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Study on Illegal Wildlife Trade Based on Linear Regression and Interpolated Prediction

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ABSTRACT

Against the backdrop of the current growing problem of illegal wildlife trade globally, this paper constructs a data-driven model that aims to significantly reduce the scale and impact of this trade. Through the collection and in-depth analysis of global statistics, we identified the Wildlife Conservation Society (WCS) as the ideal partner for the project. We made a strong argument that WCS has the influence and resources needed to implement the project. Using linear regression modeling and interpolated predictive modeling for inertia analysis, we demonstrated synergies between the project and WCS's goals. Based on the assessment of the power and resources required for WCS to implement the project, we propose a resource allocation model and discuss three policy options, namely mandatory, incentive, and cooperative policies, to ensure that the client has flexibility in the decision-making process. This study aims to make a significant contribution to global biodiversity conservation and to effectively address the threats to ecological balance posed by illegal wildlife trade.

KEYWORDS

Linear Regression Model, Interpolated Predictive Model, Illegal Wildlife Trade

1. INTRODUCTION

Illegal wildlife trade is one of the serious challenges facing the world today, with a huge negative impact on the ecological balance of wildlife and biodiversity. According to the report, this issue has attracted great attention from authoritative organizations such as the International Union for Conservation of Nature (IUCN) and the Worldwide Fund for Nature (WWF), as it not only threatens the survival of many species, but also wreaks havoc on the global ecosystem [1]. The illegal wildlife trade, estimated to be worth US$26.5 billion annually, has become the fourth largest illegal trade in the world. From ivory and rhino horn to tiger skins, rare plants and timber, the scope of this trade is alarming. Unauthorized hunting, transporting, and selling activities have resulted in many species being put at risk of overfishing and poaching, putting their survival at risk.

To address this daunting challenge, we built a data-driven model designed to significantly reduce the scale and impact of the illegal wildlife trade and contribute to global biodiversity conservation. We identified the Wildlife Conservation Society (WCS) as an ideal partner through an in-depth analysis of global data, combined with the application of linear regression and interpolated predictive models. In this paper, we detail our thinking and analytical process, including client selection, fit of project objectives with WCS, resource needs assessment, and policy options for different contexts. By doing so, we expect to provide strong support to address illegal wildlife trade and make a positive contribution to the conservation of the planet's precious biodiversity.

2. DATA PRE-PROCESSING

2.1. Data collection

We collected global statistics from 2003 to 2023, as well as specific personal data from 2013 to 2023 in several countries, such as China, India, the United States, Vietnam, South Africa, Indonesia, the Republic of Tanzania, Kenya, and the United States. This data ensures accurate descriptions and predictions of the problem of illegal wildlife trade. We will conduct statistical analysis after preprocessing it.

2.2. Data processing

However, due to incomplete national data disclosure, some data on illegal hunting of wildlife is missing. Such estimates are often based on seizure data reported at the national level, which are subject to detection and reporting biases [2]. To solve this problem, we use the following methods to refine and complete our data.

The following are the detailed processing steps:

Coding and data quantification: encode and quantify the data to facilitate subsequent calculations.

Solve the null problem: To avoid the effect of the null value on the result, the null value should be removed in the code.

Outlier processing: Use IQR method to identify outliers and replace outliers with mean values. The accuracy of the calculation results is ensured, and the outlier processing is carried out for each column of data.

Standardized processing: Due to large data differences, standardized processing is required. In the comprehensive evaluation, the index with larger variation range of variable values will have a greater impact. To eliminate the influence of dimensions, it is necessary to normalize indicators and then conduct subsequent analysis.

Consistency processing: Ensure that the direction of action of indicators is unified. For example, when evaluating the effect of multiple indicators comprehensively, the larger the positive indicator, the better, and the smaller the negative indicator, the better. If the combined effect of these two indicators is considered at the same time, it cannot be simply added because of the different directions. Therefore, it is necessary to treat inverse indicators uniformly.

The resulting data for eight representative countries are shown in Figure 1 below.

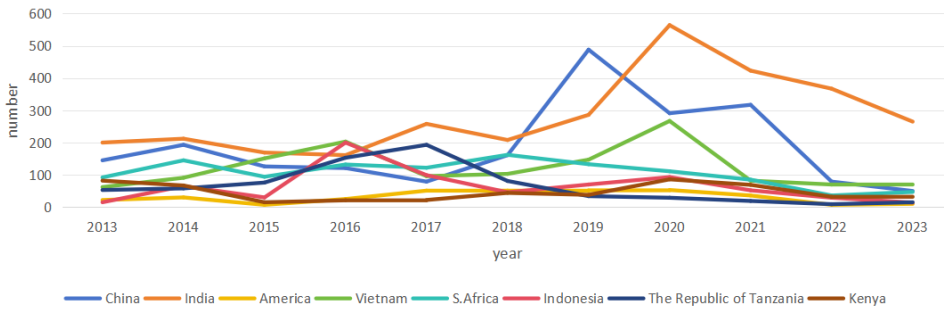

Figure 1. The number of illegal transactions per year from 2013 to 2023

3. CLIENT CHOICE

3.1. Client analysis

The best client for reducing the illegal wildlife trade should be an organization with the ability to make an impact on a global or regional scale.

Some of the best clients can be international environmental organizations such as WWF and TRAFFIC, government agencies such as national wildlife and environmental protection authorities, and multinational cooperative agencies such as the United Nations Environment Programme (UNEP).

These organizations have the necessary authority, resources, and interest to implement the relevant projects, including but not limited to the ability to enact and enforce laws, coordinate cross-border cooperation, financial resources, scientific research and technical tools, and professional personnel. They share a long-term commitment to protecting the environment and maintaining biodiversity.

When selecting clients, they need to consider their interest and responsibility in environmental protection and wildlife conservation, as well as their ability in terms of resources and power. Government departments often have legislative, enforcement and regulatory powers and play an important role in wildlife trade control. International organizations have the global reach and resources to support and drive the fight against illegal wildlife trade by coordinating international cooperation and policy development. NGO and environmental protection organizations play an important role in wildlife conservation, often with extensive experience and expertise, and can promote government and public attention to illegal trade through education, public opinion guidance and action support. Some multinational companies may also be concerned about environmental protection and sustainable development, and they can promote sustainable development and wildlife protection through the management of procurement and production chains.

Therefore, the selection of clients' needs to consider their ability and willingness in policy development, resource investment, international cooperation, and public influence to ensure that the project can be effectively implemented and achieve sustainable results.

Here is our mathematical model:

$$\text{Maximize } F(x_1, x_2, \cdots, x_n) = \sum_{s=1}^{j} w_j \cdot f_j(x_1, x_2, \cdots, x_n) \tag{1}$$

$$\text{Subject to } \ C_k(x_1, x_2, \cdots, x_n) \leq R_k, \forall k \tag{2}$$

$$x_i \geq 0\ , \ \forall i \tag{3}$$

Assuming that: x_i represents the implementation intensity of strategy i (such as capital investment, policy support, human resource allocation, etc.) $f_j(x_1, x_2, \cdots, x_n)$ represents the j objective function (e.g., reducing trade volume, strengthening law enforcement and crackdown, raising public awareness, strengthening international cooperation). $C_k(x_1, x_2, \cdots, x_n) \leq R_k$ represents the limit of the k resource, where R_k represents the available amount of that resource. w_j represents the weight of the j goal, indicating the relative importance of the different targets.

Figure 2 shows the effect of reducing illegal wildlife trade as funding increases, the results show that the America is the most relevant country.

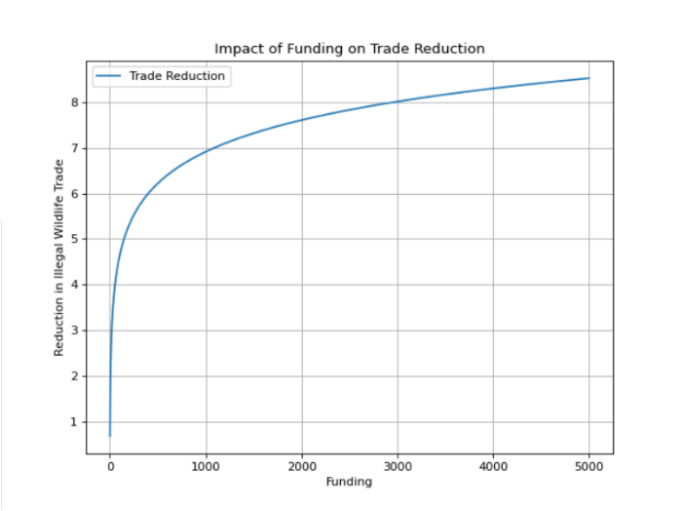

Figure 2. The effect of reducing illegal wildlife trade

3.2. Client capability

Here are seven things we can do about what the client can do.

Raise public awareness: Enhance public awareness and understanding of the illegal wildlife trade, and communicate to the public the harm of illegal wildlife trade to animals and ecosystems through educational activities, social media campaigns, publicity materials, etc.

Strengthen law enforcement and counteraction: Work with law enforcement agencies to develop and enforce strong laws and policies against illegal wildlife trade and increase efforts to combat illegal practices and improve the success rate of arrests, prosecutions, and convictions.

Establish partnerships: Establish partnerships with other relevant organizations, international agencies, research institutions, NGOs, etc., to jointly conduct research, monitoring and action on illegal wildlife trade, share information and resources, and jointly develop solutions.

Support community participation and sustainable development: By supporting the participation of local communities, providing alternative sources of income and sustainable development projects, reducing incentives for illegal wildlife trade, and encouraging communities to protect wildlife and the ecological environment. At the local scale, campaigns to educate consumers about illegal wildlife trade and its impact may help to reduce demand [3].

Strengthen international cooperation: Cooperate with other countries and international organizations to strengthen cross-border cooperation and information sharing, combat transnational illegal wildlife trade, and jointly develop transnational cooperation mechanisms and standards.

Support wildlife conservation and habitat protection: Increase support for wildlife conservation and habitat protection and reduce opportunities for illegal wildlife trade through the establishment of protected areas, habitat restoration, and wildlife conservation facilities.

Monitoring and research: Strengthen the monitoring and research of the illegal wildlife trade, collect, and analyze data, assess the scale and trends of the trade, understand the structure and operation of the illegal trade network, and provide a scientific basis for formulating and adjusting countermeasures.

4. MODEL CONSTRUCTION AND ANALYSIS OF RESULTS

4.1. Linear regression model

To convince clients, we can construct a Linear Regression Model that predicts the impact of different strategies and resource allocation on reducing the volume of illegal wildlife trade and optimize resource allocation through a Linear Programming Model [4]. The formula for the Linear Regression Model is as follows:

$$W = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon \tag{4}$$

W represents the amount of illegal wildlife trade reduced (target variable). $X_1, X_2 \ldots X_n$ represents a variety of different strategies and resource allocations (predictors), such as the amount of money invested, the intensity of technical support, and the number of public education campaigns. $\beta_1, \beta_2 \ldots \beta_n$represents the strength of each strategy's influence on the target variable. ϵ is the error term. The Linear Programming Model is briefly established as follows:

$$\text{Maximize } F(x_1, x_2, \cdots, x_n) = \sum_{j=1}^{n} \beta_j X_j \tag{5}$$

$$\text{Subject to } \sum_{j=1}^{n} C_j X_j \leq B \tag{6}$$

$$X_j \geq 0\,, \quad \forall j \tag{7}$$

C_j is the first kind of strategy cost j. B is the total budget.

Based on the above multiple regression model, we visualized the relationship between actual and predicted values and the extent to which the independent variables influence the predicted results. This helps us to understand the correlation between illegal animal trade and other indicators, as shown in Figure 3 and Figure 4, and the model can be used to predict future trends in illegal animal trade.

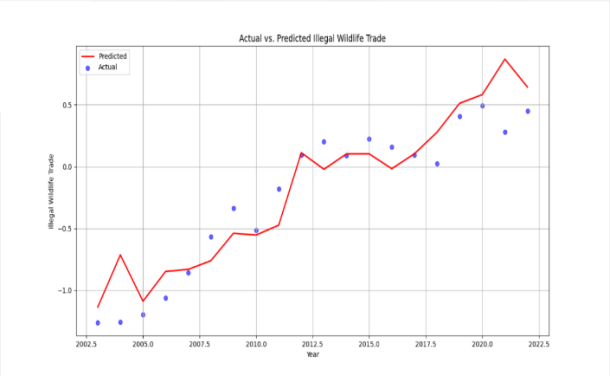

Figure 3. Multiple linear regression

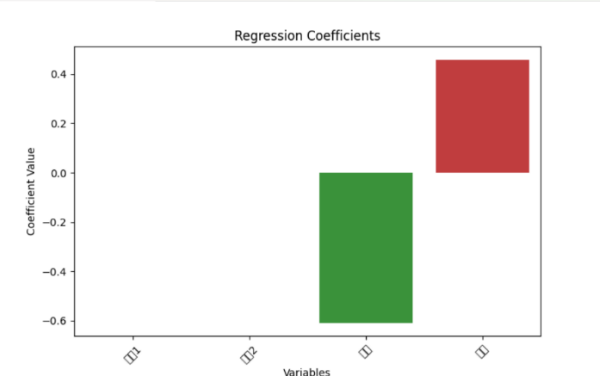

Figure 4. Linear regression coefficient heat map

4.2. Interpolation prediction model

To forecast unknown values, it is a crucial task to develop Interpolation Prediction Model. By employing mathematical modeling and analyzing the magnitude of illegal wildlife trade over recent years, we can extrapolate the correlation between known data points to unfamiliar data, thereby providing precise numerical estimations for unknown information [5]. The objective of this Predictive Model is to accurately anticipate the future trends in wildlife trade based on existing data. Through the spline interpolation method, we successfully performed the interpolation and visualized the interpolation results and the interpolation curves. This helps us to understand the trend of the illegal animal trade index over time, as shown in Figure 5.

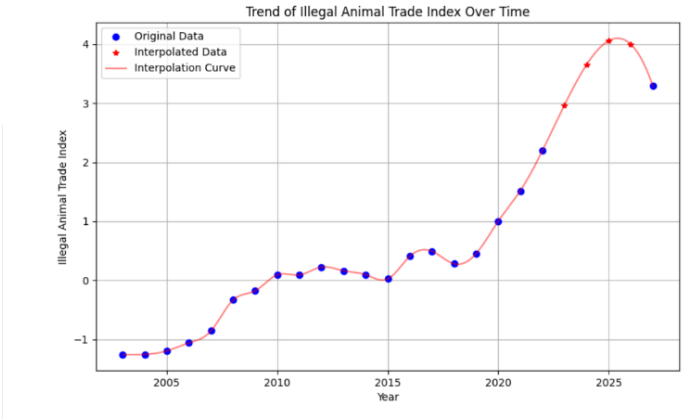

Figure 5. Interpolation Prediction Model

5. ADDITIONAL POWER AND RESOURCE ANALYSIS

5.1. Power and resources

To implement these decisions, the following additional powers and resources are usually required:

Legal Power: It needs the support of the legislature to support the implementation of decisions by amending or making new laws, regulations, etc. At the same time, administrative agencies also need to strengthen their powers to enforce laws and policies, and to conduct supervision and enforcement.

Funding: Funding is essential to increase staff, upgrade technical equipment, education and advocacy. International cooperation also requires financial support to ensure collaboration and technical assistance among different countries.

Human Resources: Professional law enforcement personnel need to be trained, such as customs, border control, wildlife supervision agencies. At the same time, education and researchers are also needed to carry out relevant scientific research and public education activities.

Technical Support: Regulating and monitoring illegal animal trade often requires specialized technical tools, such as DNA identification technology, tracking systems, and online monitoring databases. At the same time, improved data analysis and intelligence gathering capabilities can help identify illicit trade patterns and networks.

Diplomatic Resources: Government departments need international law and diplomatic negotiating capabilities to promote international cooperation and develop agreements. Policymakers may need to mobilize diplomatic channels to promote the implementation of transnational laws and treaties.

Public Relations and Communication Platforms: Public relations teams and communication channels such as social media, television, radio is needed for effective education and advocacy. Cooperation with civil society organizations and community grassroots organizations can expand the influence of publicity and the coverage of education. A report shows that many people are willing to use poaching hotlines to report violations [6].

5.2. Resource allocation model

Suppose the client needs the following additional resources: Legal Power (LP), Funding (FD), Human Resources (HR), Technical Support (TS), Diplomatic Resources (DR), Public Relations and Communication Platforms (PRCP)

Suppose the client already has some resources, and now defines the additional resources to be used as $x_L, x_F, x_H, x_T, x_D, x_P$

Assumptions: $p_L, p_F, p_H, p_T, p_D, p_P$ is the unit cost of each resource, C is the total cost of additional resources, k_{ij} is the demand coefficient of the class j resource for the i project objective, s_i is the minimum number of resources required to achieve the i project objective.

The following is a representation of the Resource Allocation Model:

$$\text{Minimize } C = p_L x_L + p_F x_F + p_H x_H + p_T x_T + p_D x_D + p_P x_P \tag{8}$$

$$\text{Subject to } k_{1L} x_L + k_{1F} x_F + k_{1H} x_H + k_{1T} x_T + k_{1D} x_D + k_{1P} x_P \geq s_1 \tag{9}$$

$$k_{2L} x_L + k_{2F} x_F + k_{2H} x_H + k_{2T} x_T + k_{2D} x_D + k_{2P} x_P \geq s_2 \tag{10}$$

$$k_{iL} x_L + k_{iF} x_F + k_{iH} x_H + k_{iT} x_T + k_{iD} x_D + k_{iP} x_P \geq s_i \tag{11}$$

$$for \quad x_L, x_F, x_H, x_T, x_D, x_P \geq 0 \tag{12}$$

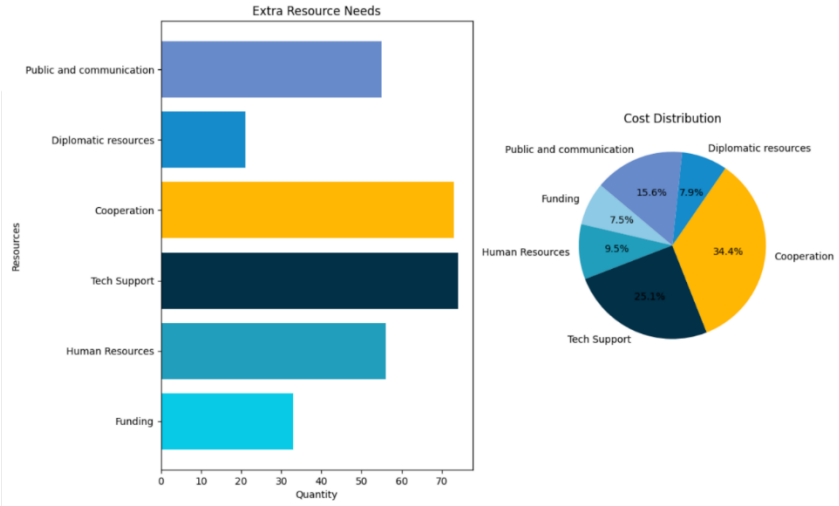

Figure 6. Additional resource volume and cost distribution

Figure 6 shows the variation in the number of additional resources required for project execution and the distribution of costs based on resource requirements and unit costs. These visualizations help customers visualize the magnitude of additional resource requirements and cost distribution to support project decision making. In practice, resource requirements and cost data should be based on detailed project planning and budget analysis.

6. POLICY PROPOSAL

Although the Convention on International Trade in Endangered Species of Wild Fauna and Flora has written a series of regulations to protect animals, the implementation is not thorough enough. One report showed that CITES reports ranged from 376% more than US customs reported (live coral exports, 2000) to 5,202% more than CITES reported (conch exports, 2000) [7]. Therefore, this paper puts forward three kinds of policies: mandatory strategy, incentive policy, and cooperation policy. The combination of the three policies can better promote wildlife protection.

6.1. Mandatory policy

The government provides training and technical support to improve the ability of law enforcement officers to identify and combat illegal wildlife trade. The state has formulated strict operating rules and legal procedures to ensure the legality and impartiality of law enforcement actions. Courts have increased criminal penalties for illegal wildlife trade, making illegal activities more costly and discouraging poachers and smugglers from selling wildlife. Special trial teams have been set up for important cases to improve the speed and effectiveness of judicial handling. Strengthen

communication and coordination in the criminal justice system to ensure that the fight against illegal wildlife trade transcends national borders. The State establishes special wildlife law enforcement departments or units to strengthen supervision and law enforcement actions against wildlife trade.

6.2. Incentive policy

Provide whistleblower protection and anonymity mechanisms to ensure the safety of whistleblowers. Establish an effective reward system, according to the value of the information and the success of the arrest of the reward. Provide financial and technical support to help local communities and peoples develop sustainable wildlife resource use projects. Incentivize innovation and the use of technology to promote sustainable agriculture and aquaculture and reduce reliance on illegal wildlife trade. Provide training and education to raise awareness and awareness of sustainable use among the local population. Establish a tip-off reward fund to encourage the public to provide valuable information and leads.

6.3. Cooperative policy

Establish cooperation frameworks and mechanisms with relevant international organizations, countries, and regions to share intelligence and resources. Participate in international conferences and forums to promote policy dialogue and cooperative actions for international cooperation. Signed cooperation agreements with key countries to jointly combat the transnational crime of illegal wildlife trade. Establish wildlife protection alliances or institutions within the region to strengthen inter-regional cooperation and coordination. Jointly develop and promote regional protection policies and action plans and establish common enforcement and regulatory standards. Promote information sharing and technology exchange in the region and establish joint patrol and reconnaissance mechanisms.

7. CONCLUSIONS

Illegal wildlife trade is a serious global problem that poses a great threat to biodiversity and ecological balance. In response to this challenge, we constructed a data-driven model that aims to significantly reduce the scale and impact of illegal trade and contribute to global biodiversity conservation. For client selection, we identified the Wildlife Conservation Society (WCS) as an ideal partner based on its influence and resources in the field of wildlife conservation. Through the use of linear regression modeling and interpolated predictive modeling, we demonstrated how well the project fits WCS's objectives and how it can be seamlessly integrated. In terms of resource needs assessment, we evaluate the additional authority and resources that WCS needs to effectively implement the program and propose three policy options: mandatory, incentive, and cooperative policies to provide flexibility to clients in the decision-making process.

In summary, we believe that the research in this paper will have a substantial impact on reducing illegal wildlife trade and contribute positively to global biodiversity conservation.

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