlying factors that contribute to the decline in biodiversity. In all instances, the p-values derived from the BPLM and Hausman tests demonstrate a substantial degree of statistical significance, thereby satisfying the criteria for rejecting the null hypothesis. Given the prevalence of cross-sectional dependence (CSD) and the potential issue of heteroskedasticity in the fixed effects (FE) model, this study employed the robust FE standard error model to conduct the analysis.

Table 5: Results of military expenditure on biodiversity loss using static approaches.

Independent variables	POLS	Random Effect	Fixed Effect	Fixed Effect Robust Standard Error
Military expenditure$_{it}$	-1.135***	0.206***	0.236***	0.236***
	(0.045)	(0.040)	(0.037)	(0.058)
Income$_{it}$	-0.102**	0.449***	0.751***	0.751***
	(0.050)	(0.061)	(0.086)	(0.174)
Population$_{it}$	0.424***	0.730***	2.312***	2.314***
	(0.020)	(0.056)	(0.136)	(0.221)
Governance$_{it}$	0.213**	-0.237***	-0.224***	-0.224***
	(0.087)	(0.053)	(0.048)	(0.084)
Constant	-0.979*	-10.912***	-39.538***	-39.587***
	(0.569)	(1.116)	(2.238)	(3.569)
BPLM Test	0.000			
Hausman Test		0.000		
Heteroscedasticity Test			0.000	
CSD Test			0.000	
Number of groups	112	112	112	112
Number of observations	890	890	890	890

Notes: Figures in the parentheses are standard errors. BPLM denotes as Breusch–Pagan LM test, and CSD denotes as cross-sectional dependence. All the BPLM test, Hausman test, Heteroscedasticity test, and CSD test are reported in p-values. Asterisks ***, **,* denote statistically significant at 1%, 5% and 10% level, respectively.

The hypothesis suggests that there is a substantial impact of militaristic pressure on the environment, as indicated by the robust standard error discovery. Research has demonstrated that a marginal increase of 1% in military spending is associated with a proportional escalation of 0.24% in the depletion of biodiversity. Despite utilising distinct environmental metrics, the current study's results are consistent with previous scholarly investigations that have explored the impact of militarism on carbon emissions and ecological footprint. This alignment is exemplified by the works of Jorgenson and Clark (2016), Bradford and Stoner (2017), Afia and Harbi (2018); Bildirici (2017a), Bildirici (2017b, 2017c), Domguia and Poumie (2019), Zandi, Haseeb, and Zainal Abidin (2019), and Erdogan, Gedikli, Çevik, and Öncü (2022).

Furthermore, the remaining explanatory variables demonstrate statistical significance at a significance level of 1%. Moreover, it is important to acknowledge that the environment is impacted not solely by military operations, but also by economic progress and population growth, as highlighted by Din, Habibullah, and Choo (2014) and Habibullah, Din, Chong, and Radam (2016). A slight augmentation of 1% in wealth or population is associated with a corresponding rise of 0.75% and 2.31% in the depletion of biodiversity. On the other hand, there is a negative correlation between an enhancement in institutional quality, as evaluated by the governance indicator, and a reduction in the environmental impact by 0.22%. The negative coefficients observed in relation to the governance indicator indicate that effective governance is associated with the implementation and enforcement of appropriate rules and regulations that promote environmental preservation.

The robustness test is performed by incorporating multiple governance measures. As initially suggested by Kaufmann, Kraay, and Mastruzzi (2008), the current study used six governance measures. The indicators encompassed in this framework consist of voice and accountability, political stability and absence of violence, governance effectiveness, regulatory quality, rule of law, and corruption control. The results displayed in Table 6 demonstrate that the biodiversity loss model demonstrates resilience, indicating its stability and reliability. At a significance level of 1%, the variable being examined demonstrates a substantial level of significance across all governance measures.

Table 6: Results of military expenditure on biodiversity loss using static approaches with robust standard error.

Independent variables	Voice and accountability	Political stability and absence of violence	Regulatory quality	Governance effectiveness	Rule of law	Control of corruption
Military expenditure$_{it}$	0.231***	0.231***	0.229***	0.236***	0.230***	0.230***
	(0.059)	(0.059)	(0.060)	(0.058)	(0.060)	(0.059)
Income$_{it}$	0.696***	0.718***	0.721***	0.751***	0.708***	0.695***
	(0.193)	(0.195)	(0.182)	(0.174)	(0.192)	(0.193)
Population$_{it}$	2.305***	2.300***	2.262***	2.314***	2.295***	2.306***
	(0.221)	(0.222)	(0.215)	(0.221)	(0.219)	(0.220)
Governance$_{it}$	-0.006	-0.105**	-0.144	-0.224***	-0.083	0.016
	(0.073)	(0.052)	(0.105)	(0.084)	(0.068)	(0.082)
Constant	-38.969***	-39.068***	-38.452***	-39.587***	-38.910***	-38.976***
	(3.541)	(3.544)	(3.508)	(3.569)	(3.506)	(3.514)
Number of groups	112	112	112	112	112	112
Number of observations	890	890	890	890	890	890

Notes: Asterisks ***, **,* denote statistically significant at 1%, 5% and 10% level, respectively.

The empirical results regarding the correlation between military spending and the decline of biodiversity are displayed in Table 7. These findings were obtained through the application of the Generalised Method of Moments (GMM) estimation technique. Several experiments have been conducted that have demonstrated that the lag-dependent variable demonstrates statistical significance independently in both the one-step and two-step System-GMM (S-GMM) methodologies. The results suggest that the ongoing decrease in biodiversity is substantially influenced by the preceding year's biodiversity loss. The estimated coefficients obtained through the one-step S-GMM approach exhibit a slight increase in comparison to the estimated coefficients derived from the two-step S-GMM approach. The analysis demonstrates that there exists a positive correlation between a 1% increase in biodiversity loss in the preceding year and a 1.02% increase in the current level of biodiversity loss.

Table 7: Results of military expenditure on biodiversity loss using dynamic approaches.

Independent variables	One-Step Difference GMM	Two-Step Difference GMM	One-Step System GMM	Two-Step System GMM
Biodiversity loss$_{it-1}$	0.227	-0.015	1.021***	0.930***
	(0.458)	(0.418)	(0.111)	(0.292)
Military expenditure$_{it}$	0.758*	0.945**	0.130	0.366
	(0.442)	(0.419)	(0.187)	(0.540)
Income$_{it}$	0.552	0.766	0.063	0.095
	(0.656)	(0.617)	(0.134)	(0.243)
Population$_{it}$	3.122**	3.753***	0.154	0.370
	(1.447)	(1.341)	(0.220)	(0.608)
Governance$_{it}$	-2.008	-2.823	0.053	0.229
	(1.996)	(2.000)	(0.257)	(0.357)
Constant			-3.170	-6.661
			(3.732)	(10.453)
Number of instruments	11	11	17	17
Number of groups	111	111	112	112
Number of observations	666	666	778	778
AR (1)	0.009	0.057	0.001	0.002
AR (2)	0.526	0.726	0.037	0.028
Sargan test	0.102	-	0.000	-
Hansen test	-	0.105	-	0.000

Notes: Figures in the parentheses are standard errors. All the AR(1), AR(2), Sargan test, and Hansen test are reported in p-values. Asterisks ***,**,* denote statistically significant at 1%, 5% and 10% level, respectively.

However, the two-step System Generalised Method of Moments (GMM) is widely regarded as a more advantageous approach owing to its capacity to effectively identify and address issues related to autocorrelation and heteroskedasticity. Consequently, this methodology produces coefficient estimates that exhibit consistency and autocorrelation tests that demonstrate enhanced accuracy. Nevertheless, the examination presented in Table 7 demonstrates that military expenditure holds little statistical significance, implying that it does not exert a substantial impact on the decline of biodiversity. In the context of the two-step S-GMM model, it is evident that none of the remaining explanatory variables demonstrate statistical significance. Furthermore, it is worth noting that the two-step S-GMM fails to satisfy the consistency test, which encompasses the Hansen test and the AR (2) test.

Conclusion and Policy Implications

This study aims to deepen our understanding of the anthropogenic factors that contribute to environmental degradation by investigating the impact of military expenditure on the decline of biodiversity. Prior studies have faced challenges in effectively evaluating the ecological impacts of escalating military activities, specifically in terms of accurately measuring the magnitude of biodiversity decline. To achieve the intended result, a comprehensive analysis is performed on a panel study encompassing 112 countries over the period from 2013 to 2020. This analysis utilises both static panel and dynamic panel methodologies. Based on the available empirical evidence, it can be inferred that the static model exhibits greater favorability in comparison to the dynamic model. However, the application of the fixed effects (FE) model with robust standard errors has demonstrated its effectiveness in static methodologies for accurately describing the biodiversity loss model. This is mainly due to the presence of common sources of disturbance (CSD) and concerns regarding heteroskedasticity.

The increase in financial resources allocated to military expenditures has been demonstrated to have negative impacts on the natural environment. The increase in endangered species populations can be attributed to the impact of military operations, which has resulted in the degradation of their natural habitats and a subsequent reduction in genetic diversity. The aforementioned conclusion is substantiated by the presence of a positive and statistically significant coefficient that has been computed. Furthermore, the findings of this study suggest that the rapid rate of economic growth and population growth are additional factors that contribute to the impending risk of extinction experienced by numerous animal and plant species. This discovery offers further substantiation for the tendency of these countries to prioritise economic advancement and societal welfare over environmental conservation.

It is crucial to recognise that the concept of human security transcends the limitations imposed by a prevailing military power. The incorporation of environmental security into the context of human security necessitates careful examination. The current condition of environmental degradation possesses the capacity to yield disastrous consequences for future generations. The escalating phenomenon of species extinction will exert a substantial influence not only on the existing species' ecological food web but also on the subsequent diminishment of plant and animal populations. The significance of reducing the population of susceptible species is a crucial element in the preservation of an ecologically sustainable ecosystem. The findings of this study offer additional support for the importance of governance within the specific context under investigation. The inclusion of a negative sign in the estimated coefficient pertaining to the governance indicator signifies a clear association between elevated institutional excellence and enhanced environmental quality.

Therefore, it is imperative for governments to take into account the concept of militarism when formulating strategies aimed at safeguarding the environment. The narrative holds considerable importance due to the potential peril that arises from advancements in military operations, infrastructure, and weaponry, which jeopardise the existence of various life forms. The integration of environmental factors into military policies and overarching frameworks necessitates cooperative endeavours between local governments and international organisations. To address the issue of reliance on limited resources, it is crucial to embrace an environmentally conscious approach when designing and manufacturing defensive equipment. Furthermore, the adoption of strategies aimed at limiting armed conflicts and interstate hostilities, coupled with the efficient administration of military campaigns and their extent, could potentially play a role in reducing the negative consequences for biodiversity arising from militaristic activities.

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