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**ARTICLE**

# Assessing the Impact of Development Projects on Wildlife Abundance in Campo-Ma'an National Park, Southern Cameroon, from 2008 to 2020

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## ABSTRACT

The concentration of development projects near protected areas can undermine their conservation objectives. This study examines the impact of such projects on wildlife abundance in Campo-Ma'an National Park (CMNP). Information from the CMNP Conservation Department was analysed to investigate the link between development projects around the park and changes in wildlife populations, and analysis was conducted using statistical tools, including Excel 2020 and SPSS. Pearson's correlation coefficient was employed to assess the relationship between wildlife abundance indicators and the number of development projects surrounding the park. The findings reveal a significant decline in the abundance of key species, including elephants, great apes (such as gorillas and chimpanzees), and mandrills, over the past decade. Although a brief period of improvement was observed in the early 2010s, these gains were quickly reversed. Overall, the pattern shows that as development activities increased, wildlife numbers tended to decrease. These results underscore the urgent need for stricter regulation of development near the park and for comprehensive environmental and social impact

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assessments to be conducted before projects commencement. This process must receive greater attention from authorities and stakeholders to regulate activities around national parks and foster conservation efforts. Strengthening this oversight will help to maintain the park's ecological integrity and promote sustainable conservation.

***Keywords:*** Protected Area; Impact Assessment; Wildlife Abundance Indicators; Accumulation of Development Projects; Pearson Correlation

# 1. Introduction

Human activities have been identified as a primary driver of environmental change, particularly in protected areas [1]. According to the United Nations Food and Agriculture Organization (FAO) report "Global Forest Resources Assessment 2020", an estimated 47 million hectares of forest cover are expected to disappear between 2010 and 2020 [2]. The primary factors contributing to this depletion of forest resources comprise a wide range of human interventions in proximity to ecosystems or protected areas. These interventions include industrial and subsistence agriculture, logging and mining, large-scale development projects (such as dams, industrial port complexes, and bridges), road projects, forest resource development projects, and industrial sawmills [2–5].

The role of development projects and the mechanisms set up to implement them are not always clearly defined. The implementation of these projects is subject to the completion of an environmental and social impact assessment, which is a powerful mechanism available to states to ensure that the positive and negative impacts of projects and all development initiatives are taken into account [6]. Nevertheless, despite the existence of these mechanisms, environmental degradation persists as a salient issue, with consequences so pervasive that numerous species are at risk of extinction, including forest elephants, great apes (gorillas, chimpanzees), pangolins, water chevrotains, and wild dogs, among others [7,8].

In conservation science, good monitoring entails the systematic collection and analysis of repeated observations or measurements. This process enables the assessment of changes and progress toward a predetermined conservation objective [9]. This monitoring is predicated on a comprehensive array of data collected through the utilization of indicators about the conservation status. The objective of this monitoring is to provide a comprehensive report on the environmental changes that have transpired, while also elucidating the interactions between these changes and the actions that have contributed to them [10–12]. In the domain of protected area management, indicators function as instruments that facilitate the representation of a phenomenon, factor, or quantity through measurable variables. This process enables the provision of an accurate overview of the subject under consideration [10]. Moreover, they enable the communication of trends about phenomena, processes, or valued environmental components that organizations influence through their actions, albeit occasionally only in a limited capacity [12]. The utilization of these indicators facilitates the evaluation of whether trends are congruent with the valued aspects of protected areas in response to environmental pressures.

Numerous authors have developed indicators, including Dennis et al. [13], who used abundance indicators to demonstrate changes in the density of certain species in Scotland. These authors report in their research that negative environmental changes in Scotland, which may have particularly affected butterflies, largely result from developed human activities. They concluded that the overall abundance of species in protected areas is decreasing and recommended further work on the factors responsible for these changes. In their seminal study, Young et al. [14] employed wildlife abundance indicators to elucidate the extinction threat confronting selected significant species in protected areas globally. They further recommended that attention be directed towards the correlation between activities adjacent to protected areas and declines in abundance indicators. As demonstrated in the research conducted by Jones et al. [15], the implementation of indicators of human activities in designated protected areas facilitates the assessment of pressures on these areas. However, it is essential to acknowledge that identifying the underlying causes is crucial for comprehending the phenomenon. Newbold et al. [16]. demonstrate a correlation between the magnitude of pressure within protected areas and the activities that transpire in their environs. In most cases, this correlation is manifested by a transformation that precipitates a swift decline in species. Nevertheless, a paucity of studies has examined the associations between changes in protected area status indicators and the occurrence of development projects in the proximity of these areas. In this regard, the Campo-Ma'an National Park (CMNP) is situated within the Technical Operational Unit (TOU), which encompasses development projects, particularly those about agro-industry (The Cameroon Palm Oil Company (SOCAPALM), the Cameroon Rubber Company (HEVECAM) and the Cameroon Green Company (CAMVERT), as well as the forestry companies WIJMA and the Cameroon Wood Industry and Exploitation Company (SCIEB)) operators, industrial facilities (Autonomous port, Memve'ele dam) and the BOICAM project for the development of forest resources, has to be taken into account. This raises the issue of interaction between development projects and protected areas [17–19].

In this article, we propose an analysis of the dependence between park conservation indicators, i.e., those related to the abundance of wildlife species (index of abundance density and Kilometric Abundance Index (KAI)), as a function of the cumulative evolution of projects. The approach adopted is based on the assumption that critical components in protected areas are in rapid decline, and that the accumulation of development projects is a contributing factor to this decline. The CMNP, which is of particular interest for biodiversity in Cameroon due to its creation, status, and location within the Campo-Ma'an technical operational unit, was selected for this study. The overarching objective of this study was to assess the impact of development projects on wildlife abundance in CMNP. Specifically, the objectives were to (i) select the components of wildlife diversity to be included in the study, (ii) analyze changes in wildlife indicators within the CMNP, and (iii) assess the dependencies between wildlife indicators and the accumulation of projects deployed over the period 2008–2020.

# 2. Materials and Methods

## 2.1. Study Area

The CMNP, with an area of 264,064 hectares, represents 34.3% of the Campo Ma'an technical operational unit, which covers an area of 771,668 hectares, or approximately 16.3% of the southern Cameroon region. The protected area encompasses four subdivisions: Campo, Akom II, and Niete in the ocean division, and Ma'an in the Ntem Valley division. In recent years, the area of the technical operational unit has experienced significant pressure due to the implementation of various structural projects, including the Autonomous port, the Memve'ele dam, the agro-industrial development of HEVECAM, and the construction of an industrial complex for the production and processing of palm oil by the CAMVERT company in the Campo district [19]. In the case of CMNP, this pressure is felt in its two main parts, the northern part and the island of Dipikar in the south (**Figure 1**).

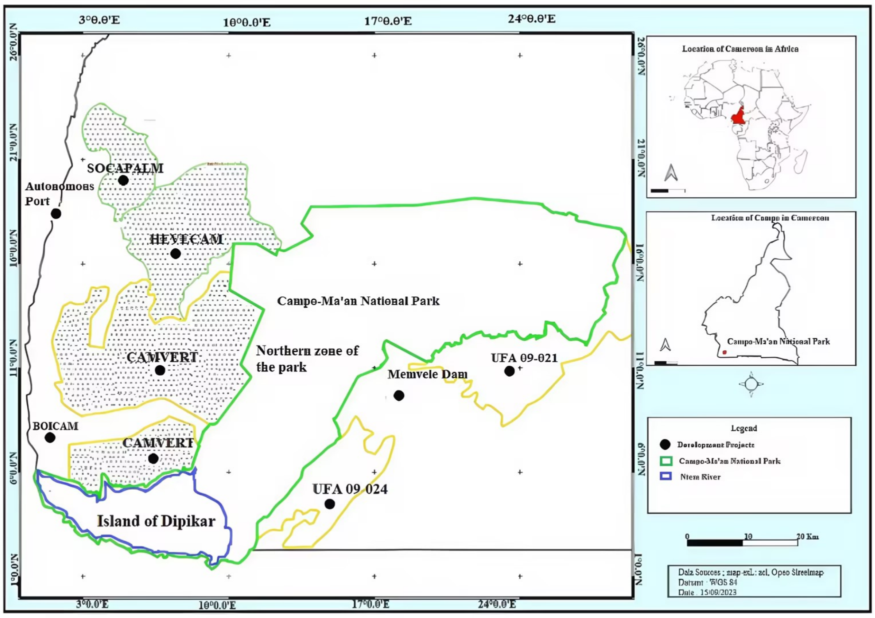


**Figure 1.** The situation of the CMNP and some development projects in the year 2020.

## 2.2. Methodology

### 2.2.1. Data Collection

The initial phase of the study involved gathering data on the various species of large mammals such as the great apes (chimpanzee and gorilla), the agile mangabey, the Brazza monkey, the water chevrotain, the black colobus, African dwarf crocodile, African forest elephant, Allen's bush baby, African manatee, mandrill, long-tailed pangolin, giant pangolin, panther and sea turtle in CMNP. This data was obtained from the Campo Ma'an Park conservation department, in collaboration with organizations such as the World Wildlife Fund (WWF) and the African Wildlife Foundation (AWF), with offices located in the study area. The next phase included conducting a field survey from July 3rd to October 3rd, 2023, coinciding with our internship at the conservation department. The main goals of this survey were to evaluate:

- The overall condition of the park, including its components, issues, and management practices.

The status of indicators monitoring the density of selected wildlife species. This included assessing wildlife abundance by identifying all animals and their signs found directly on or above the transect line, as well as calculating the KAI using Equation (1)[20]:

$$\mathrm{KAI} = \frac{\text{Number of presence sightings or signs}}{\text{Transect length covered (km)}} \quad (1)$$

A content analysis of the documents and discussions with several resource persons from the park's Conservation Department and its partners yielded data on the effort of 102 transects covering 255 km, 106 transects covering 265 km, 138 transects covering 234 km, and 139 transects covering 209 km for the years 2008, 2011, 2014, and 2020, respectively.

Additionally, we examined the development and industrialization plans for the site since the establishment of the park, which has significant implications for the park's conservation and management efforts. This analysis aimed to highlight the interactions between ongoing development activities and the conservation status of the park's biodiversity.

### 2.2.2. Data Processing and Analysis

In the present study, data processing and analysis were based on the following elements:

1. The utilization of statistical tools such as Excel 2020 and SPSS was imperative.
2. The use of two statistical analysis methods was essential: descriptive analysis and explanatory analysis.

The preferred reporting items for systematic reviews and meta-analyses (PRISMA) analysis was used to select the species to be included in the study, following the guidelines established by Gedda[21]. The phases considered ranged from data collection to the selection of species to be included in the study. The following inclusion criteria were applied:

- be a species present in the CMNP;
- be a species classified A by MINFOF[22], which establishes the modalities for the classification of animal species in protection classes.

The species selected after this phase were sorted out according to the availability of data contained in the various wildlife inventory reports analyzed at CMNP. Those for which data were available and in sufficient quantity were included in the statistical summary. The data obtained made it possible to plot changes in the various parameters over the period 2008–2020[23–29].

The databases necessary for the analysis were compiled from the inventory results for the aforementioned years and the reports of the various management plans of the Campo-Ma'an Technical Operational Unit, as well as from the reports of technical studies to corroborate the various results in the number of projects per inventory year. A cumulative addition between two inventory periods is the origin of the data on the number of projects implemented in this period.

Pearson's correlation is the statistical method employed to describe the dependencies between the values of the indicators and the number of projects grouped. This method enables the execution of a bivariate analysis, which describes the degree of associativity between two random variables[30,31]. The data were analyzed both by component and by theme for all periods of inventory to facilitate the analysis. The addiction study data were analyzed using SPSS software. However, the correlation analysis presented in this study is based on a dataset limited to four time points (n = 4).

A small sample size is a significant statistical limitation because it reduces the power of the tests, making it difficult to detect meaningful relationships between variables. Furthermore, extreme values or random fluctuations may strongly influence the correlation coefficients obtained, which could compromise their reliability. Consequently, robust conclusions cannot be drawn from the results obtained, but they can serve as an exploratory basis for guiding future research. The following Equation (2) was used to calculate the correlation coefficients[31]:

$$\left\{ r = \frac{\text{cov}(x,y)}{\sigma(x).\sigma(y)} = \frac{\text{cov}(x,y)}{\sqrt{v(x)}.\sqrt{v(y)}} \right. \tag{2}$$

with, r = Pearson Correlation coefficient.

Variance:

$$s_x^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2 = \frac{1}{n}\sum_{i=1}^{n}x_i^2 - (\overline{x})^2, \quad s_y^2 = \frac{1}{n}\sum_{i=1}^{n}y_i^2 - (\overline{y})^2 \tag{3}$$

Covariance:

$$\text{cov}(x,y) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y}) = \frac{1}{n}\sum_{i=1}^{n}x_i y_i - \overline{x}\,\overline{y} \tag{4}$$

The following criteria were employed to characterize and interpret the strength and direction of the dependencies:

- If r = 0, there is no correlation between the average values of the indicators and the cumulative value of the number of projects;
- If 0 < r < 0.25, there is a weak correlation between the average values of the indicator and the cumulative value of the number of projects;
- If 0.25 ≤ r < 0.75, there is a medium correlation between the average values of the indicator and the cumulative value of the number of projects;
- If 0.75 ≤ r < 1, then there will be a strong correlation between the average values of the indicator and the cumulative value of the number of projects;
- If r = 1, there is a perfect correlation between the average values of the indicators and the cumulative value of the number of projects.

An in-depth analysis was carried out on the main areas of the reserve to highlight the main trends and their possible links with the accumulation of projects. The following formula was used to analyze the trends between 2 inventory periods:

$$\Delta_n = \left(\frac{N_{n+1} - N_n}{N_{n+1} + N_n}\right) * 100 \tag{5}$$

Where:

- n represents an inventory period;
- $N_n$ is the average value of the indicator in year n;
- $\Delta_n$ represents the rate of variability between periods n.

The following evaluation was used:

- If $\Delta_n = 0$, no variation was observed;
- If $\Delta_n < 0$, there was a decrease in the abundance indicator of the component within the protected area;
- $\Delta_n > 0$, there was an increase in the abundance indicator for the component within the protected area.

Once the dependencies had been analyzed. These took into account changes in the indicators over the inventory periods.

The methodological approach is summarized in **Figure 2**.

## 3. Results

At the end of the data analysis, it is reported that approximately 2,500 identified species are present in the CMNP, and are distributed as follows:

- 1,500 plant species;
- 80 mammal species, 23 of which are endangered;
- 302 bird species, of which 24 are rare or endangered;
- 122 species of reptiles;
- 80 species of amphibians;
- Nesting sites for four (04) sea turtle species.

Thus, the analysis of the documentation highlights the process of selecting species to be included in the quantitative synthesis (**Figure 3**).

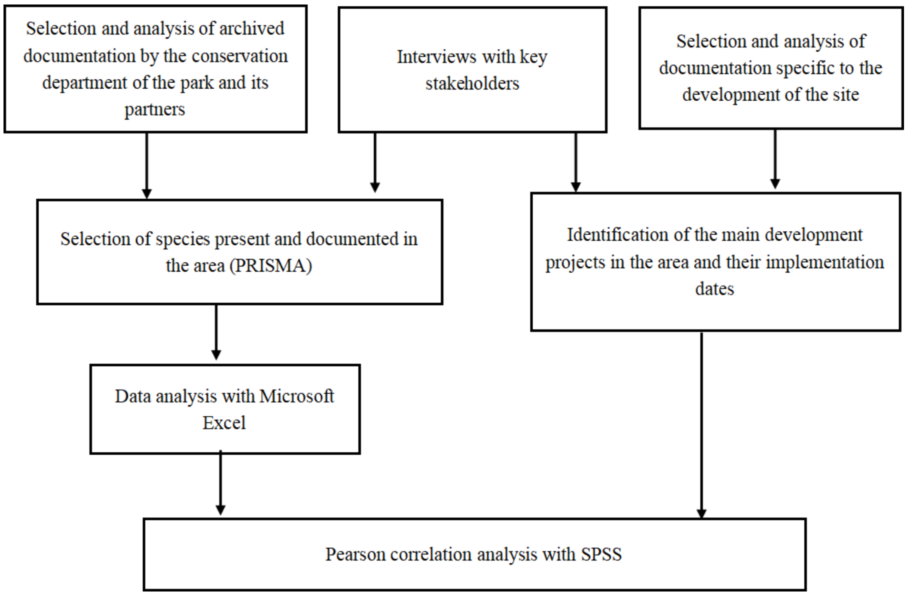


**Figure 2.** Summary of methodological approach.

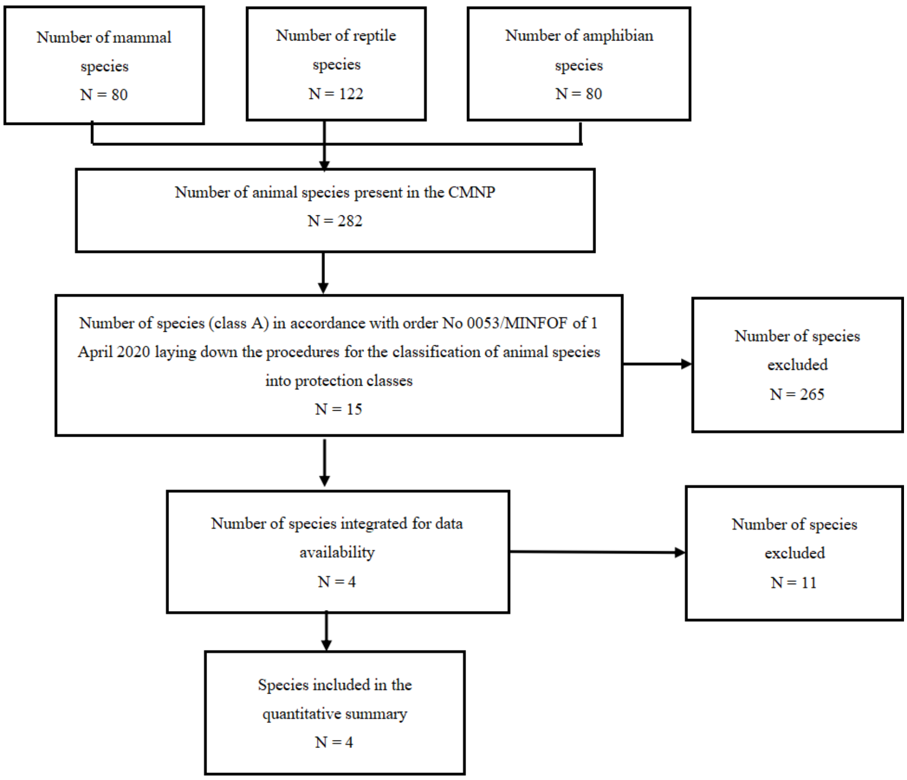


**Figure 3.** Diagram of the species selection process.

According to **Figure 3**, CMNP has been identified as the habitat of nearly 282 species of animals, excluding birds. Of these species, 15 were selected for classification as class A animals according to the methods established by the Ministry of Forestry and Fisheries (MINFOF) for the classification of animal species into protection classes. Following a thorough evaluation of the available documentation, four species were selected based on the documentation presented in **Table 1**, based on their documented presence.

**Table 1.** Presence of species in the park during the different inventory periods.

| No. | Selected Species | 2008 Inventory | 2011 Inventory | 2014 Inventory | 2020 Inventory |
|---|---|---|---|---|---|
| 1 | Agile mangabey | No | Yes | No | No |
| 2 | De brazza's monkey | Yes | No | No | No |
| 3 | Water chevrotain | Yes | Yes | No | Yes |
| 4 | Chimpanzee | Yes | Yes | Yes | Yes |
| 5 | Black colobus | | Yes | No | No |
| 6 | African dwarf crocodile | No | No | No | No |
| 7 | African forest elephant | Yes | Yes | Yes | Yes |
| 8 | Allen's bush baby | Yes | No | No | No |
| 9 | Gorilla | Yes | Yes | Yes | Yes |
| 10 | African manatee | No | No | No | No |
| 11 | Mandrill | Yes | Yes | Yes | Yes |
| 12 | Long-tailed Pangolin | Yes | No | No | No |
| 13 | Giant pangolin | Yes | Yes | No | No |
| 14 | Panther | Yes | Yes | No | No |
| 15 | Sea Turtle | No | No | No | No |

**Note:** No: species not present during the inventory period; and Yes: species present during the inventory period. According to **Table 1**, the critical species documented within CMNP are: African forest elephant, Gorilla, Chimpanzee, and Mandrill.

## 3.1. Analysis of Changes in Status Indicators Within CMNP

### 3.1.1. The Trend of Elephants in CMNP

**Table 2** summarizes the main data points from the elephant survey.

According to the documentation analyzed, the trend of elephants is shown in **Figure 4**, which shows their trends in terms of numbers of individuals within the park since 2008, the date of the first documented inventory of large and medium-sized mammals.

**Figure 4** shows the evolution of elephant species in CMNP from 2008 to 2020. The analysis shows that elephant species have fluctuated over the 12 years (2008 to 2020); the trends are negative since the linear regression analysis shows a decline in elephant species. It should be noted that the $R^2$ value = 0.3806 reflects a significant variation depending on the year.

**Table 2.** Summary of data on elephant abundance in the park.

| Year | Dipikar Island | Variation Rate $\Delta n_1$ (Dipikar Island) | Northern Zone | Variation Rate $\Delta n_2$ (Northern Zone) | CMNP | Variation Rate $\Delta n$ (CMNP) |
|---|---|---|---|---|---|---|
| 2008 | Nothing to report | Nothing to report | Nothing to report | | 335 | 28.03% |
| 2011 | Nothing to report | Nothing to report | Nothing to report | | 596 | −30.99% |
| 2015 | 227 | −65.69% | 87 | −22.54% | 314 | −46.73% |
| 2020 | 47 | | 55 | | 114 | |

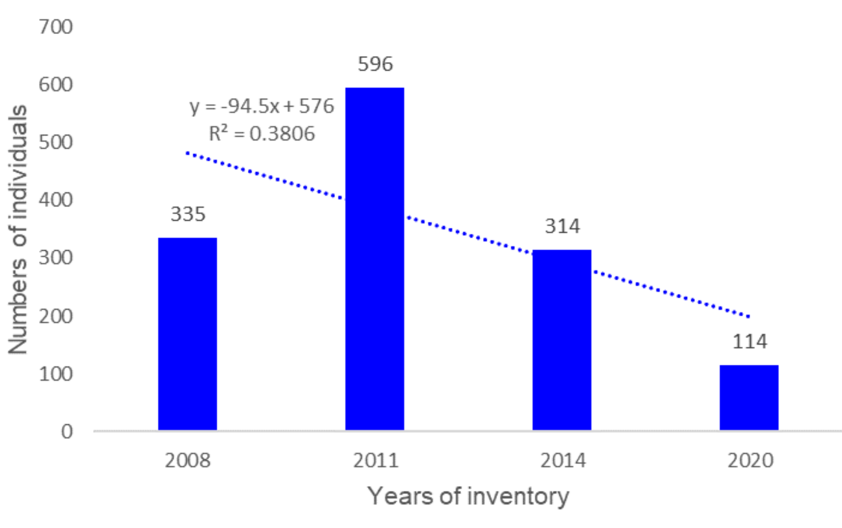


**Figure 4.** Changes in elephant numbers in CMNP from 2008 to 2020.

**Figure 5** shows the trend of individuals in the two main areas of the CMNP. **Figure 5** shows that when the first 02 inventories were carried out, i.e., in 2008 and 2011, the CMNP was considered to be a single unit, whereas the inventories carried out since 2014 have taken this specificity into account. The data also show that in 2014, of the 314 individuals inventoried, 227 were found on Dipikar Island and only 87 in the northern zone of the park, whereas in 2020, 102 individuals were identified, 55 in the northern zone of the park and 47 on Dipikar Island.

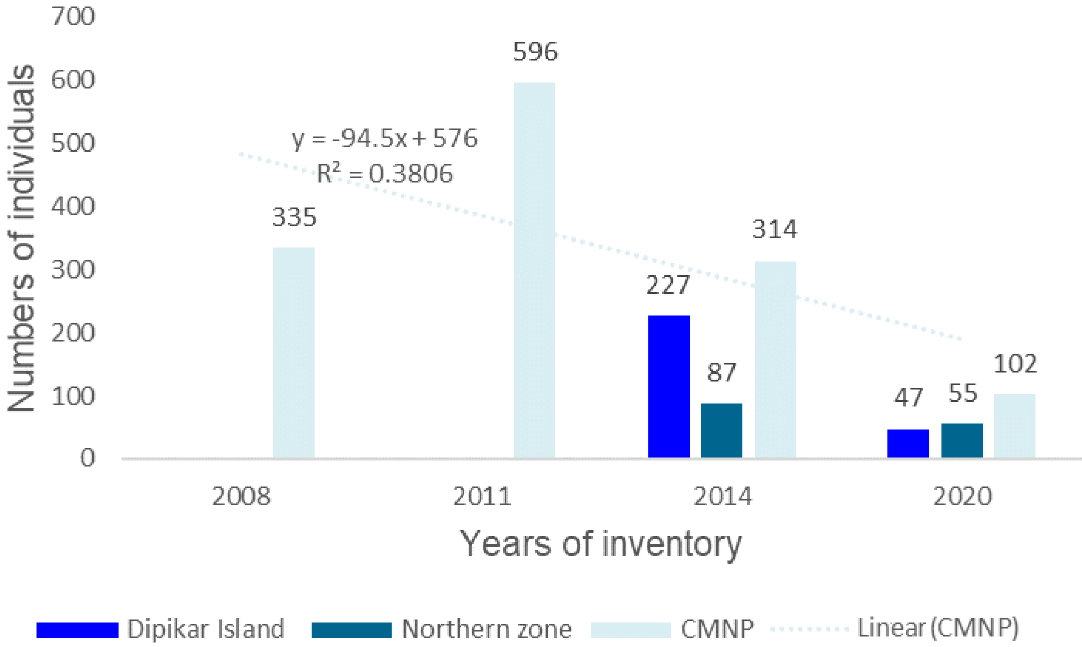


**Figure 5.** Elephant distribution trend from 2008 to 2020 within the 2 CMNP zones.

### 3.1.2. The Trend of the Great Apes (Gorillas and Chimpanzees) in CMNP

**Table 3** shows a summary of the main data points from the great ape's survey.

According to the documents analyzed, the trend of the great apes (gorillas and chimpanzees) is shown in **Figure 6**, which shows the trend of the number of individuals in the park since 2008, the date of the first inventory of large and medium-sized mammals.

**Figure 7** shows the evolution of the great apes (gorillas and chimpanzees) species in CMNP from 2008 to 2020. The analysis shows that elephant species have fluctuated over the 12 years (2008 to 2020); the trends are negative since the linear regression analysis shows a decline in elephant species. It should be noted that the $R^2$ value = 0.3054 reflects a significant variation depending on the year.

This analysis also shows that in 2014, out of the 1,472 individuals inventoried, 694 were found on Dipikar Island and 778 in the northern zone of the park, whereas in 2020, 547 individuals were identified, with 410 in the northern zone of the park and 137 on Dipikar Island.

**Table 3.** Summary of data on great apes' (gorillas and chimpanzees) abundance in the park.

| Year | Dipikar Island | Variation Rate $\Delta n_1$ (Dipikar Island) | Northern Zone | Variation Rate $\Delta n_2$ (Northern Zone) | CMNP | Variation Rate $\Delta n$ (CMNP) |
|---|---|---|---|---|---|---|
| 2008 | Nothing to report | Nothing to report | Nothing to report | Nothing to report | 1,304 | 28.15% |
| 2011 | Nothing to report | Nothing to report | Nothing to report | Nothing to report | 2,326 | −22.49% |
| 2015 | 694 | −67.03% | 778 | −30.98% | 1,472 | −34.43% |
| 2020 | 137 | | 410 | | 547 | |

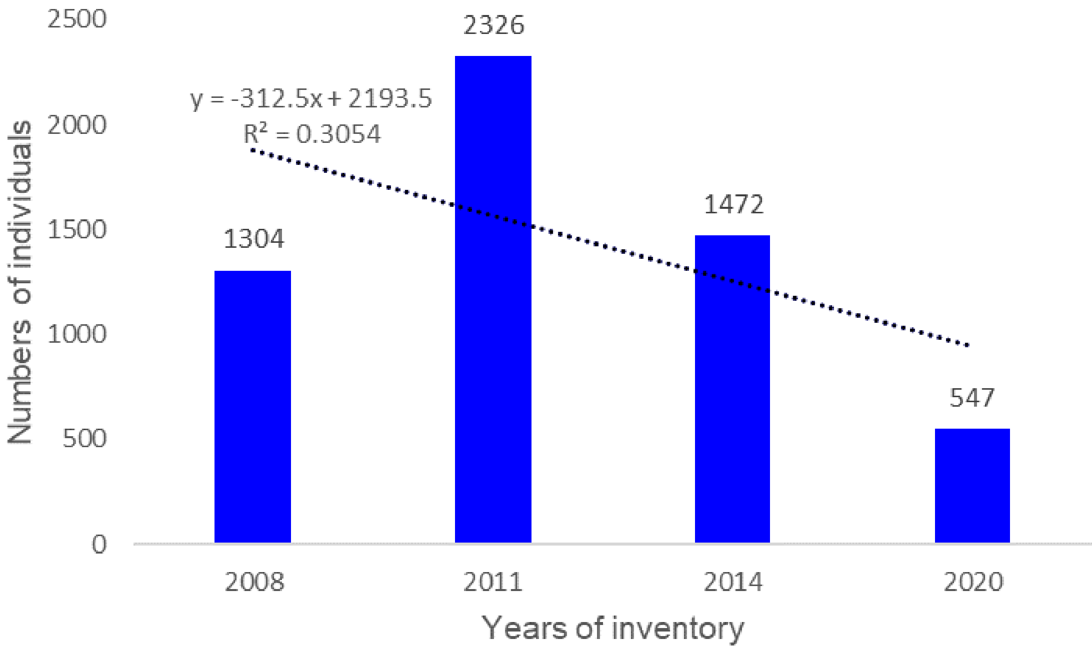


**Figure 6.** Trend of great apes (gorillas and chimpanzees) in CMNP from 2008 to 2020.

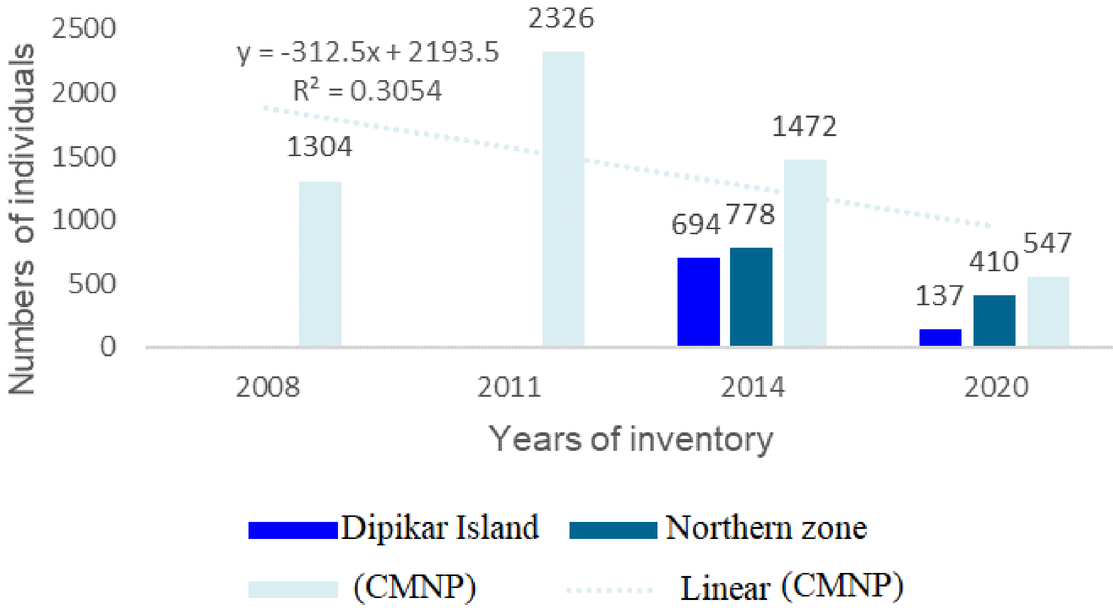


**Figure 7.** Trend in the distribution of great apes (gorillas and chimpanzees) from 2008 to 2020 in the 2 CMNP zones.

### 3.1.3. Trend of Mandrills in the CMNP

**Table 4** shows a summary of the main data points from the Mandrill's survey.

According to the documentation analyzed, the trend of Mandrills is shown in **Figure 8**, which shows their trend in terms of the KAI within the park since 2008, the date of the first survey of large and medium-sized mammals.

**Figure 8** shows the evolution of the Mandrill species in CMNP from 2008 to 2020. The analysis shows that the Mandrill species have fluctuated over the 12 years (2008 to 2020); the trends are negative since the linear regression analysis shows a decline in the Mandrill species. It should be noted that the $R^2$ value = 0.0908 reflects a significant variation depending on the year.

**Figure 9** shows the trend of abundance in the two main areas of the CMNP. The data show that the density of 0.223, 0.139 is concentrated on the island of Dipikar and 0.084 on the northern zone. For 2020, a density of 0.033 has been identified, distributed as follows: 0.027 on the island of Dipikar and 0.006 in the northern zone.

**Table 4.** Summary of data on Mandrill's abundance in the park.

| Year | Dipikar Island | Variation Rate $\Delta n_1$ Dipikar Island | Northern Zone | Variation Rate $\Delta n_2$ (Northern Zone) | CMNP | Variation Rate $\Delta n$ (CMNP) |
|---|---|---|---|---|---|---|
| 2008 | Nothing to report | Nothing to report | Nothing to report | Nothing to report | 0.1 | 63.64% |
| 2011 | Nothing to report | Nothing to report | Nothing to report | Nothing to report | 0.45 | −63.34% |
| 2015 | 0.139 | −67.47% | 0.084 | −86.67% | 0.101 | −78.76% |
| 2020 | 0.027 | | 0.006 | | 0.012 | |

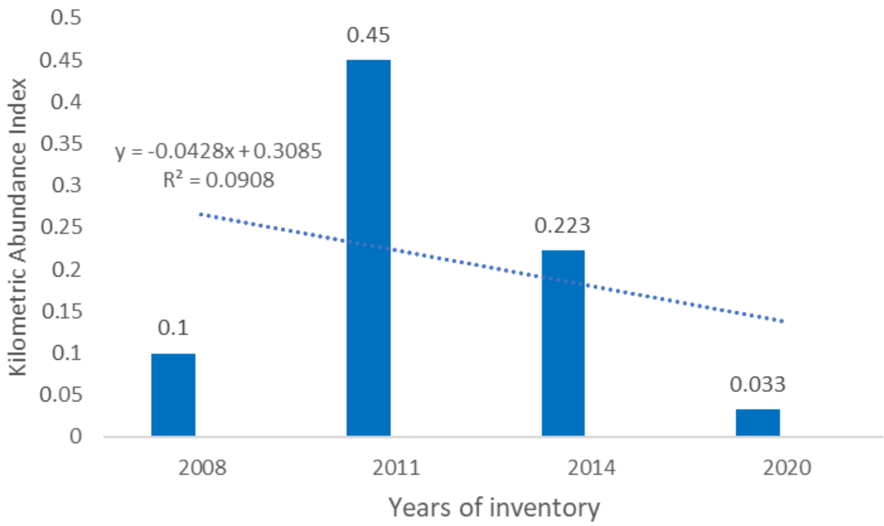


**Figure 8.** Changes in Mandrill KAI between 2008 and 2020.

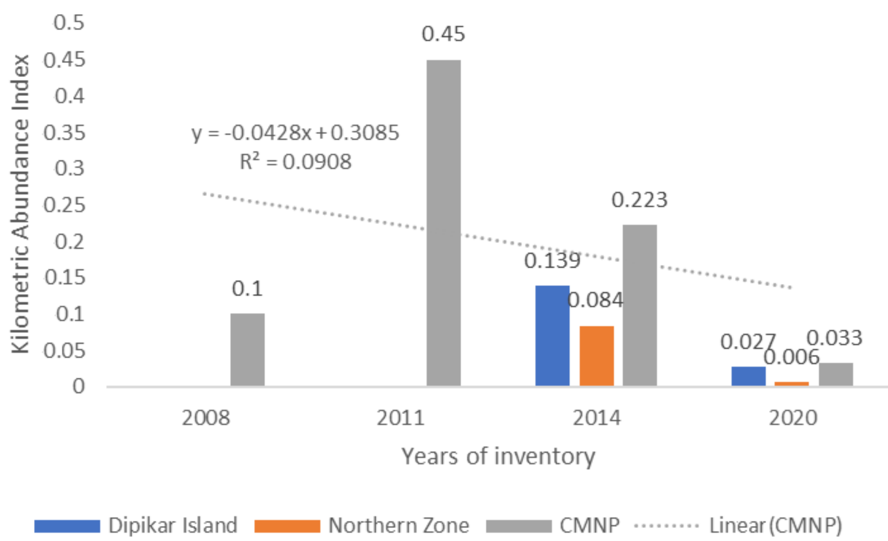


**Figure 9.** Mandrill distribution trend from 2008 to 2020 within the 2 CMNP zones.

## 3.2. Analysis of Dependency Between Wildlife Indicators About the Accumulation of Projects

**Table 5** shows the locations of the various projects and how far they are from the park.

The results of the analysis of the dependence of wildlife abundance indicators within the park on the cumulative number of projects are presented in this section. **Tables 6** and **7** present the park's situation and its critical species, as well as the number of projects in the vicinity during the various inventory periods.

**Table 5.** Location of the various projects adjacent to the CMNP.

| Projects | Project Name | GPS Coordinate | Sector of Activity | Distance From the CMNP |
|---|---|---|---|---|
| SINOSTEEL | Mont des Mamelles iron ore mining project | 2°52'51"N 9°53'35"E | Mining activities | 0–10 Km |
| CAMVERT | Oil palm exploitation project | 2°19'54"N 9°54'22"E | Agricultural production | 0–10 Km |
| HEVECAM | Project to develop and exploit rubber plantations for the production of natural rubber | 2°43'08"N 10°03'56"E | Agricultural production | 0–10 Km and 10–50 Km |
| MEMVE'ELE | Project to build a hydroelectric dam on the River Ntem | 2°22'28"N 10°20'56"E | water supply and sanitation | 0–10 Km |
| CAMIRON Railway | Railway development project | | Transport | 0–10 Km and 10–50 Km |
| BOICAM | Project to produce wood-based biomass from the renewal of HEVECAM plantations | 2°47'14"N 09°49'53"E | water supply and sanitation | 10–50 km |
| PAK | Project to build an autonomous port | 2°56'25"N 9°54'25"E | Transport | 10–50 km |
| WIJMA | Forest Management Unit (FMU) UFA-09- 021 | 2°17'58"N 10°56'45"E | Forestry | 10–50 km |

**Table 6.** Evolution of the abundance indicators in relation to the number of projects from 2008 to 2020.

| Year Concerned | Project Title | Cumulative Number | Number of Elephants | Number of Great Apes |
|---|---|---|---|---|
| 2008 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024 and UFA-09-025 | 5 | 335 | 851 |
| 2011 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024, UFA-09-025, BIOCAM and Memve'ele Dam | 7 | 596 | 2,326 |
| 2014 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024, UFA-09-025, BIOCAM, Memve'ele Dam | 7 | 314 | 1,956 |
| 2020 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024, UFA-09-025, BIOCAM, Memve'ele Dam, Autonomous port and CAMVERT | 9 | 114 | 718 |

**Table 7.** Evolution of the KAI in relation to the number of projects from 2008 to 2020.

| Year Concerned | Project Title | Cumulative Number | KAI of Mandrills |
|---|---|---|---|
| 2008 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024 and UFA-09-025 | 5 | 0.100 |
| 2011 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024, UFA-09-025, BIOCAM and Memve'ele Dam | 7 | 0.450 |
| 2014 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024, UFA-09-025, BIOCAM, Memve'ele Dam | 7 | 0.223 |
| 2020 | HEVECAM, SOCAPALM, UFA-09-021, UFA-09-024, UFA-09-025, BIOCAM, Memve'ele Dam, Autonomous port and CAMVERT | 9 | 0.033 |

According to **Tables 6** and **7**, 9 projects have been implemented within the study area that interact with the park. Specifically, 05 projects were implemented between 2000 and 2008, 07 projects between 2008 and 2011, 07 projects between 2011 and 2014, and 09 projects between 2014 and 2020.

**Figure 10** shows the evolution of the spatial distribution of the various development projects around the CMNP between 2008 and 2020.

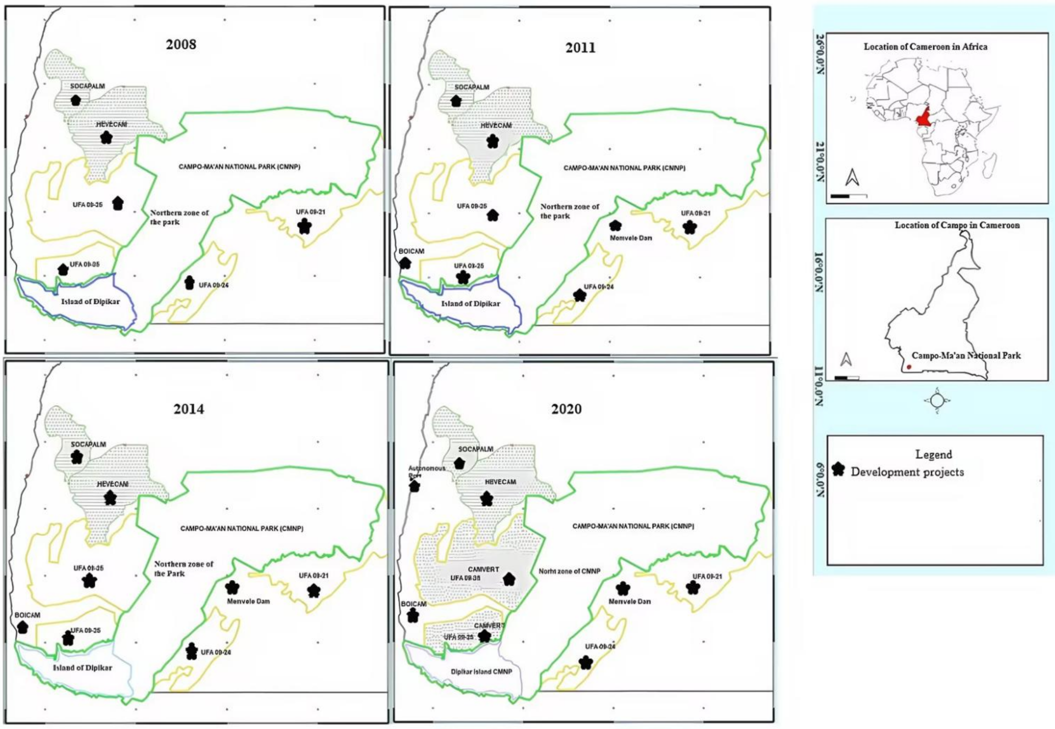


**Figure 10.** Evolution of the spatial distribution of the various development projects around the CMNP between 2008 and 2020.

**Figure 10** shows that in 2008, there were 5 projects near CMNP, including 1 on Dipikar Island and 4 in the northern zone; then in 2011, there were 7 projects near CMNP, including 2 on Dipikar Island and 5 in the northern zone. The same is true for 2014, and finally for 2020, 9 projects were in the vicinity of CMNP, including 2 on the island of Dipikar and 7 in the northern zone.

### 3.2.1. Analysis of the Dependence of Wildlife Abundance Indicators on Project Accumulation

**Table 8** shows the dependency matrix between the indicators of wildlife abundance and the indicators in the park, as well as the number of projects implemented.

**Table 8.** Correlation between the cumulative number of projects and wildlife abundance indicators in the CMNP.

| | | Nbr_Ind_Elp | Nbr_Ind_GSg | Ind_Abd_Mdll | Nbr_Prj |
|---|---|---|---|---|---|
| Nbr_Ind_Elp | Pearson Correlation | 1 | 0.989 | 0.951 | −0.456 |
| | Sig. (2-tailed) | | 0.011 | 0.049 | 0.544 |
| | N | 4 | 4 | 4 | 4 |
| Nbr_Ind_GSg | Pearson Correlation | 0.989 | 1 | 0.956 | −0.360 |
| | Sig. (2-tailed) | 0.011 | | 0.044 | 0.640 |
| | N | 4 | 4 | 4 | 4 |
| Ind_Abd_Mdll | Pearson Correlation | 0.951 | 0.956 | 1 | −0.149 |
| | Sig. (2-tailed) | 0.049 | 0.044 | | 0.815 |
| | N | 4 | 4 | 4 | 4 |
| Nbr_Prj | Pearson Correlation | −0.456 | −0.360 | −0.185 | 1 |
| | Sig. (2-tailed) | 0.544 | 0.640 | 0.815 | |
| | N | 4 | 4 | 4 | 4 |

**Note:** Nbr_Prj: Cumulative number of projects deployed; KAI_Mdll: KAI; Nbr_Ind_GSg: Number of great apes (gorillas and chimpanzees); Nbr_Ind_Elp: Number of Elephants; N: Sample size; Sig: Significance.

According to **Table 8**, the correlation coefficient between the average number of elephants per year and the number of cumulative projects is $r = -0.46$, which lies in the interval $0.25 \leq r < 0.75$, which means that there is an average relationship between the number of elephants and the number of projects implemented, demonstrating that the variation in the number of elephants in the park is related to the number of development projects implemented around the park and therefore negatively affects the elephant population within CMNP.

Thus, according to this table, the correlation coefficient between the average number of elephants per year and the number of cumulative projects is r = −0.36, which lies in the interval 0.25 ≤ r < 0.75, which means that there is an average correlation between the number of elephants and the number of projects. This indicates an average influence between the number of cumulative projects and the number of great apes (gorillas and chimpanzees) at CMNP, highlighting a weak negative impact on the great ape population (gorillas and chimpanzees).

According to this table, the correlation coefficient between mandrill KAI per year and the cumulative number of projects is r = −0.149, which is in the range, 0 ≤ r < 0.25 meaning that there is a weak relationship between mandrill KAI and the number of projects deployed, demonstrating that the variation in mandrill KAI at the CMNP is in function of the number of development projects deployed in the vicinity, and therefore may have a negative impact on the mandrill population.

**Figures 11–13** summarize the data obtained and the changes observed between the different survey periods.

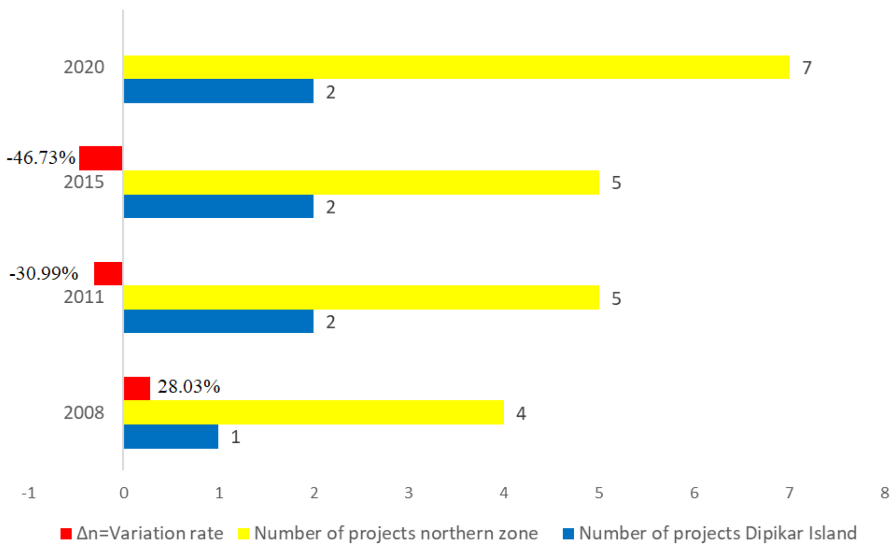


**Figure 11.** Distribution of projects by park zone and variability of elephant abundance.

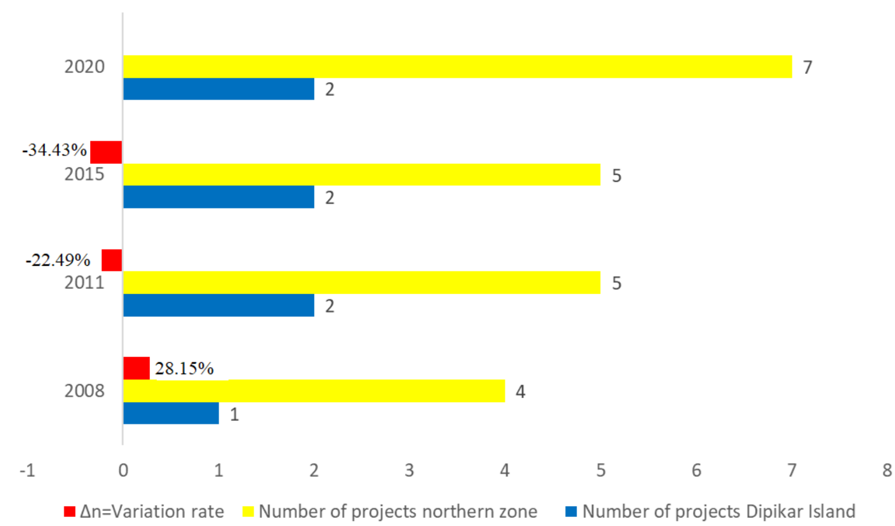


**Figure 12.** Distribution of projects by park zone and variability of great apes (gorillas and chimpanzees) abundance.

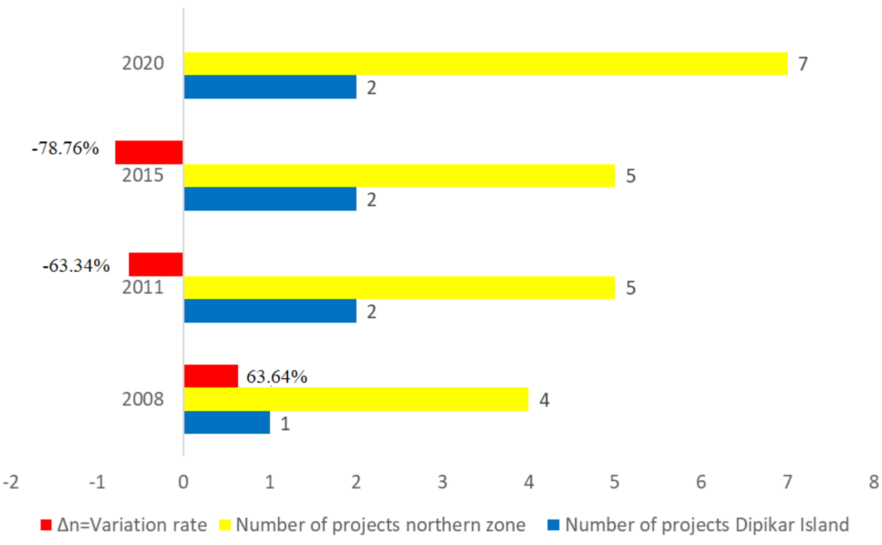


**Figure 13.** Distribution of projects by park zone and variability of Mandrill abundance.

**Figure 11** shows that seven (07) of the nine (09) development projects are located in the northern zone of the park and two (02) of the nine (09) on Dipikar Island. One of the projects spans both zones. In terms of trends in the number of individuals, the figure shows that the first observation is a 28.03 % increase in the number of individuals in the park between 2008 and 2011, with a cumulative number of projects deployed of five (05). This was followed by a significant decrease of −30.99 % in the number of individuals, although the number of projects remained unchanged at seven (07). Finally, the final trend for the year 2020 shows that the 9 projects identified in the vicinity of CMNP may have been responsible for the −46.73% decrease in elephant abundance within the park.

Regarding **Figure 12**, the trends in the number of individuals indicate a 28.15% increase between 2008 and 2011, with a cumulative number of projects deployed of five (05). This was followed by a significant decrease of −22.49% in the number of individuals, although the number of projects remained unchanged at seven (07). Finally, the final trend for the year 2020 shows that the 9 projects identified in the vicinity of CMNP may have been responsible for the −34.43% decrease in great apes (gorillas and chimpanzees) abundance within the park.

Regarding **Figure 13**, the trends in km density indicate that the first observation is an increase of 63.64% in km density within the park between 2008 and 2011, with a cumulative number of projects deployed of six (06). This was followed by a significant decrease of −63.34% in the number of individuals, although the number of projects remained unchanged at seven (07). Finally, the final trend for the year 2020 shows that the 9 projects identified in the vicinity of CMNP may have been responsible for the −78.76% decrease in mandrill abundance within the park.

## 4. Discussion

This study assessed the impact of development projects on wildlife indicators. This analysis revealed that, despite the average correlation that exists between these indicators and the cumulative number of projects per inventory year, the CMNP is under strong pressure, as evidenced by the decrease in the density of the presence of elephants, great apes (gorillas and chimpanzees), and mandrills. Specifically, wildlife abundance indicators have decreased from 335 and 1,304 in 2008 to 114 and 547 in 2020, respectively, for elephants and great apes (gorillas and chimpanzees). Furthermore, the KAI of mandrills has decreased from 0.1 in 2008 to 0.033 in 2020. Nevertheless, the period from 2008 to 2011 showed an increase in the abundance of African forest elephants, great apes (gorillas and chimpanzees), and mandrills, despite the cumulative increase in the number of projects from 5 to 7. This can be explained by the fact that the introduction of activities on the periphery of the park has encouraged the animals to move away from high-risk areas and take refuge inside the park, and by the fact that the implementation of development projects is accompanied by an environmental and social management plan which, given the sensitivity of the area, has been able to incorporate certain measures aimed at ensuring the protection of critical species. These results are consistent with the work of Bitondo[32] and Campbell[33]. However, the intensification of these activities, characterized by the exploitation phases, may justify the observed declines, in addition to the implementation of new development projects, especially in the period 2014-2020, where record declines were observed for African forest elephants, great apes (gorillas and chimpanzees) and mandrills, justifying the variations observed between 2011 and the other inventory periods.

The observed variability in abundance distribution rates may be attributed to the uneven implementation of development projects across different sectors—primarily agriculture and forestry—between the two areas of the park during the study period, with a particular concentration in the northern region and on Dipikar Island. Additionally, the proximity of these projects to the park's buffer zones was not considered in the analysis, despite these boundaries remain largely indistinct in the field. These components are therefore at high risk of extinction, which aligns with the findings of the study by Young et al.[14]. According to this study, large and medium-sized mammals are threatened with extinction in most terrestrial ecosystems, including within protected areas that are intended to eliminate or reduce impacts. This work corroborates the hypothesis that development projects undertaken in proximity to protected areas can be regarded as a contributing factor to the diminution of their ecological significance and the inability to attain management objectives[5,25].

Furthermore, Ashagrie et al.[34] demonstrated that development projects are not the only aspects to be considered, as the subsistence activities (subsistence farming and livestock rearing) of the populations living in the vicinity of protected areas have a significant impact on their needs and consumption habits. This aspect should not be overlooked. Given the intricacies involved in identifying the causes of biodiversity loss, it is recommended that consumers residing in proximity to protected areas adopt improved and diversified consumption patterns. Additionally, intensified anti-poaching initiatives and the provision of material, human, and financial resources to conservation stakeholders to effectively manage protected areas are suggested.

When evaluating the relationship between condition indicators and the number of projects implemented, the findings suggest that the cumulative occurrence of development projects contributes to variability in observed indicators within the park. This results in a medium association for wildlife abundance indicators and a strong association for indicators related to human activity. This underscores the notion that all development projects may influence CMNP in terms of the correlation values obtained. These findings are consistent with those reported by Newbold et al.[16], who found that approximately 70% of ecosystems are altered by human activities in their surrounding environments. However, in contrast to the study by Salomon et al.[4], which drew significant conclusions based on satellite images demonstrating the negative impact of human activities on the landscape of a park, the results of this study do not permit the assertion that the observed changes within CMNP are attributable to the cumulative presence of the projects. The absence of any element of influence in this study precludes the use of these elements as influencing factors. In addition to the number of employees per project, their distance from the CMNP, and the equipment or facilities used, which are closely linked to the sector of activity, other factors may be considered as potential dependencies, such as subsistence farming, livestock rearing, and artisanal mining. Nevertheless, it establishes a foundation for deliberation on the elements that must be considered to ensure comprehensive protection of the CMNP in the context of development initiatives, given its conservation significance[32].

In light of these concerns, there is a clear need to enhance ecological monitoring and implement early warning mechanisms for critical components. Moreover, the presence of development projects has been identified as a contributing factor to the escalation in indicators of human activity within protected areas[33,35]. Consequently, there is an imperative to enhance the oversight of these projects in the localities where protected areas are situated, to ensure their optimal functionality[36]. From an integrated management standpoint, it is advisable to develop multi-stakeholder initiatives aimed at addressing impacts by considering the spatial distribution of projects within the park and the observed variability rates. Such an approach would foster collaboration among all stakeholders engaged in the park's conservation and the sustainable management of its environment. The application within the CMNP has facilitated this understanding, despite the paucity of data.

## 5. Conclusion

The assessment of the impact of development projects on wildlife abundance in CMNP indicates that key species such as elephants, great apes (gorillas and chimpanzees), and mandrills are under threat. An assessment of the dependence of selected conservation indicators on development projects suggests that this threat stems from the increasing number of development projects around the park. This is supported by a decline in wildlife abundance indicators. The assessment reveals a moderate correlation between development projects within CMNP and indicators of wildlife abundance. This suggests that the CMNP may be affected by the cumulative impacts of these development projects. Although the correlation analysis in this study relies on data from only four time points, the findings are not sufficient to support definitive conclusions. Nonetheless, they provide a useful foundation for exploratory research. To ensure effective conservation, various actors and stakeholders must take responsibility for the protection of these protected areas. The Environmental and Social Assessment (ESA) process, as required by law, is a valuable tool that can facilitate the planning of development projects, taking into account the interactions between projects and their environment. The results of this study underscore the need to pay greater attention to integrating cumulative impacts into conservation efforts, as these impacts can compromise the integrity and management objectives of protected areas. Given the impact of development projects on the abundance of different species and the inadequacy of regular monitoring of different species in CMNP, there is an urgent need to define more appropriate and sustainable species monitoring strategies to address the likely threat of extinction or extirpation of species in this CMNP, particularly species (elephants, gorillas, and chimpanzees). The development of projects around CMNP, therefore, represents a serious threat to the various species present in CMNP and a real obstacle to maintaining the balance of the park's ecosystem. Therefore, it is important to carry out regular inventories of the various species using modern monitoring methods, which will undoubtedly provide accurate data for the implementation of an effective local conservation policy for the CMNP.

## Author Contributions

Conceptualization, G.M.Z.E., B.Y., and D.B.; methodology, G.M.Z.E., B.Y., C.I.M.A., and D.B.; software, G.M.Z.E., B.Y., and P.P.N.; validation, B.Y., S.M.M., C.I.M.A., and D.B.; formal analysis, G.M.Z.E., B.Y., S.M.M., and P.P.N.; investigation, G.M.Z.E. and C.I.M.A.; resources, C.I.M.A.; data curation, G.M.Z.E., B.Y., S.M.M., and P.P.N.; writing—original draft preparation, G.M.Z.E., B.Y., S.M.M., and P.P.N.; writing—review and editing, G.M.Z.E. and B.Y.; visualization, G.M.Z.E., B.Y., and D.B.; supervision, D.B.; project administration, D.B. All authors have read and agreed to the published version of the manuscript.

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Not applicable.

## Informed Consent Statement

Not applicable.

## Data Availability Statement

The datasets analyzed in this study are not publicly accessible due to data protection in Cameroon; therefore, the data are not public but are available from the corresponding author upon reasonable request.

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## Conflicts of Interest

The authors declare that there is no conflict of interest.

## Abbreviation

| | |
|---|---|
| AWF | African Wildlife Foundation |
| CMNP | Campo-Ma'an National Park |
| ESA | Environmental and Social Assessment |
| FAO | United Nations Food and Agriculture Organization |
| KIA | Kilometric Abundance Index |
| TOU | Technical Operational Unit |
| WWF | World Wildlife Fund |

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