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ASSESSING PHILIPPINE SEISMICITY: A DESCRIPTIVE INVESTIGATION OF EARTHQUAKE FREQUENCY, MAGNITUDE, AND DEPTH

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ABSTRACT

This study examined the monthly patterns and temporal trends of earthquake occurrences in the Philippines using earthquake records from the Philippine Institute of Volcanology and Seismology (PHIVOLCS) covering the period from January 2018 to July 2026. A quantitative descriptive research design was employed to analyze 132,226 recorded earthquakes and determine variations in earthquake frequency, magnitude, and depth across the twelve calendar months. Frequency distributions, descriptive statistics, graphical trend analysis, Welch's One-Way Analysis of Variance (ANOVA), and Pearson's correlation analysis were utilized to evaluate temporal patterns and statistical differences among monthly groups. Results revealed substantial variability in earthquake occurrences throughout the study period, indicating that seismic activity was not uniformly distributed across months. June recorded the highest number of earthquake occurrences (14,218), while February recorded the lowest (8,609). Although monthly frequencies fluctuated considerably, annual totals generally increased over time. Welch's ANOVA demonstrated statistically significant differences in both earthquake depth ($F = 23.25$, $p < .001$) and earthquake magnitude ($F = 18.64$, $p < .001$) across calendar months. However, the observed differences in mean magnitude were minimal, suggesting limited practical significance. Pearson's correlation analysis revealed a statistically significant but very weak positive relationship between earthquake depth and magnitude ($r = 0.06$, $r^2 = 0.0036$, $p < .001$), indicating that depth explained less than one percent of the variation in earthquake magnitude. The findings demonstrated that earthquake activity in the

Philippines exhibited significant temporal variability in terms of frequency, depth, and magnitude. While historical earthquake records provided valuable insights for seismic monitoring, disaster preparedness, and risk awareness, the observed patterns should not be interpreted as predictive indicators of future earthquake occurrence. Continuous monitoring and further investigation of spatial and tectonic factors are recommended to enhance understanding of Philippine seismic activity.

Keywords: *Earthquakes, Philippines, PHIVOLCS, Seismic Activity, Earthquake Magnitude, Earthquake Depth, Temporal Trends, Disaster Preparedness.*

INTRODUCTION

Earthquakes are among the most destructive natural phenomena, posing significant threats to human lives, infrastructure, and the environment (Mendez et al., 2025). An earthquake is a weak to violent shaking of the ground produced by the sudden movement of materials below the Earth's surface (Philippine Institute of Volcanology and Seismology [PHIVOLCS). Earthquakes (EQs) occur when crustal fractures are triggered by the buildup of energy beneath the lithosphere, resulting in severe damage to infrastructure and loss of life (Li et al., 2025; Mendez et al., 2026; Perez et al., 2023). This unusual energy occurs during periods of tectonic stress, leading to brittle failures in the lithosphere. (Khan et al., 2025). Earthquake data represent time series data with location, time, depth, and magnitude information.

By forecasting earthquakes, individuals can take timely actions to protect themselves and reduce damage and economic losses. Researchers tirelessly seek methods to predict earthquakes due to their destructive potential and far-reaching consequences (Baitus III et al., n.d.; Erdik, 2021; Jena et al., 2020; Pubellier et al., 1991). Accurate forecasts could mitigate the impact through preventive measures and public preparedness, with a focus on location, timing, and magnitude. Historical trends inform predictions, but the frequent and unpredictable nature of earthquakes presents ongoing challenges(Ibrahim & Al-Bander, 2024).

The Philippines is one of the countries most frequently affected by earthquakes because it lies within the Pacific Ring of Fire. The Philippines is prone to natural disasters, including earthquakes. 5 active faults surround it: the Western Philippine Fault, the Eastern Philippine Fault, the South of Mindanao Fault, the Central Philippine Fault, and the Marikina/Valley Fault. PHIVOLCS recorded an average of 20 earthquakes per day, and almost 100–150 of them are felt each year (Ong et al., 2021).

Every day, the Philippines experiences earthquakes from low to high intensity. The PHIVOLCS operates seismic monitoring stations all over the Philippines. These stations are equipped with seismometers that detect and record earthquakes. Data is sent to the PHIVOLCS Data Receiving Center (DRC) to determine earthquake parameters such as magnitude, focal depth, and epicenter (PHIVOLCS) (Acharya, 1978; Gitanes et al., 2024; Ortiz et al., n.d.; Stewart & Cohn, 1979). Monitoring seismic activity is therefore essential

for improving earthquake prediction, assessing the extent of post-event damage, and characterizing crustal deformation following major events (Wu et al., 2026).

Earthquakes in the Philippines are not evenly distributed over time since earthquakes cannot be predicted. Earthquake frequency per month since January 1, 2018, to July 31, 2026, varies. Some months record a high number of earthquakes, but that does not automatically mean those months experienced significant damage. Earthquake occurrences may vary over time and are not necessarily distributed uniformly across calendar periods. Christiansen et al. (2005) examined long-term earthquake records from volcanic centers in the western United States and identified statistically significant seasonal variations in seismicity in several regions. However, the observed patterns differed among locations, indicating that temporal variation in earthquake activity may be location-specific. The study examined monthly earthquake frequencies in the Philippines and emphasized that observed monthly differences should not automatically be interpreted as evidence of a universal seasonal pattern (Baitus III et al., n.d.; Ortiz et al., n.d.). Numerous methods have been developed for earthquake prediction to date. However, because earthquakes are generally complex and unpredictable, achieving successful results can be quite challenging.

This study aimed to assess the monthly distribution and observable trends of earthquake occurrences in the Philippines from January 2018 to July 2026. Specifically, it examined the monthly frequency of recorded earthquakes, identified observable patterns or fluctuations over the study period, and determined whether significant differences existed in earthquake depth and magnitude across months. By examining these patterns using historical PHIVOLCS records, the study sought to improve understanding of temporal variations in Philippine seismic activity and to provide supporting information for disaster preparedness, risk awareness, and future research. However, the findings are intended to describe historical patterns and should not be interpreted as a means of predicting the exact occurrence of future earthquakes.

Research Questions

This study addressed the following questions:

1. What is the monthly distribution of earthquake occurrences in the Philippines from January 2018 to July 2026?
2. What trend can be observed in the monthly frequency of earthquake occurrences from January 2018 to July 2026?
3. Are there significant differences in earthquake depth and magnitude across the months of the year?
4. Is there a significant relationship between earthquake magnitude and depth in the Philippines from January 2018 to July 2026?

METHODOLOGY

Research Design

This study employed a quantitative descriptive research design to examine the monthly patterns and trends of earthquake occurrences in the Philippines. The study used secondary earthquake records and summarized the data according to month and year to describe variations in earthquake frequency throughout the study period. Descriptive statistics were also used to examine the distribution of earthquake depth and magnitude across the months of the year. In addition, Welch's One-Way Analysis of Variance (ANOVA) was used to determine whether statistically significant differences existed in earthquake depth and magnitude among the twelve calendar months (Acuna et al., 2024; Gitanes et al., 2024). The study did not involve variable manipulation or experimental intervention. Instead, it analyzed existing earthquake records to identify patterns and differences within the specified period.

Data Source and Study Period

Earthquake data were obtained from the (PHIVOLCS) Earthquake Bulletins. The records contain earthquake information such as date and time, latitude, longitude, depth, magnitude, and location. The data were collected from January 1, 2018, to July 31, 2026, comprising 132,226 earthquake records. The data were organized by year and month to determine the monthly frequency of earthquakes. Because the 2026 dataset covers only January through July, the 2026 annual total was treated as a partial-year total and was not interpreted as directly comparable with the complete annual totals from 2018 to 2025.

Data Analysis

The earthquake records were organized and classified by month and year of occurrence. Monthly earthquake frequency was obtained by counting the number of recorded earthquakes occurring in each calendar month.

The variables analyzed in the study were:

1. Month – the twelve calendar months, from January to December, used as the grouping variable in the comparison of earthquake characteristics.
2. Year – the year of earthquake occurrence, covering 2018 to July 2026.
3. Earthquake frequency – the number of earthquake occurrences recorded each month.
4. Earthquake depth – the depth of each recorded Earthquake, expressed in kilometers.
5. Earthquake magnitude – the recorded magnitude of each Earthquake.

For the monthly descriptive analysis, earthquake frequency was summarized by month and year. Earthquake depth and magnitude were summarized for each calendar month using the number of observations (N), mean, and standard deviation (SD). Not all earthquake records contained complete depth values. Therefore, the number of observations (N) used in the descriptive statistics and Welch's One-Way ANOVA may be

slightly lower than the total number of earthquake occurrences reported in Table 1. Only records with available values for the respective variable were included in the corresponding statistical analysis. The data were analyzed using Jamovi statistical software (Corbita et al., 2024, 2025; Galang et al., 2025). The statistical procedures were selected based on the study's objectives and the four research questions.

Monthly Distribution of Earthquake Occurrences

To answer the first research question, the earthquake records were grouped according to month and year. Frequency counts were used to determine the number of recorded earthquake occurrences for each month. Monthly totals were presented in a tabular form to describe the distribution of earthquake occurrences throughout the study period. To answer the second research question, a line graph was used to visualize the monthly frequency of earthquake occurrences from January 2018 to July 2026. The graph was examined for observable increases, decreases, fluctuations, and notable peaks or low-frequency periods across the study period. The analysis was descriptive and was intended to identify the observed pattern or trend in earthquake frequency rather than to predict future earthquake occurrences.

Differences in Earthquake Depth and Magnitude

To answer the third research question, Welch's One-Way ANOVA was conducted separately for earthquake depth and earthquake magnitude, with the twelve calendar months serving as the comparison groups. Welch's ANOVA was used to assess whether the mean earthquake depth and mean magnitude differed significantly across the months. A significance level of $\alpha = 0.05$ was used in determining statistical significance. A p-value less than 0.05 was interpreted as evidence of a statistically significant difference among the monthly groups. In contrast, a p-value greater than or equal to 0.05 was interpreted as insufficient evidence of a statistically significant difference. Descriptive statistics, including the mean and standard deviation, were examined alongside the ANOVA results to describe the direction and magnitude of differences in earthquake depth and magnitude across the months.

Correlation Between Earthquake Magnitude and Depth

To answer the fourth research question, Pearson's product-moment correlation coefficient (Pearson's r) was used to determine the strength and direction of the linear relationship between earthquake magnitude and depth. The analysis was conducted using individual earthquake records with available values for both magnitude and depth (Acuna et al., 2024; Gitanes et al., 2024). The correlation coefficient (r) and p-value were examined to determine the direction, strength, and statistical significance of the relationship. The coefficient of determination (R^2) was also calculated by squaring the Pearson correlation coefficient to quantify the proportion of variation in earthquake magnitude explained by its linear relationship with earthquake depth.

RESULTS AND DISCUSSION

Table 1 presented the monthly distribution of earthquake occurrences in the Philippines from January 2018 to July 2026, with a total of 132,226 earthquakes recorded. The results showed that earthquake activity varied considerably across months, with June recording the highest cumulative number of occurrences (14,218), followed closely by October (14,180) and July (12,428). In contrast, February had the lowest cumulative occurrence (8,609), followed by September (8,713) and November (9,509). The results indicated that earthquake occurrences were not evenly distributed throughout the year, with relatively higher activity observed particularly during June, July, and October. However, the highest and lowest cumulative counts of earthquake occurrences may change as additional data become available, since the dataset used in this study covers only the period through July 31, 2026. Earthquake data for the succeeding months were not yet available at the time this study was conducted.

Table 1
Monthly Distribution of Earthquake Occurrences in the Philippines

Period	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
Jan	374	621	1,746	783	787	907	1,898	1,443	2,224	**10,783**
Feb	366	930	863	826	638	1,091	1,457	1,213	1,225	**8,609**
Mar	369	884	1,115	818	1,432	1,249	1,634	1,401	1,250	**10,152**
Apr	466	1,259	1,346	840	1,153	1,243	1,463	1,332	1,540	**10,642**
May	598	981	1,307	933	1,051	1,114	1,509	1,559	1,771	**10,823**
Jun	539	785	1,249	1,580	1,043	1,075	1,540	1,637	4,770	**14,218**
Jul	508	869	1,093	1,100	1,799	1,085	1,476	1,421	3,077	**12,428**
Aug	529	554	1,294	1,340	1,913	1,138	2,057	1,632	N/A	**10,457**
Sept	581	899	1,063	1,000	1,118	1,102	1,441	1,509	N/A	**8,713**
Oct	708	1,820	1,139	1,147	1,355	1,179	1,247	5,585	N/A	**14,180**
Nov	659	1,787	881	960	1,177	1,164	1,198	1,683	N/A	**9,509**
Dec	561	1,645	999	745	872	4,285	1,229	1,376	N/A	**11,712**
Total	**6,258**	**13,034**	**14,095**	**12,072**	**14,338**	**16,632**	**18,149**	**21,791**	**15,857**	**132,226**

N/A – no available data yet

Over the nine years, the annual totals also showed an overall increase in recorded earthquakes, from 6,258 in 2018 to 21,791 in 2025. The highest annual total was recorded in 2025, while the lowest was in 2018. This increase may reflect variations in actual seismic activity as well as improvements in earthquake detection and monitoring. Although 2025 recorded the highest annual total in the available complete-year data, this finding may change once the 2026 dataset is complete. From January to July 2025, the records showed 10,006 earthquake occurrences, whereas from January to July 2026,

15,857 occurrences had already been recorded. Given that the 2026 data currently cover only the first seven months of the year, the 2026 annual total may exceed the 2025 total after data for August to December become available. These data were not yet available at the time the study was conducted.

Table 2 presented the average earthquake depth by month and year from January 2018 to July 2026. The results showed considerable variation across months and years. The highest average depth was recorded in December 2018 (41.36 km), while the lowest was recorded in December 2023 (20.76 km). For 2026, the average depth ranged from 21.59 km in January to 29.01 km in May, based on the available January–July data. Overall, the results showed no consistent pattern in average earthquake depth across months and years, indicating that depth varied over the study period. However, the highest and lowest average depths may change as additional data become available, since the dataset used in this study covers only the period up to July 31, 2026. Earthquake data for the succeeding months were not yet available at the time this study was conducted.

Table 2
Average depth (km) of earthquakes in the Philippines

Period	2018	2019	2020	2021	2022	2023	2024	2025	2026
Jan	30.76	34.47	24.36	35.81	34.43	35.66	26.27	29.96	21.59
Feb	37.65	22.10	30.62	30.39	34.75	28.11	28.25	28.74	27.47
Mar	35.19	29.11	33.86	31.36	29.69	28.56	29.54	26.57	26.03
Apr	35.21	27.41	35.05	31.19	29.04	32.17	28.35	28.81	28.91
May	40.25	33.25	31.50	33.78	37.01	27.55	30.40	29.98	29.01
Jun	33.29	34.61	37.84	25.95	29.23	30.09	30.64	31.77	26.12
Jul	36.75	29.59	36.32	40.74	22.34	34.02	31.32	31.38	27.06
Aug	36.15	34.69	31.34	37.05	23.73	32.33	24.74	30.09	N/A
Sept	35.30	36.58	32.51	36.09	27.42	31.39	26.04	30.98	N/A
Oct	39.43	28.83	30.11	33.03	25.71	30.82	27.49	21.28	N/A
Nov	34.00	24.54	33.18	31.60	29.48	33.59	27.09	24.28	N/A
Dec	41.36	26.74	34.58	34.81	29.75	20.76	27.79	25.26	N/A

N/A – no available data yet

Figure 1 presented a line graph illustrating the monthly earthquake occurrences in the Philippines. Throughout the study period, there was no clear upward or downward trend. The fluctuations suggested that earthquakes were not evenly distributed over time. October 2025 experienced the highest activity, followed by June 2026 and December 2023, while some months showed fewer events. These variations implied periods of heightened seismic activity. Furthermore, the absence of a consistent seasonal pattern in earthquake depth raised important implications for understanding regional seismic

behavior. The significant variation across months and years indicated that earthquake depths were likely governed by multiple interacting geological processes rather than by seasonal or environmental factors. This variability complicated efforts to forecast seismic activity based solely on seasonal trends.

Figure 1
Monthly Frequency of Earthquake Occurrence, Philippines, January 2018 - July 2026

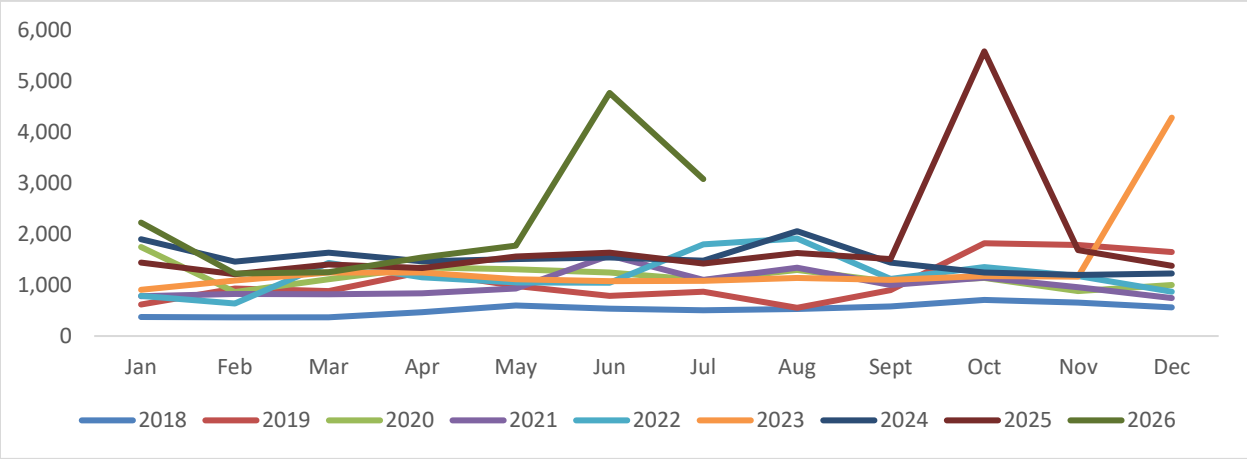
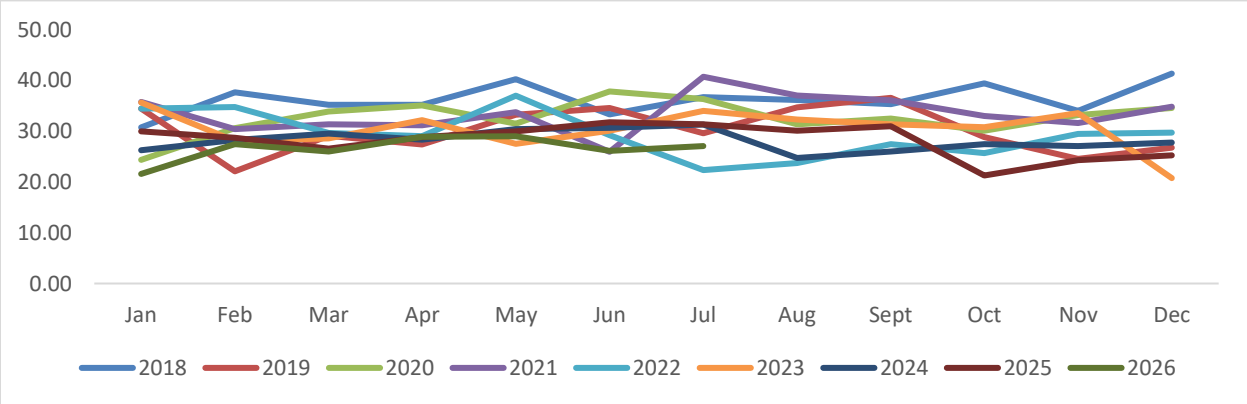


Figure 2 provided a comprehensive overview of the mean earthquake depth in the Philippines, analyzed month by month from January 2018 through July 2026. This detailed presentation highlighted significant fluctuations in earthquake depths across months and years. The data revealed that the average depths during this period ranged from roughly 20 km to 41 km beneath Earth's surface. Such variation underscored the dynamic nature of seismic activity in the region, emphasizing that earthquake depths varied widely over time.

Figure 2
Mean Earthquake Depth(km) by Month, Philippines, January 2018 – July 2026



In Figure 2, the observed range did not follow a straightforward trend; instead, it pointed to a complex pattern influenced by various geological factors. Notably, the mean depths did not show a clear systematic trend when viewed across the entire timeline. This lack of a discernible depth pattern suggested that seismic activity varied widely and did not exhibit seasonal or predictable periodicity. Consequently, researchers and policymakers needed to consider this complex and non-uniform pattern when developing earthquake preparedness and mitigation strategies, acknowledging that earthquake depth remained unpredictable and highly variable over time.

Table 3
Descriptive Statistics of Earthquake Magnitude and Depth by Month in the Philippines

Month	Magnitude	Depth(km)
Jan	2.49 (SD=0.71)	28.20 (SD=35.78)
Feb	2.49 (SD=0.71)	28.85 (SD=36.81)
Mar	2.46 (SD=0.68)	29.39 (SD=36.50)
Apr	2.47 (SD=0.71)	30.27 (SD=36.09)
May	2.47 (SD=0.70)	31.69 (SD=40.37)
Jun	2.47 (SD=0.70)	29.54 (SD=34.84)
Jul	2.47 (SD=0.70)	30.58 (SD=38.59)
Aug	2.51 (SD=0.71)	29.71 (SD=39.16)
Sept	2.54 (SD=0.71)	31.40 (SD=42.69)
Oct	2.45 (SD=0.70)	26.58 (SD=32.51)
Nov	2.48 (SD=0.68)	28.70 (SD=36.28)
Dec	2.55 (SD=0.72)	26.60 (SD=35.58)

$r=0.06$, $r^2= 0.0036$, $p<.001$

Table 3 presented the descriptive statistics for earthquake depth and magnitude across the 12 months. For earthquake magnitude, the monthly means were relatively consistent, ranging from 2.45 in October to 2.55 in December. Although the differences in mean magnitude appeared small, the large sample sizes per month resulted in statistically significant differences in Welch's ANOVA, as shown in Table 3.

The mean earthquake depth ranged from 26.58 km in October to 31.69 km in May, indicating noticeable variation in the typical depth of earthquakes across months. The standard deviations, ranging from 32.51 to 42.69 km, also showed considerable variability in earthquake depths within each month. Overall, the descriptive results suggested that earthquake depth varied more noticeably across months than earthquake magnitude, while both variables exhibited variation across months.

Although ANOVA revealed statistically significant monthly differences in earthquake magnitude, the actual variation was minimal, with the difference between the lowest and highest monthly mean totaling only about 0.10 magnitude units. This small difference suggested that, despite statistical significance, the monthly variations in earthquake magnitude are not practically large. Therefore, statistical significance alone should not be taken as evidence of meaningful or substantial monthly changes.

The Pearson correlation analysis indicated a statistically significant positive relationship between earthquake magnitude and depth, with a correlation coefficient of $r = 0.06$ ($p < .001$). However, this relationship was very weak, implying that deeper earthquakes tended to have slightly higher magnitudes. Despite its statistical significance, the correlation was weak, as evidenced by the coefficient of determination ($r^2 = 0.0036$), which indicated that only about 0.36% of the variation in earthquake magnitude can be explained by depth. Given these findings, the depth alone did not significantly influence earthquake magnitude. Although there was a statistically significant association, its practical significance was limited. These results highlighted the need for further research to identify other factors that might better explain variations in earthquake magnitudes, as depth alone appeared to have minimal impact.

Welch's One-Way ANOVA showed that both earthquake depth and magnitude differed significantly across the months, with depth $F = 23.25$, $p < .001$, and magnitude $F = 18.64$, $p < .001$. The value indicated that earthquake depth and magnitude were not consistent across months, suggesting significant monthly variation during the study period. It also revealed statistically significant differences in both earthquake magnitude and depth across the groups during the study period. These findings suggested that earthquake magnitude and depth varied considerably from January 2018 to July 2026.

Table 4
Test of Difference on Earthquake Depth and Magnitude by Months

Variables	F	p	Remarks
Depth (km)	23.25	<.001	There is a statistically significant difference in earthquake depth across months and years.
Magnitude	18.64	<.001	There is a statistically significant difference in earthquake magnitude across months and years.

Conclusions

The findings demonstrated substantial temporal variability in earthquake occurrence across the Philippines, highlighting the importance of continuous monitoring and data-driven disaster preparedness strategies. Based on earthquake records analyzed from January 2018 to July 2026, earthquake occurrences in the Philippines varied over time. The monthly distribution indicated that earthquake activity was not uniform, with some periods recording more earthquake events than others. However, a higher number of recorded earthquakes in a particular month does not necessarily indicate stronger earthquakes or greater damage, since earthquake impacts also depend on differences in magnitude, depth, location, and proximity to populated areas. Overall, the findings demonstrated that earthquake activity in the Philippines was variable rather than constant. The results reinforced the importance of continuous seismic monitoring and the use of historical earthquake records in understanding patterns of seismic activity. However, observed patterns should not be interpreted as a means of predicting when future earthquakes will occur.

Recommendations

Based on the study's findings, the researchers recommended continued monitoring and systematic assessment of earthquake occurrences using updated PHIVOLCS earthquake records. Future studies may examine longer observation periods and include other earthquake characteristics such as geographic location, tectonic origin, intensity, and proximity to active faults. Furthermore, the statistical assessment using One-Way ANOVA and descriptives is sufficient to support the study's aim of specifically determining trends in the monthly frequency of earthquake occurrences, differences in depth and magnitude, and whether significant differences exist among the twelve calendar months. Researchers may also examine earthquake frequency together with magnitude and depth to provide a more comprehensive understanding of seismic activity in the Philippines. The results may be useful as supporting information for disaster preparedness, risk awareness, and evidence-based planning, while recognizing that historical earthquake patterns cannot reliably predict the exact occurrence of future earthquakes.

Compliance with Ethical Standards

This study used secondary earthquake data obtained from the publicly available earthquake records of the (PHIVOLCS). No human participants, personal information, or confidential data were involved in the study. The researchers properly acknowledged and cited the sources of the data and related literature used in the research. The data were analyzed solely for academic and research purposes, and the researchers aimed to present the findings objectively and without alteration or misrepresentation.

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