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Study on the Status of Illegal Trade in Wild Fauna and Flora Based on Multiple Linear Stepwise Regression and DEA

Qiting Ou[1,*]

[1]*Shi Cheng College, Hunan Normal University, Changsha, China*
[*]*Corresponding author: 1870313917@qq.com*

Abstract: *This study aims to assess the effectiveness of the International Coordinating Body for Combating Wildlife Crime (ICCWC) in the field of combating illegal wildlife trade. The selection of ICCWC was successfully validated in terms of rankings and ratios by using the Analytical Hierarchy Process (AHP) to determine the weights of the indicators and the Weighted Rank Sum Ratio (WRSR) as a score for each organisation. Next, a predictive model for project implementation was developed using multiple linear stepwise regression methodology, which predicted a significant reduction in illegal wildlife trade over the next five years. In addition, the combined benefit value of the project was calculated to be 1 by Data Envelopment Analysis (DEA), indicating that our project has the best relative effectiveness. Finally, ICCWC's need for additional resources was determined through a linear programming approach, and a predictive model of measurable impacts was developed. The results of the study indicate that our programme will significantly reduce the volume of illegal wildlife trade and contribute to the growth rate of per capita disposable income. In summary, this study provides strong support and guidance for the future development of ICCWC.*

Keywords: *AHP, Multiple linear stepwise regression, DEA*

1. Introduction

The illegal wildlife trade poses a serious threat to ecosystems and the survival of species, which has prompted the international community to join forces and take measures to combat this global problem. In this context, the role of the International Coordinating Body on Combating Wildlife Crime (ICCWC) has become increasingly important. This study aims to assess the effectiveness of ICCWC in the field of combating illegal wildlife trade and to formulate a plan for its development in the next five years. By using methods such as Analytic Hierarchy Process (AHP) and Weighted Rank Sum Ratio (WRSR), we successfully validated the selection of ICCWC in terms of ranking and effectiveness. The multiple linear stepwise regression method was further used to develop a predictive model for project implementation, which predicted a significant reduction in illegal wildlife trade over the next five years. In addition, the combined effectiveness value of the project was calculated to be 1 by Data Envelopment Analysis (DEA), indicating that our project had the best relative effectiveness. This study also determined ICCWC's need for additional resources through a linear programming approach, as well as developed a predictive model for measurable impacts. The findings show that our programme is expected to significantly reduce the volume of illegal wildlife trade and contribute to the growth rate of per capita disposable income. These findings provide strong support and guidance for the future development of ICCWC and contribute positively to the cause of global wildlife conservation [1].

2. Comprehensive Evaluation Modle for Verification

2.1 Determining Weights Using the Analytic Hierarchy Process

We chose the International Consortium on Combating Wildlife Crime (ICCWC) as our client based on an analysis of the organisations' funding, technological tools, law enforcement capabilities, cross-border cooperation coordination and interests.

Next, we verify the results obtained through rational analysis.

We selected three primary indicators: resources, power, and interest, as well as five secondary

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indicators: organizational funding, technological tools, enforcement power, transnational cooperation coordination, and interest.

Using the Analytic Hierarchy Process (AHP) to calculate weights [2], the AHP results showed that the largest eigenvalue is 5.409. According to the RI table, the corresponding RI value is 1.11, hence $CR = CI/RI = 0.092 < 0.1$, passing the consistency check.

The calculated weights are as follows: the weight for organizational funding is 0.09395, for technological tools is 0.13574, for enforcement power is 0.33048, for transnational cooperation coordination is 0.19943, and for interest is 0.2404.

2.2 Comprehensive Scoring Calculation Based on the Rank Sum Ratio Synthesis Evaluation Model

Assuming the seven objects we have selected are:

$$(\alpha_1, \alpha_2, \dots, \alpha_7) \tag{1}$$

They can be considered as a sample space with a statistical capacity of 7.

Arranged in ascending order to obtain a new sequence:

$$(\beta_1, \beta_2, \dots, \beta_7) \tag{2}$$

Define $k = 1,2,3, \dots ,7$, if there are:

$$\alpha_i = \beta_k \tag{3}$$

Then k is the rank of x in the y sample, denoted as K_i.

For each $i = 1, \dots ,7$, we define K_i as the i-th statistic.

Next, utilizing the whole rank sum ratio method, we rank each statistic. Since the indicators in this case are all positive indicators, we adopt an ascending order. The ordinal number i is thus considered the value of the rank.

Figure 1: Ranks of Indicators Corresponding to Each Object

We calculate the ranks as shown in the Figure 1 by searching for relevant data and analyzing literature as well as reports from experts.

Finally, we obtain the Weighted Rank Sum Ratio $WRSR$ as final score by summing the products of weights and the values:

$$WRSR_i = \frac{1}{n}\sum_{j=1}^{m} \omega_j R_{ij}, (m = 5, n = 7) \tag{4}$$

Here, i represents an organization within a certain selection range, and j represents an evaluation indicator.

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Table 1: Weighted Rank Sum Ratios and Order Results for Each Object

organization	WRSR	WRSR rank
ICCWC	0.84	1
WAP	0.543	4
WCS	0.348	6
CWCA	0.486	5
DW	0.339	7
UNEP	0.667	2
ICPO	0.607	3

The results of the calculations are shown in Table 1, where ICCWC is ranked first with an RSR score of 0.84. This indicates that our results have passed the test, demonstrating that ICCWC is the most compliant in terms of the authority, resources and benefits required to combat illegal wildlife trade.

3. Current State of Global Illegal Wildlife Trade

3.1 Illegal Wildlife Trade Volume and Its Changes

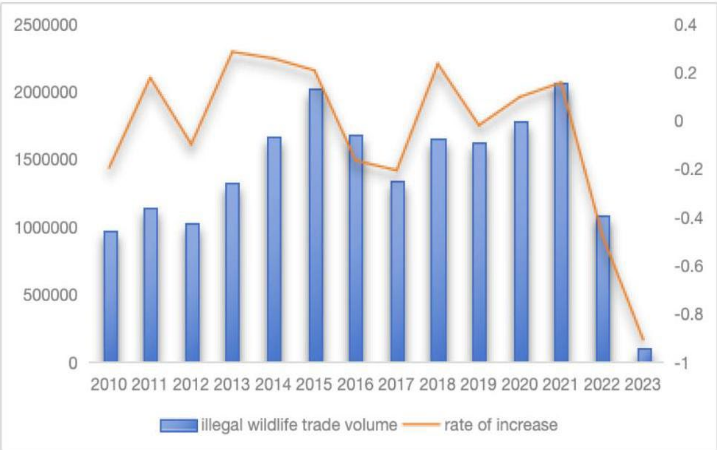

Figure 2: The Volume of Illegal Wildlife Trade and Its Changes

As illustrated in Figure 2, we can derive an analysis of the volume of global illegal wildlife trade:

• The growth rate of the illegal wildlife trade volume oscillates around zero, indicating that law enforcement agencies and criminal organizations involved in illegal wildlife trade have been engaged in a relentless struggle.

• Since 2021, there has been a significant decline in the volume of illegal wildlife trade, suggesting that recent efforts to combat this illegal trade have been highly effective. This success provides valuable insights and references for our projects.

3.2 Growth Rate of Illegal Wildlife Trade Volume

We selected the major participating countries in the global illegal wildlife trade, including source countries, transit countries, and demand countries, to calculate the average growth rate of the illegal wildlife trade volume from 2010 to 2023.

The Rank-Sum Ratio Comprehensive Evaluation Model was proposed in 1988 by Professor Tian Fengtiao, a Chinese scholar and former member of the Chinese Academy of Preventive Medicine. It is a statistical analysis method that integrates the advantages of both classical parametric statistics and modern non-parametric statistics [3].

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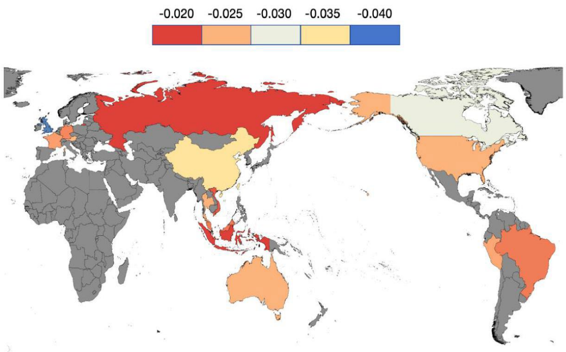


Figure 3: The Growth Rate of Illegal Wildlife Trade Volume

As shown in Figure 3, we can obtain a global analysis of the average growth rate of the illegal wildlife trade volume:

• The average growth rate of the illegal wildlife trade volume from 2010 to 2023 for the major participating countries is negative, indicating that countries are actively combating criminal organizations involved in illegal wildlife trade.

• Among them, the United Kingdom has the lowest average growth rate of illegal wildlife trade volume, and its policies to combat illegal wildlife trade can serve as a reference.

3.3 Data-driven Analysis

3.3.1 Project Execution Prediction Model

Assuming that the correlation between the illegal wildlife trade volume and the stage completion check indicators remains constant during the plan's implementation.

Let fund input (FI), the number of joint enforcement actions (NJE), wildlife trade volume (WTV), unemployment rate in source countries (Urate), per capita GNI in source countries $(AGNI)$, World Bank loans (L), total area of global nature reserves (A), and the number of relevant treaties (N) be the indicators.

From the results of the F-test, we can analyze that the significance P-value is 0.00012, which is less than the significance level of 0.01, rejecting the null hypothesis that the regression coefficients are zero, indicating that it is reasonable to fit with stepwise regression.

In the multivariate linear stepwise regression model [4], we filter according to the significance of each indicator's effect on IWTV, retaining the variables FI, NJE, WTV :

$$IWTV = \alpha_0 + \alpha_1 \cdot NJE + \alpha_2 \cdot FI + \alpha_3 \cdot WTV \tag{5}$$

Where, $\alpha_0 = -1163455, \alpha_1 = 98923.323, \alpha_2 = 42979.953, \alpha_3 = 0.001$.

Figure 4 show that our final R^2 value is 0.99, very close to 1, indicating a good fit; for the collinearity of variables, all VIF are less than 10, so there is no multicollinearity problem in the model, and the model is well-constructed.

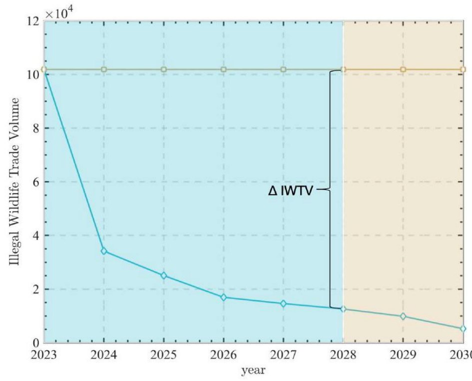


Figure 4: Prediction of Changes in the Value of Illegal Wildlife Trade

3.3.2 Project Efficiency Analysis Model

To analyze our project's efficiency in utilizing resources such as fund inputs and joint enforcement actions, we innovatively introduce Data Envelopment Analysis (DEA) [5].

Targeting the efficiency index of the indicators, considering radical conditions:

$$\sum \tau_j = 1, j = 1,2, \dots n \tag{6}$$

In conjunction with the efficiency constraints of each indicator, the BCC model can be obtained:

$$\begin{cases} \min\eta \\ \text{s.t. } \sum_{j=1}^{n} \tau_j y_j + s^+ = \eta x_0 \\ \sum_{j=1}^{n} \tau_j y_j - d^- = \eta y_0 \\ \sum_j = 1, j = 1,2, \dots n \\ d^+ \geq 0, d^- \leq 0 \end{cases} \tag{7}$$

Wherein, d^+represents the slack variable, and d^-represents the surplus variable, which indicate the amount of input that needs to be reduced and the amount of output that needs to be increased, respectively, to achieve the optimal allocation.

If $\eta^* = 1$ and $d^{*+} = 0, d^{*-} = 0$, then the indicator is DEA effective, indicating both technical efficiency and scale efficiency.

If $\eta^* = 1$ but $d^{*+} > 0$ or $d^{*-} > 0$, it is DEA weakly effective, with technical efficiency and scale efficiency not coexisting.

If $\eta^* < 1$, it is not DEA effective, meaning it is neither technically efficient nor scale efficient.

We treat resources such as fund inputs and joint enforcement actions as inputs, and the reduction in the illegal wildlife trade volume compared to 2023 as the output. We obtained a scale efficiency of 1, a technical efficiency of 1, and an overall efficiency of 1 for the project, indicating that our project's input-output structure is rational and has optimal relative efficiency.

4. Additional Resource Needs Model

4.1 Multivariate Linear Programming Measure

Considering the limited total amount of actual resources and power of ICCWC, let the total cost of resource and power be denoted as Pr. The demand for each project resource is denoted as x_i, with a unit cost of y_i.

Considering that the achievement of each project goal requires a minimum amount of resources, let's assume the minimum resource amount for project goal j is s_j, resulting in the constraint conditions:

$$\text{s.t. } \sum_{i=1}^{8} x_{ij} y_i \gamma_{ij} \geq S_j (j = 1,2, \dots, 7) \tag{8}$$

Where γ_{ij} is the demand coefficient for the i-th project resource input for the j-th project goal. Taking the total cost of resource power z as the objective function, with the project resource demand x_i as decision variables, the goal is to minimize the total cost, thereby establishing a multilinear programming model:

$$\Pr = \sum_{i=1}^{8} x_i y_i \tag{9}$$

4.2 Additional Resource Assistance

The results obtained through MATLAB solution are shown in Figure 5.

Increasing the proportion of investments in areas Funding Support, Enforcement Capacity, Science and Technology, and International Cooperation and Collaboration Platform can reduce overall costs, reflecting the maximum effectiveness of investments in these four aspects, thus necessitating additional assistance.

The detailed analysis is as follows:

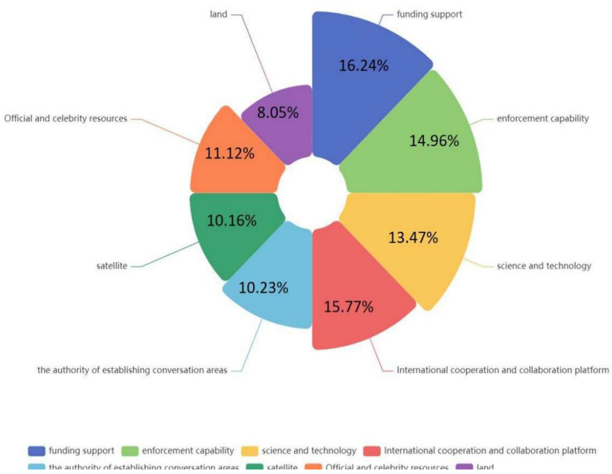


Figure 5: Relative Demand for Project Resources

5. Measurable Impacts Prediction Model

5.1 Grey Prediction Measure

Step 1: Data Processing

Due to the scarcity and irregularity of data on illegal trade volumes and per capita disposable income without project execution, we use an accumulative method to obtain a new sequence [6].

$$x^{(1)} = \left(x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n)\right) \tag{10}$$

Where: $x^{(1)}(m) = \sum_{\mathrm{i=1}}^{\mathrm{m}} x^{(0)}(i), m = 1,2, \ldots, n \cdot x^{(1)}(m)$ is the indicators before cumulative addition.

Step 2: Differential Equation Establishment and Solution

After accumulation, the values tend to follow an exponential model, hence a firstorder linear ordinary differential equation is established:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \tag{11}$$

By applying the difference method to eliminate the randomness of the data, and combining it with the condition of minimizing the sum of squared deviations, we can solve for:

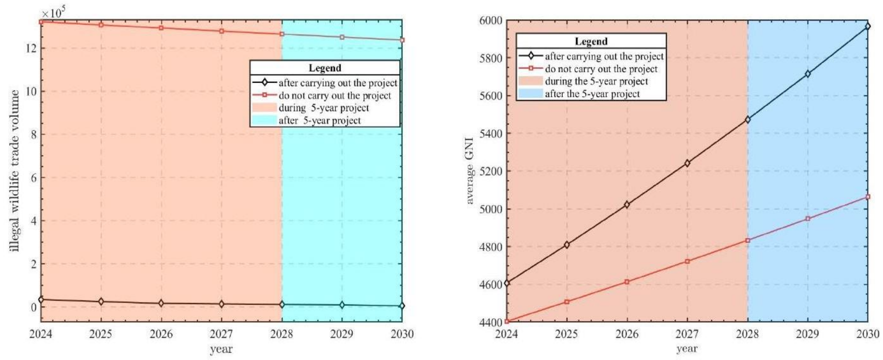
$$\hat{x}^{(0)}(m+1) = \hat{x}^{(1)}(m+1) - \hat{x}^{(1)}(m) = (1 - e^{a})\left[x^{(0)}(1) - \frac{\hat{b}}{a}\right] e^{-\hat{a}m}, m = 1,2, \ldots, n-1 \tag{12}$$

5.2 Analysis of Measurable Impact Results

We measure the changes in the volume of illegal wildlife trade over the next 5 years (without and with intervention) (Figure 6) and find that, without our proposed measures, the reduction in illegal wildlife trade will be slow, with a trade volume of $1,624,250 still expected by 2028. With our project plan, the illegal wildlife trade volume is expected to decrease rapidly, with an 87% reduction in trade volume by 2028 compared to 2023.

By examining the export countries involved in the illegal wildlife trade, we measure the impact of our plan through changes in per capita disposable income.

Over the next five years, if our plan is implemented, the growth rate of per capita disposable income in the export countries will be higher than that without our plan, effectively improving the living standards of the people in these countries. This will reduce reliance on wildlife trade for income, thereby decreasing illegal wildlife trade.



(a) The Volume of Illegal Wildlife Trade (b) The Per Capita Disposable Income

Figure 6: Comparison without and with intervention

6. Conclusions

The International Coordinating Body for Combating Wildlife Crime (ICCWC) plays an important role in the field of combating illegal wildlife trade. Using a variety of methods and models, we have successfully assessed the effectiveness of the ICCWC and proposed a concrete plan for the next five years. Our study shows that the implementation of our proposed plan is expected to significantly reduce the volume of illegal wildlife trade and contribute to the per capita disposable income growth rate. Through data envelopment analysis and linear programming methods, we identified ICCWC's need for additional resources and developed predictive models with measurable impacts. These findings provide important support and guidance for the future development of ICCWC.

In future studies, we recommend further attention to the implementation details and execution effects of ICCWC in order to continuously optimise and enhance its effectiveness. At the same time, there is a need to further explore how to strengthen international cooperation and coordination in order to jointly address the global challenge of illegal wildlife trade. Ultimately, we believe that through sustained efforts and cooperation, the goals of protecting wildlife resources and maintaining ecological balance will be better achieved. We look forward to the future development of ICCWC and its greater contribution to the cause of global biodiversity and sustainable development.

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