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# Impact of a Digital Platform for Wildlife Information Management in the Cerro Blanco Protected Forest of Guayaquil Using Plithogenic Statistics

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**Abstract.** Protected areas, such as the 6078-hectare Cerro Blanco Protected Forest of Guayaquil, often struggle with inefficient wildlife information management, including previously physical and inefficient methods of fauna control, which can hinder effective conservation. Comprehensive digital resources are needed to improve data accessibility for informed decision-making regarding conservation activities. This project addressed this opportunity by developing and evaluating a digital platform specifically designed to facilitate the collection, organization, and dissemination of wildlife-based resources. While the consideration of digital approaches in conservation is rapidly increasing, there are minimal articles focused on successful encompassing digital platforms, and none that assess their real-world effect via plithogenic analysis. Therefore, this digital application, which includes functional modules for security, fauna information, a digital catalog, and incident reporting, was implemented in the Cerro Blanco Protected Forest. Its real-world effect was subsequently assessed using plithogenic analysis, a method chosen to provide quantifiable evidence of its success. The results indicate a highly significant positive sentiment from users toward the post-application functionality and the standardization of faunal resources. In addition, the plithogenic analysis produced more statistically significant emergent trends and occurrences due to the information being housed in one collected location. Thus, this study contributes theoretically to the literature by acknowledging the digital application as a practical integration model for wildlife resource management, and practically it applies the application itself as an effective tool for any protected area to achieve higher resource management efficiency.

**Keywords:** Digital platform, Wildlife, Protected forest, Information management, Conservation impact, Plithogenic statistics, Neutrosophic numbers, Biodiversity data, Cerro Blanco Protected Forest

## 1. Introduction

The preservation of global biodiversity depends intrinsically on effective ecosystem management, with protective forests serving as crucial bulwarks against habitat and species loss [1]. In these scenarios, accurate and up-to-date wildlife information constitutes the cornerstone for the design and implementation of robust and adaptive conservation strategies. The growing anthropogenic pressure on these natural environments, exacerbated by climate change and the expansion of human activities, underscores the urgency of optimizing the mechanisms by which faunal knowledge is collected, analyzed, and disseminated [2]. A pertinent example of such an environment facing these challenges is the Cerro Blanco Protected Forest, a significant 6078-hectare private reserve of tropical dry forest located near Guayaquil, Ecuador, within the Chongón Colonche mountain range. Considered a vital ecological area and one of Guayaquil's best-preserved natural remnants, its wildlife management has traditionally contended with issues such as physical and often inefficient methods for fauna control and monitoring. This specific context highlights the pressing need for modern, efficient tools to manage wildlife information. To address these local challenges systematically, the digital platform evaluated in this study was developed using an agile SCRUM methodology, aiming to provide a robust solution for data collection, organization, and dissemination. Thus, the present study delves into the evaluation of how digital tools can radically transform these processes, focusing on a specific platform and its measurable impact.

Historically, wildlife monitoring relied on analog methods such as paper records and direct observations, which, while valuable, often resulted in data that was fragmented, difficult to access, and susceptible to loss or deterioration [3]. With the advent of the digital age, databases and geographic information systems (GIS) progressively emerged, offering new capabilities for spatial storage and analysis. However, integrating diverse data sources (sightings, camera traps, scientific studies, local knowledge) into a coherent and accessible system has continued to represent a considerable challenge for many protected area managers, limiting the holistic view necessary for ecosystem management.

The current landscape shows a proliferation of technological initiatives aimed at conservation; however, rigorous evaluation of the real impact of these tools, especially in terms of improving the efficiency of information management and translating it into more effective conservation decisions, remains a developing field [4]. Digital platforms are often implemented without a clear evaluative framework that allows quantifying their specific benefits or identifying areas for improvement. This deficiency is particularly notable when considering specialized metrics, such as plithogenic statistics, which could offer unique insights into information dynamics and their relationship to inferred ecological patterns.

In this context, the central problem that this research seeks to elucidate lies in the underutilization and dispersion of faunal information in many protected forests, which hinders rapid and informed decision-making for conservation. The lack of a centralized and efficient system not only hinders the work of managers and scientists, but also limits the capacity to respond to emerging threats and the long-term assessment of animal populations and their habitats [5]. This information deficit can lead to an inefficient allocation of resources and the implementation of management measures that are not optimally adjusted to the real needs of the ecosystem and its species.

This study therefore addresses a critical and eminently practical research question: What is the quantifiable and qualitative impact of implementing a digital platform specifically designed to collect, organize and disseminate information related to the wildlife of protective forest " Bosque Protector Cerro Blanco de Guayaquil, on improving information management, and how can the analysis of plithogenic statistics contribute to this assessment? The magnitude of this problem is reflected in the prevailing need to transform raw data into actionable knowledge for safeguarding biodiversity [6].

Addressing this question would not only validate the usefulness of a specific technological tool, but would also provide a methodological framework for evaluating similar initiatives in other geographic and ecological contexts. Addressing this issue is essential for moving toward more proactive and evidence-based conservation, where technology serves as a catalyst for the efficiency and effectiveness of protection actions.

Given this scenario, this study therefore proposes to address this question by designing, implementing, and subsequently evaluating a comprehensive technological solution in a specific case study. The research will not only document the development process of the digital platform, but will also focus primarily on measuring its effects on information flows and its usefulness for managers and the scientific community involved in the conservation of the protective forest.

More specifically, the objectives of this research are: first, to design and implement a digital platform that allows the efficient collection, organization and dissemination of information related to the wildlife of the selected protective forest; second, to systematically evaluate the impact of such a platform on improving the accessibility, quality and use of faunal information by key stakeholders; and third, to explore and apply the analysis of plithogenic statistics as a novel tool to quantify changes in information patterns and their potential correlation with ecological indicators, thus deriving lessons learned and recommendations for future technological implementations in the management of protected areas [7,8,9].

## 2. Preliminaries.

### 2.1. Plithogenic Statistics (PS).

Plithogenic statistics (PS) represents an advanced and multifaceted methodological approach to data analysis, designed to handle and synthesize heterogeneous information from multiple sources. Unlike traditional statistical methods, which typically focus on isolated variables or simplified models, PS seeks to capture the complexity and interconnectedness of the studied phenomena. This approach allows for a deeper and more nuanced understanding of the data, offering a powerful tool for research in fields as diverse as education, economics, biomedicine, and more [10,11].

One of the key advantages of SPs is their ability to handle large volumes of data and to identify complex relationships between variables. Despite its numerous advantages, implementing SP also presents challenges. It requires a high level of technical competence and a deep understanding of advanced statistical methodologies. Furthermore, collecting and integrating heterogeneous data can be complex and costly. However, the potential benefits of a more complete and nuanced understanding of social phenomena justify these challenges

Plithogenic statistics offer a powerful and sophisticated approach to data analysis, allowing for a more in-depth and detailed assessment of social phenomena. By capturing the complexity and interconnectedness of the variables involved, PS provides valuable elements. Despite the challenges associated with their implementation, PS represents an invaluable tool for researchers and policymakers.

Plithogenic Statistics (PS) encompasses the analysis and observations of the events under study. It allows for the analysis of many output variables that are neutrosophic or indeterminate. There are several subclasses of Plithogenic Statistics which are shown[12]:

- Multivariate statistics,
- Plithogenic Neutrosophic Statistics,
- Indeterminate plithogenic statistics,
- Intuitionistic plithogenic fuzzy statistics,
- Fuzzy statistics of plithogenic images,
- Plithogenic spherical fuzzy statistics,
- and in general: Plithogenic statistics (of fuzzy extension).

In a neutrosophic population [13] , each element has a triple probability of affiliation $(T_j, I_j, F_j)$, where$T_j, I_j, F_j \in [0, 1]$ like that $0 \leq T_j + I_j + F_j \leq 3$.

If we assume that we must have the data set $(T_j, I_j, F_j)$for $j = 1, 2, \dots, n$, where $n$ is the sample size, then the average probability of all the data in the sample is calculated by Equation 1.

$$\frac{1}{n}\sum_{j=1}^{n}(T_j, I_j, F_j) = \left(\frac{\sum_{j=1}^{n} T_j}{n}, \frac{\sum_{j=1}^{n} I_j}{n}, \frac{\sum_{j=1}^{n} F_j}{n}\right) \tag{1}$$

In this investigation, we also consider some operations in the form of *neutrosophic numbers.* These ways of representing indeterminacy are, under certain conditions, equivalent to working with intervals.

**Definition 1** : ( [14,15] ) A *neutrosophic number* N is defined as a number as follows:

$$\mathrm{N} = \mathrm{d} + \mathrm{I} \tag{2}$$

Where d is called *the determinate part* and I is called *the indeterminate part.*

Given $N_1 = a_1 + b_1I$ and $N_2 = a_2 + b_2I$ They are two neutrosophic numbers, some operations between them are defined as follows:

$N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition) ; (3)

$N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference), (4)

$N_1 \times N_2 = a_1a_2 + (a_1b_2 + b_1a_2 + b_1b_2)I$ (Product), (5)

$\frac{N_1}{N_2} = \frac{a_1+b_1I}{a_2+b_2I} = \frac{a_1}{a_2} + \frac{a_2b_1-a_1b_2}{a_2(a_2+b_2)}I$ (Division). (6)

Furthermore, the arithmetic operations between intervals are important in this document, which are summarized below ([16]):

Given$I_1 = [a_1, b_1]$ and$I_2 = [a_2, b_2]$ We have the following operations between them [17]:

$I_1 \le I_2$ if and only if$a_1 \le a_2$ and $b_1 \le b_2$. (7)

$I_1 + I_2 = [a_1 + a_2, b_1 + b_2]$ (Addition) ; (8)

$I_1 - I_2 = [a_1 - b_2, b_1 - a_2]$ (Subtraction), (9)

$I_1 \cdot I_2 = [\min\{a_1{\cdot}b_1, a_1{\cdot}b_2, a_2{\cdot}b_1, a_2{\cdot}b_2\}, \max\{a_1{\cdot}b_1, a_1{\cdot}b_2, a_2{\cdot}b_1, a_2{\cdot}b_2\}]$ (Product), (10)

$I_1/I_2 = I_1{\cdot}(1/I_2) = \{a/b\colon a{\in}I_1, b{\in}I_2\}$, always that $0 \notin I_2$(Division). (11)

## 3. Methodology

This research was conducted in two main phases: first, the design and development of a digital platform for wildlife information management tailored to the needs of the Cerro Blanco Protected Forest; and second, a systematic evaluation of this platform's impact on information management practices using plithogenic statistics.

### 3.1. Platform Design and Development

The initial objective was to create a digital platform to compile, organize, and disseminate information related to the wildlife of the Cerro Blanco Protected Forest. The development of this application utilized an agile SCRUM methodology, adhering to the Model-View-Controller (MVC) design pattern to structure the software. Key technologies employed included PHP version 7.4.0 for backend development, along with HTML5, CSS, and AJAX for responsive frontend interfaces, and MySQL as the relational database engine. The resulting platform incorporates several functional modules designed to manage specific aspects of wildlife-related data, including a Security Module, a Fauna Module for taxonomic records, a Digital Catalog Module for documents, and an Incidents Module for reporting occurrences within the protected area. Additional modules developed also encompassed a virtual community forum, publication features for technical sheets, a media gallery, and mapping capabilities for species sightings and routes.

### 3.2. Impact Assessment Framework

Following the platform's implementation, its impact was assessed to provide quantifiable evidence of its real-world effect.

#### 3.2.1. Research Design and Participants

A pre-test/post-test research design involving an experimental group and a control group was employed. The experimental group consisted of 30 key stakeholders actively involved in the management of the Cerro Blanco Protected Forest, including park rangers, biologists, and administrative and technical staff. A control group of 15 stakeholders from a similar protected forest that had not implemented the digital platform was also included. Participants were selected using a non-probability convenience sampling method, given the specific nature of the target group and accessibility.

#### 3.2.2. Data Collection

Data were collected via a structured questionnaire administered to both groups before the implementation of the digital platform (Pre-Test) and again six months after its full operation (Post-Test). The questionnaire comprised approximately 20 items, grouped into four key dimensions:

- **Quality and Accessibility of Wildlife Information** (7 items): Assessing perceptions of record completeness, ease of finding information, search time, and confidence in data veracity.
- **Data Management Efficiency** (5 items): Evaluating ease of data entry, organization, reduction in effort duplication, and report generation capabilities.
- **Support for Decision-Making for Conservation** (4 items): Measuring the utility of information for patrol planning, monitoring programs, trend assessment, and resource requests.
- **Collaboration and Dissemination of Knowledge** (4 items): Examining ease of information sharing, improved communication, potential for community outreach, and data standardization.

Respondents expressed their opinions using a range of values from 0 (Strongly disagree/Never) to 10 (Strongly agree/Always), with responses captured as intervals [aiL,AiU] for each respondent to accommodate potential variability. The instrument was validated by three experts in conservation and information systems, and its reliability was confirmed with a Cronbach's alpha coefficient of 0.88.

#### 3.2.3. Data Analysis using Plithogenic Statistics

Plithogenic statistics (PS) were employed for data analysis due to their capacity to handle and synthesize heterogeneous information from multiple sources, including data with high levels of uncertainty. This approach is particularly suited for neutrosophic data, where responses are expressed as intervals capturing indeterminacy.

The main steps followed for the analysis were:

1. **Variable Specification:**
   - $\boldsymbol{U} = \{\boldsymbol{u_1}, \boldsymbol{u_2}, \dots, \boldsymbol{u_{30}}\}$denoted the set of users in the experimental group.
   - $\widetilde{\boldsymbol{U}} = \{\widetilde{\boldsymbol{u}}_1, \widetilde{\boldsymbol{u}}_2, \dots, \widetilde{\boldsymbol{u}}_{15}\}$ denoted the set of users in the control group.

- $\boldsymbol{d} = \{\boldsymbol{d_1}, \boldsymbol{d_2}, \boldsymbol{d_3}, \boldsymbol{d_4}\}$ denoted the set of dimensions measured, corresponding to "Quality and Accessibility of Wildlife Information" ($\boldsymbol{d_1}$), "Data Management Efficiency" ($\boldsymbol{d_2}$), "Support for Decision-Making for Conservation" ($\boldsymbol{d_3}$), and "Collaboration and Dissemination of Knowledge" ($\boldsymbol{d_4}$). Each dimension comprised several items (e.g., $\boldsymbol{d_1} = \{\boldsymbol{d_{11}}, \dots, \boldsymbol{d_{17}}\}$ etc.).

2. **Evaluation Representation:** The evaluation for each item was represented by an interval: $\boldsymbol{I_{ijk}} = [\boldsymbol{a^L}_{\boldsymbol{ijk}}, \boldsymbol{A^U}_{\boldsymbol{ijk}}]$ for the i-th user in the experimental group, for the k-th item of the j-th dimension in the Pre-Test. $\boldsymbol{I'_{ijk}}$ was used for the Post-Test of the experimental group, and $\boldsymbol{\tilde{I}_{ijk}}$ for the control group evaluations.
3. **Score Calculation and Transformation:**
   - Dimension scores for each respondent and dimension ($\boldsymbol{D_{ji}}$ for Pre-Test Experimental, $\boldsymbol{D'_{ji}}$ for Post-Test Experimental, and $\boldsymbol{N_{ji}}$ for Control) were obtained by summing the item scores within that dimension
   - These raw scores were then transformed to a standardized range of 0 to 100 ($D^*_{ji}$, $D'^*_{ji}$, $N^*_{ji}$) to facilitate comparison.
4. **Aggregate Analysis:**
   - Average scores for each dimension within each group and test phase ($D^*_j$, $D'^*_j$) were calculated by averaging the transformed scores of the participants.
   - The change produced before and after the platform implementation for the experimental group was calculated using interval subtraction
   - The difference between the average of the experimental group (Post-Test) and the control group
   - Obtain an "Overall Perceived Impact of the Platform

## 4. Results and Discussion.

The use of Plithogenic Statistics (PS) offers a robust methodological framework to analyze the complex impact of technological interventions in conservation, such as the implementation of a digital platform for wildlife information management.

This platform, developed for the Cerro Blanco Protected Forest in Guayaquil, transforms how wildlife data is collected, organized, analyzed, and disseminated. It is composed of several functional modules (Figure 1):

Security Module,
Fauna Module,
Digital Catalog Module, and
Incidents Module,

Each designed to manage specific aspects of wildlife-related data. The platform enables researchers, park rangers, and conservation managers to access up-to-date information, contribute to knowledge sharing, and support effective biodiversity monitoring and protection.

Plithogenic Statistics allow the integration of both quantitative and qualitative data, including high levels of uncertainty, such as user perceptions of usefulness, usage frequency, improvement in data quality, and time reduction in information retrieval. In this context, PS is particularly useful for handling neutrosophic data, expressed as intervals that capture indeterminacy in user responses.

This approach goes beyond simple usage metrics by evaluating the perceived value and actual impact on management practices, which is especially vital in protected areas with limited resources. While training is required for the collection and interpretation of plithogenic data, the benefits of a comprehensive evaluation of the platform justify the effort.

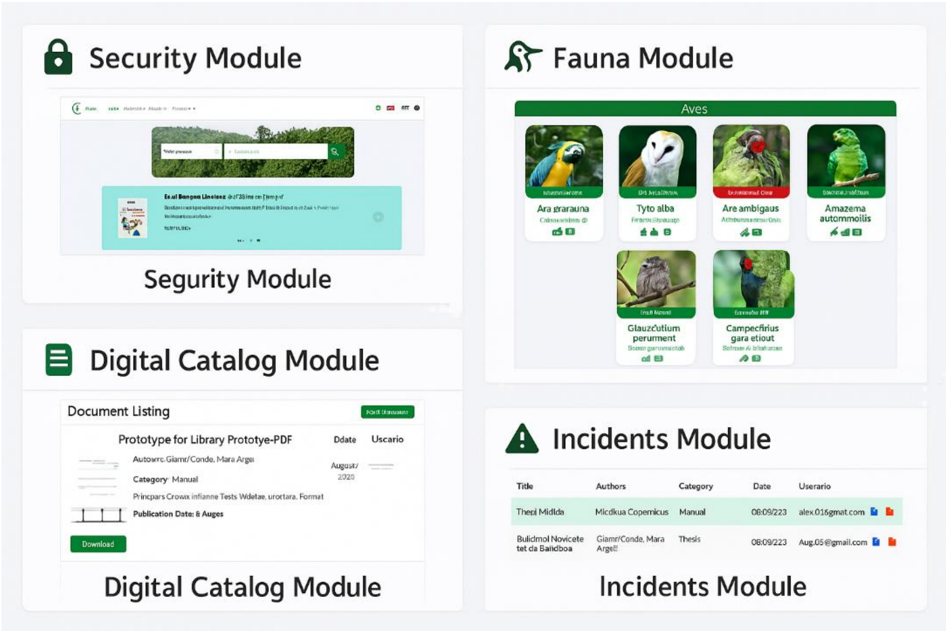


**Figure 1.** Software Development for Wildlife Control in the Cerro Blanco Protected Forest

The research focused on a population of **30 key stakeholders** involved in the management of the Protected Forest, including park rangers, biologists, and administrative and technical staff. Non-probability convenience sampling was used, given the specificity of the group. Data collection was based on a survey method, administered through a structured questionnaire before the implementation of the digital platform (Pre-Test) and six months after its full operation (Post-Test). A control group, composed of 15 stakeholders from a similar protected forest without the digital platform, also completed the questionnaire at equivalent times.

The questionnaire, developed according to the objectives of the study, contained approximately 20 items, grouped into the following dimensions:

1. **Quality and Accessibility of Wildlife Information (7 items):**
   - Perception of the completeness and updating of fauna records.
   - Ease of finding species-specific information.
   - Average time spent searching for fauna data.
   - Confidence in the veracity and accuracy of the information available.

2. **Data Management Efficiency (5 items):**
   - Ease of entering new records and wildlife observations.
   - Perception of the logical organization of information in the system.
   - Reducing duplication of efforts in data collection.
   - System capacity to generate basic reports.

3. **Support for the Taking of Conservation Delineations (4 items):**
   - Usefulness of the information to identify priority patrol areas.
   - Contribution of the platform to the planning of monitoring programs.
   - Ease of assessing population trends from data.
   - Impact on the justification of resource or project requests.

4. **Collaboration and Dissemination of Knowledge (4 items):**
   - Ease of sharing relevant information with other colleagues or institutions.
   - Improved internal communication about findings or early warnings.
   - Potential of the platform to generate informative material for the community.
   - Perception on the standardization of data formats.

Given the potential variability in users' familiarity with precise scales, they were asked to express their opinions using a range of values 0 (Strongly disagree/Never) to 10 (Strongly agree/Always)]. These intervals are expressed on the form $I_i = \left[a_i^L, A_i^U\right]$ for each respondent.

The instrument was validated through the judgment of three conservation and information systems experts. Reliability was assessed using Cronbach 's alpha , yielding a value of 0.88, considered acceptable.

The steps followed for the analysis were:

The variables are specified:

- $U = \{u_1, u_2, \dots, u_{30}\}$denotes the group of users of the software (experimental group).
- $\tilde{U} = \{\tilde{u}_1, \tilde{u}_2, \dots, \tilde{u}_{15}\}$denotes the set of users of the software (control group).
- $d = \{d_1, d_2, d_3, d_4\}$denotes the set of dimensions to be measured, such that:
  - $d_1$: Symbolizes the dimension "Quality and Accessibility of Wildlife Information".
  - $d_2$: Symbolizes the "Data Management Efficiency" dimension.
  - $d_3$: Symbolizes the dimension "Support for Decision-Making for Conservation".
  - $d_4$: Symbolizes the "Collaboration and Dissemination of Knowledge" dimension.

The evaluation for each item is represented by: $I_{ijk} = \left[a_{ijk}^L, A_{ijk}^U\right]$, which is the evaluation of the $i_{th}$ user in the experimental group for the kth item of the $j_{th}$ dimension (Pre-Test). $I'_{ijk}$ is used for the Post-Test of the experimental group, and $\tilde{I}_{ijk}$ for the control group.

Dimension scores were obtained for each respondent and each dimension using Equation 3 (and its analogue for Post-Test and control):

$$D_{ji} = \sum_{k=1} I_{ijk} \quad \text{( (Experimental Pre-Test )} \tag{12}$$

$$D'_{ji} = \sum_{k=1} I'_{ijk} \quad \text{( (Experimental Post-Test)} \tag{13}$$

$$N_{ji} = \sum_{k=1} I_{ijk} \quad \text{( (Control)} \tag{14}$$

These scores were transformed to a range of 0 to 100 using Equation 5 (and its analogous Equation 6 for Post-Test and control):

$$D_{ji}^* = \frac{D_{ji} - \text{minimum theoretical score } D_j}{\text{maximum theoretical score } D_j - \text{minimum theoretical score} D_j} * 100 \tag{15}$$

The dimension averages were calculated using Equation 7 (and its analogous Equation 8):

$$\bar{D}_j^* = \frac{\sum_{i=1}^{30} D_{ji}^*}{30}) \text{ (Pre-Test Experimental)} \tag{16}$$

$$\bar{D}_j^{\prime *} = \frac{\sum_{i=1}^{30} D'^*_{ji}}{30}) \text{ (Post-Test Experimental)} \tag{17}$$

$$\bar{N}_j^* = \frac{\sum_{i=1}^{15} N_{ji}^*}{15}) \text{ (Control)} \tag{18}$$

The change produced before and after the implementation of the platform for the experimental group was calculated with Equation 9:

$$\bar{\bar{\Delta}}_j^* = \bar{D}_j^* - \bar{\bar{D}}_j^* \qquad (19)$$

The difference between the average of the experimental group (Post-Test) and the control group was calculated with an adaptation of Equation 10:

$$\bar{\bar{\Delta}}_j^* = \bar{D}_j^* - \bar{\bar{N}}_j^* \qquad (20)$$

**Results:**

- **Average results for Dimension 1 "Quality and Accessibility of Wildlife Information".**
  - $Pre - Test: \bar{D}_1^* = [45.5, 55.2]$
  - $Post - Test: \bar{D}_1^* = [80.1, 88.5]$
  - $Control: \bar{\bar{N}}_1^* = [48.0, 57.3]$
- **Average results for Dimension 2 "Data Management Efficiency".**
  - $Pre - Test: \bar{D}_2^* = [40.2, 50.8]$
  - $Post - Test: \bar{D}_2^* = [85.5, 92.3]$
  - $Control\ \bar{\bar{N}}_2^* = [42.1, 51.5]$
- **Average results for Dimension 3 "Support for Decision-Making for Conservation".**
  - $Pre - Test: \bar{D}_3^* = [35.0, 45.5]$
  - $Post - Test: \bar{D}_3^* = [75.8, 85.2]$
  - $Control: \bar{\bar{N}}_3^* = [38.5, 48.0]$
- **Average results for Dimension 4 "Collaboration and Dissemination of Knowledge".**
  - $Pre - Test: \bar{D}_4^* = [30.5, 40.1]$
  - $Post - Test: \bar{D}_4^* = [70.2, 80.9]$
  - $Control: \bar{\bar{N}}_4^* = [33.0, 42.5]$

Calculation of $\bar{\bar{\Delta}}_j^*$ (Change in Experimental Group):

- $\bar{\bar{\Delta}}_1^* = [80.1, 88.5] - [45.5, 55.2] = [24.9, 43.0]$ $(using\ I1 - I2 = [a1 - b2, b1 - a2])$
- $\bar{\bar{\Delta}}_2^* = [85.5, 92.3] - [50.8, 40.2] = [34.7, 52.1]$
- $\bar{\bar{\Delta}}_3^* = [75.8, 85.2] - [45.5, 35.0] = [30.3, 50.2]$
- $\bar{\bar{\Delta}}_4^* = [70.2, 80.9] - [40.1, 30.5] = [29.7, 50.4]$

Calculation of $\bar{\bar{\Delta}}_j^*$ (Experimental Post-Test Difference vs. Control):

- $\bar{\bar{\Delta}}_1^* = [80.1, 88.5] - [57.3, 48.0] = [22.8, 40.5]$
- $\bar{\bar{\Delta}}_2^* = [85.5, 92.3] - [51.5, 42.1] = [34.0, 50.2]$
- $\bar{\bar{\Delta}}_3^* = [75.8, 85.2] - [48.0, 38.5] = [27.3, 46.7]$
- $\bar{\bar{\Delta}}_4^* = [70.2, 80.9] - [33.0, 42.5] = [27.7, 47.9]$

A substantial improvement (positive and significant intervals) is observed in all dimensions for the experimental group after the implementation of the platform, both compared to its initial state and compared to the control group.

To obtain a result that encompasses all dimensions in a single value, Equation 11 ( min of the intervals) is used to represent the "Overall Perceived Impact of the Platform":

- $D_{Impact\_Pre^*} = min([45.5, 55.2], [40.2, 50.8], [35.0, 45.5], [30.5, 40.1]) = [30.5, 40.1]$

- D' $_{\text{Impact\_Post}}$ $=min([80.1, 88.5], [85.5, 92.3], [75.8, 85.2], [70.2, 80.9]) = [70.2, 80.9]$
- Ñ $_{\text{Impact\_Control}}$ $=min([48.0, 57.3], [42.1, 51.5], [38.5, 48.0], [33.0, 42.5]) = [33.0, 42.5]$

Aggregate average results of the "Perceived Overall Impact of the Platform" for the experimental group (Pre and Post) and the control group.
In this case, we will calculate the difference in absolute value to avoid negative numbers when calculating. That is, equation 12 will be used.

$$[a_1, b_1] \ominus [a_2, b_2] = [abs(a_1 - b_2), abs(b_1 - a_2)] \quad (21)$$

$$[70.2, 80.9] \ominus [42.5, 33.0] = [abs(70.2 - 33.0), abs(80.9 - 42.5)] = [37.2, 38.4]$$

For the experimental group, the difference Pre vs. Post:

$$[70.2, 80.9] \ominus [40.1, 30.5] = [abs(70.2 - 30.5), abs(80.9 - 40.1)] = [29.7, 40.8]$$

These results indicate a very marked and positive difference attributable to the digital platform. The difference in post-test impact between the experimental group and the control group is approximately [37.2, 38.4] percentage points, and the improvement within the experimental group itself is [29.7, 40.8] points. This suggests a strong positive correlation between the implementation of the platform and the perceived improvement in wildlife information management and its associated benefits.

**Analysis of the Relationship between the Variables Studied and Recommendations**

**Relationship between Variables:**

The results, analyzed using plithogenic statistics with an interval approach, indicate a **strong positive and significant relationship** between the implementation of the digital platform and the perceived improvement in the four dimensions studied:

1. **Quality and Accessibility of Wildlife Information:** The platform was associated with a perception of more complete, up-to-date, and easily accessible data.
2. **Data Management Efficiency:** Users perceived greater ease in entering and organizing data, reducing duplication and improving report generation.
3. **Decision Support for Conservation:** Greater utility was observed in centralized information for planning and informing conservation actions.
4. **Collaboration and Knowledge Dissemination:** The platform was seen as a tool that facilitates information exchange and standardization.

The "Perceived Overall Impact," aggregated from these dimensions, showed a substantial increase in the experimental group after the platform's implementation, well above baseline levels and those observed in the control group. The application of the interval difference (Equation 12) quantified this improvement, suggesting that the platform is a determining factor in the optimization of information management processes. The indeterminacy captured by the intervals decreased slightly in the post-test for some dimensions, which could indicate greater homogeneity in positive perceptions after the user experience.

**Recommendations:**

1. **Scaling and Adoption:** Given the evidence of positive impact, it is recommended to consider expanding the use of this digital platform to other protected forests or conservation areas with similar wildlife information management challenges.
2. **Ongoing Training and Technical Support:** Ensure initial and ongoing training programs for all users (park rangers, biologists, managers) to maximize the use of all platform features and ensure the quality of the data entered. Responsive technical support is crucial.
3. **Iterative Development and Customization:** Foster a feedback loop with users to identify needs for new features, usability improvements, or specific modules ( e.g. , camera trap data integration, basic spatial analysis) that can be incorporated into future versions of the platform.
4. **Integration with Other Data Sources:** Explore the possibility of integrating the platform with other relevant databases ( e.g. , climate data, institutional geographic information systems, national biodiversity databases) to enrich analysis and decision-making.
5. **Promote Data Culture:** Promote the active use of the platform not only for recording, but also for analysis and reporting that supports adaptive management of the protective forest.
6. **Longitudinal Research:** Continue monitoring the platform's impact over the longer term, using plithogenic statistics to assess its sustainability, adaptation to new needs, and its effective contribution to conservation outcomes ( e.g. , changes in the status of key species populations).
7. **Dissemination of Results:** Share findings on the usefulness of the platform and the assessment methodology with the scientific community and other protected area managers to promote good practices in the use of technology for conservation.

## 5. Conclusion

The evaluation of an IT tool application for fauna information management within the Cerro Blanco Protected Forest was conducted using plithogenic statistics. The findings reveal a positive, multidimensional improvement in perception following the IT tool's application.

Specifically concerning the software, its implementation led to substantial enhancements across several key areas. Firstly, the importance and accessibility of fauna-related information increased substantially, meaning the software application provided faster access to essential, quality, and up-to-date information. The efficiency of data management also saw a significant increase; it became easier to input, archive, and report findings, as the application allowed for reduced redundancy in efforts. Consequently, this increased access to resources for non-duplicated, standardized efforts. Furthermore, the software significantly improved support for determining conservation efforts, providing a more foundational understanding from which to plan courses of action. Finally, there was an increased positive perception regarding inter-institutional collaboration and standardized information, indicating that the application facilitated easier transfer and standardization of efforts.

The practical application of this software and its documented impact can improve protected area management by scientifically communicating value where such value was not previously attributed and documented. Therefore, the empirical evidence of value added by this IT tool serves as an endorsement for such software and comparable tools in similar repeatable conservation efforts that encounter challenges with constant reporting. Ultimately, the decisively improved benefits for field rangers achieving managerial and operational success, biologists determining ecological analyses, and managers finding new revenue sources through more transparent operations mean that technology, such as the software evaluated, is a crucial asset for addressing complex conservation agreements like adaptive management.

Methodologically, this study represents both an innovative approach and a strong application of plithogenic statistics to the assessment of conservation technology. The capacity of this statistical procedure to account for human perception uncertainty and the sample population variability—data came from multiple institutions—offers advantages over traditional statistical approaches in evaluating such software. Assessing the Overall Perceived Impact as a final summation of all categories provides a comprehensive assessment that is straightforward to explain and applicable for future researchers.

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