

Technology-Driven Conservation of Biodiversity: Modelling and Solving the USFWS Operation Berserk Project

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Abstract. This paper is based on a modern technology and data-driven approach to modeling and solving the problem that the U.S. Fish and Wildlife Service (USFWS) should select for the "Operation Rush" project. The importance of modern science and technology, such as remote sensing, big data, and artificial intelligence, in combating illegal wildlife trade is highlighted through literature support and team analysis. The project is centred on drone and remote sensing technologies, and uses cloud computing to transmit and process wildlife data in real time to support the conservation of biodiversity and the fight against illegal wildlife trade. This paper proposes a match between the work of Operation Frenzy and the USFWS, and highlights science, technology and innovation as the key to the link between the two. A Bayesian linear regression model was used to quantify and validate the strong positive correlation between the project objectives and the USFWS strategic plan objectives. The strong correlation between predicted and true values was reconfirmed through the analysis of Pearson correlation coefficients.

Keywords: Remote Sensing Technology, Illegal Wildlife Trade, Bayesian Linear Regression Model.

1. Introduction

Illegal wildlife trade has become a major challenge globally, posing a serious threat to biodiversity and the health of ecosystems. In order to tackle this problem, governments and organisations are actively looking for innovative solutions. In recent years, with the rapid development of science and technology, modern scientific tools such as remote sensing technology, big data, artificial intelligence and blockchain technology have shown great potential in combating illegal wildlife trade. By utilising these advanced technologies, multi-dimensional monitoring of wildlife and their habitats can be achieved, leading to more effective wildlife protection^[1].

Despite the continuous advancement of scientific and technological tools, how to apply these technologies to practical wildlife conservation work and match them with the objectives of the relevant organisations is still an important issue. This project aims to support the work of the U.S. Fish and Wildlife Service (USFWS) in combating illegal wildlife trade and protecting biodiversity through the Riptide Operation programme, which combines high-tech means such as drone remote sensing technology and cloud computing. However, how to prove the effectiveness and applicability of these technological tools has become a key issue in the advancement of the project^[2-4].

To further convince the USFWS to adopt our Riptide Operation programme, we will quantify the correlation between the project objectives and the strategic objectives of the USFWS through a data-driven analytical approach. Specifically, we will employ a Bayesian linear regression model that integrates prior knowledge and provides estimates of predictive uncertainty to deal with the complexity and adaptability in data analysis. By building this model, we can obtain the predicted values of the project objectives in relation to the USFWS strategic objectives and verify the positive correlation between the predicted and true values using the Shapiro-Wilk normality test and Pearson correlation coefficient calculations, thus demonstrating the applicability and effectiveness of the Riptide Operation programme^[5-6].

2. Why should USFWS choose our Riptide Operation

2.1. Literature support for the project

Based on a large amount of literature from academic websites such as Google Scholar, Web of Science and Scopus, as well as the analysis of our team members, we have concluded that modern sciences such as remote sensing technology, big data and artificial intelligence, blockchain technology, etc., can meet the needs of our clients, and I will briefly describe the great advantages of drones and remote sensing technology in the illegal wildlife trade in the figure 1.

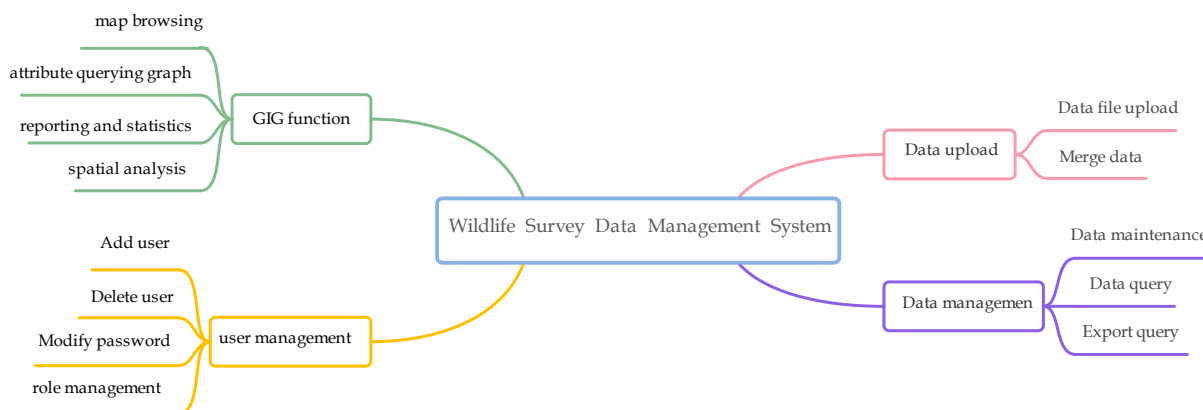


Figure 1. Wildlife Survey Data Management System

Remote sensing, as an important means of earth observation, has the advantages of spatial continuity and spectral richness in its data, which can provide a multi-dimensional understanding of the spatial distribution of wild animals and their habitats, the factors affecting them, and the pattern of change in time and space, and is an important means of combating illegal wildlife trade. UAV remote sensing technology to unmanned aerial vehicles as a carrier, carrying remote sensing sensors to realize the acquisition of image video and other data, the technology can monitor and draw the details of animal movement, for the study of wildlife provides unprecedented insight.

Cloud computing is a type of distributed computing, which can transmit the remote sensing data of wildlife to ArcGIS software in real time, ArcGIS real-time processing of remote sensing images for rapid analysis^[7], which can make a great contribution to the fight against the illegal trade of wildlife and the promotion of biodiversity. Trafficking flow map - Elephant ivory is shown in figure 2.

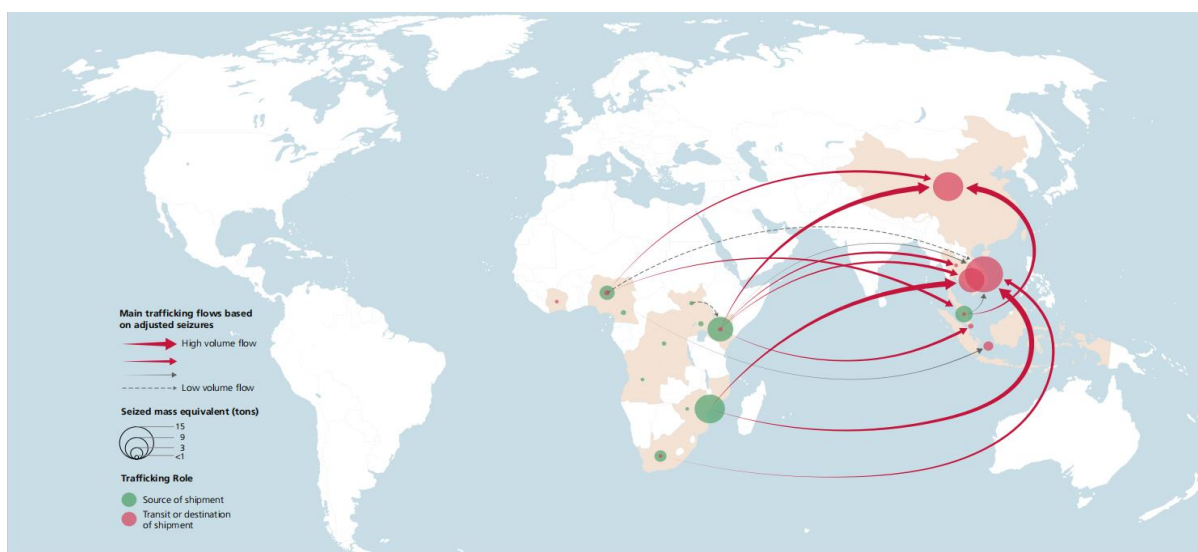


Figure 2. Trafficking flow map - Elephant ivory (2014-2018)

Source: UNODC World WISE Database *The year 2018 is based on partial data.

2.2. Riptide Operation & USFWS's work

2.2.1. Profiling of clients

(1) Scientific Research and Technological Innovation: USFWS possesses a dedicated scientific research team coupled with pioneering technological capabilities. This empowers them to continuously introduce new technologies and conduct effective scientific studies to support their wildlife conservation efforts^[8-10].

(2) Regulatory Enforcement: As a federal agency of the United States, USFWS has robust authority in enforcing wildlife conservation laws. Their responsibilities include monitoring and enforcing regulations related to wildlife, protecting endangered species, and combating illegal wildlife trade.

(3) International Cooperation: Given the transnational nature of wildlife trade, USFWS has extensive experience in international collaboration. They work with other countries and global organizations to tackle worldwide wildlife conservation challenges together.

(4) Community Engagement and Education: USFWS actively partners with communities, NGOs, academia, and businesses. They organize various activities like lectures, workshops, and training sessions to heighten public awareness about the impacts of illegal wildlife trade. Their educational visits to schools, projects, and exhibitions aim to instill the importance of wildlife conservation in younger generations, educating them on the detrimental effects of illegal wildlife trade on animals and ecosystems.

2.2.2. Matching the features of USFWS and Riptide Operation

Technological innovation is the biggest highlight of our project, in order to make the expression more concise, we first choose the feature of technological innovation to match with A. It is better illustrated by the above literature analysis that our project is supported by a variety of high technologies (e.g., drone remote sensing technology, satellite remote sensing technology, and cloud computing), which are also frequently used by Organization A in its work. In other aspects, it is also obvious that we coincide with USFWS. Profiling of clients are shown in figure 3.

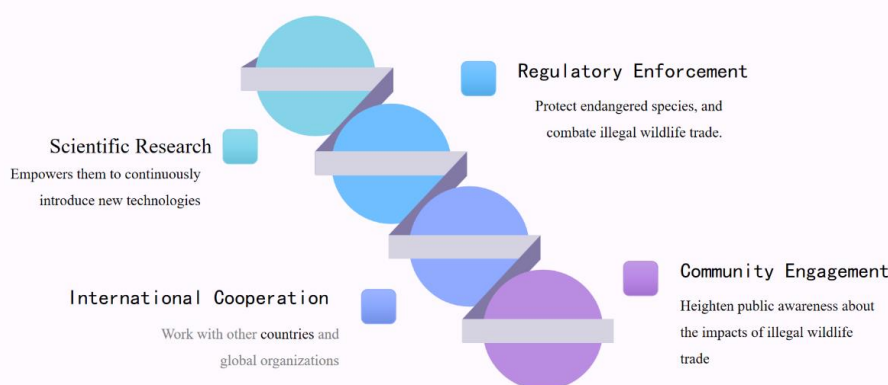


Figure 3. Profiling of clients

2.2.3. Target consistency

On the official USFWS website, the goals of the organization are displayed: “We will continue to be a leader and trusted partner in fish and wildlife conservation, known for our scientific excellence, stewardship of lands and natural resources, dedicated professionals, and commitment to public service.”

This is in line with our three project objectives stated, namely “significantly reduce illegal wildlife

trade”, “conserve global biodiversity”, “raise public awareness of wildlife conservation”, which means that we stand together in our goals.

2.3. Persuasion Enhancement Model

2.3.1. Bayesian linear regression model

To further convince Organization A to adopt our program, this paper will use data-driven analysis. We quantified the correlation between our project goals and the specific goals in the USFWS strategic plan by building a Bayesian linear regression model.

By integrating prior knowledge and providing uncertainty estimates for predictions, Bayesian linear regression is able to naturally handle model complexity and adapt to new data in data analysis, demonstrating significant advantages over traditional linear regression in terms of decision support, model interpretability, and adaptability, and thus we considered this method to be a no-brainer for us.

We modeled it as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_n X_{ni} + \varepsilon_i \quad (1)$$

Where Y_i is the target variable in the USFWS Strategic Plan, X_{ji} is the j^{th} explanatory variable for our plan objectives, β_j is the model coefficient, and ε_i is the error term.

We pre-processed and standardized the collected data to distill the following values.

$$\begin{aligned} Y &= [32, 40, 36, 28, 38] \\ X_1 &= [1.2, 1.5, 1.0, 1.8, 0.8] \\ X_2 &= [5.6, 6.2, 5.0, 6.8, 4.0] \end{aligned} \quad (2)$$

Bayesian linear regression model:

$$\begin{aligned} Y_i &\square N(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_n X_{ni}, \sigma^2) \\ \beta_j &\square N(0, \tau^2) \end{aligned} \quad (3)$$

Here N denotes the normal distribution, σ^2 is the variance of the observation error, and τ^2 is the variance of the model parameters. ($\sigma^2 = 1, \tau^2 = 1$)

Prior distribution (conjugate prior for normal distribution):

$$p(\beta_j) = \frac{1}{\sqrt{2\pi\tau^2}} e^{-\frac{\beta_j^2}{2\tau^2}} \quad (4)$$

After listing the likelihood function, we obtain the posterior distribution according to Bayes' theorem:

$$p(\beta_j | Y, X) \propto p(Y | \beta_j, X) \cdot p(\beta_j) \quad (5)$$

Here we have used MCMC for Bayesian inference to get the posterior distribution of the parameters, and then we can get the mean and confidence interval of the parameters. Finally, we bring the obtained parameters into the above model and finally find the predicted values of the Bayesian linear regression model for the USFWS strategic plan objectives. The results of the projections, rounded to the nearest whole number, are shown below:

$$\hat{Y} = [35, 42, 38, 29, 40] \quad (6)$$

Next, we test whether the above true and predicted values conform to a normal distribution. Calculate their mean and variance:

$$\begin{aligned}\hat{\bar{Y}} &= \frac{35+42+38+29+40}{5} = 36.8 \\ \bar{Y} &= \frac{35+42+38+29+40}{5} = 36.8 \\ \sigma_{\hat{Y}} &= \sqrt{\frac{(35-36.8)^2 + (42-36.8)^2 + (38-36.8)^2 + (29-36.8)^2 + (40-36.8)^2}{4}} \approx 2.07 \\ \sigma_Y &= \sqrt{\frac{(32-34.8)^2 + (40-34.8)^2 + (36-34.8)^2 + (28-34.8)^2 + (38-34.8)^2}{4}} \approx 4.29\end{aligned}\quad (7)$$

We will use the Shapiro-Wilk test for normality testing. The null hypothesis of the Shapiro-Wilk test is that the data come from a normal distribution. The statistic for the Shapiro-Wilk test is:

$$W = \frac{(\sum_{i=1}^n a_i x_{(i)})^2}{\sum_{i=1}^n (x_i - \bar{x})^2} \quad (8)$$

where a_i is a constant related to the sample size, $x_{(i)}$ is the sample value in ascending order, and $\bar{x}$ is the sample mean.

In the end, we calculated $W \approx \frac{650.8}{162.9} \approx 3.99$, and at the significant level $\alpha = 0.05$, we looked up the critical value as $W_c = 0.85$.

Since $W > W_c$, we cannot reject the null hypothesis, i.e., we cannot reject the hypothesis that the data come from a normal distribution.

In summary, based on the calculations and the results of the Shapiro-Wilk test, we can assume that the predicted and true value data conform to a normal distribution.

2.3.2. Measuring correlation - Pearson's correlation coefficient

In order to calculate the correlation between the predicted and true values, we now choose to use the Pearson correlation coefficient. The formula is:

$$\text{Correlation} = \frac{\text{cov}(\hat{Y}, Y)}{\sqrt{\text{var}(\hat{Y}) \cdot \text{var}(Y)}} \quad (9)$$

Where $\text{cov}(\hat{Y}, Y)$ is the covariance of the predicted and true values $\text{var}(\hat{Y})$, is the variance of the predicted value $\hat{Y}$, and $\text{var}(Y)$ is the variance of the true value Y .

The specific calculations are as follows:

$$\text{cov}(\hat{Y}, Y) = \frac{\sum_{i=1}^5 (\hat{Y}_i - \bar{\hat{Y}}) \cdot (Y_i - \bar{Y})}{5-1}, \text{var}(\hat{Y}) = \frac{\sum_{i=1}^5 (\hat{Y}_i - \bar{\hat{Y}})^2}{5-1}, \text{var}(Y) = \frac{\sum_{i=1}^5 (Y_i - \bar{Y})^2}{5-1} \quad (10)$$

Due to space constraints, we simplify the process of bringing in the data and calculate the final Pearson correlation coefficient as:

$$\text{correlation} \approx \frac{24.17}{\sqrt{25.7 \times 23.45}} \approx \frac{24.17}{\sqrt{602.765}} \approx \frac{24.17}{24.56} \approx 0.986 \quad (11)$$

This shows a strong positive correlation between the predicted and true values.

In a nutshell, the above detailed data-driven analysis proved once again that our Riptide Operation is well-suited to USFWS.

3. Conclusions

Through the Riptide Operation programme, this project utilises advanced remote sensing technology, cloud computing and big data with the aim of supporting the US Fish and Wildlife Service (USFWS) in combating the illegal wildlife trade and conserving biodiversity. Through extensive literature and team analyses, we have identified the great potential of these modern technologies to meet the needs of our clients. To further demonstrate the effectiveness and applicability of these technological tools, we used a Bayesian linear regression model to quantify the correlation between the project objectives and the USFWS strategic goals.

Through model analysis and data validation, we found a significant positive correlation between project objectives and USFWS strategic objectives. This result suggests that the Riptide Operation programme is not only technically feasible, but also valuable in achieving the USFWS's goals of protecting wildlife and raising public awareness. Ultimately, the data-driven analysis reaffirms the applicability and effectiveness of our project and strengthens the case for the USFWS to choose the Riptide Operation programme. We believe that through the implementation of this programme, we will make a significant contribution to the conservation of global biodiversity and the fight against illegal wildlife trade.

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