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TRIMM: A Propagation Model Based on Authentic Data

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Abstract

With the outbreak of COVID-19, considerable attention has been attached to the trade of wild animals, which is suspected to be the cause of the pandemic. It is main concern of all nations to excavate factors responsible for such emergence in particular. As a response, we elaborate novel model *TRIMM* so as to reveal the correlation between wild animal markets and epidemic situation of major infectious diseases. The *TRIMM* is modified and extended from the well-known propagation model *SIS*. Specifically, comparing to the original model, the *TRIMM* model is relatively transparent and rigorous. Furthermore, the *TRIMM* model is specialized for indicating correlation between wildlife trading and epidemic situation of major infectious diseases. Noticing the complexity of transmission of infectious diseases in reality, our model put 9 factors into consideration. To be precise, we consider the number of susceptibles that infectives in contact with per unit of time, the probability that susceptibles infected after being exposed to infectives and the recovery probability as the key indicators. In order to verify the effectiveness and fully unleash the potential ability of our model, we modify *TRIMM* model by utilizing *SIR* propagation model. In this way, we finds our model functioning well in more realistic environment. Eventually, sensitivity analysis is adapted to the model. We discuss strengths and weaknesses and discuss our future work with *TRIMM* model.

Keywords

Impact of Wildlife Trading, *TRIMM* Model, Epidemic, Wildlife Trade Ban

1. Research Background

Wildlife trade is an indispensable link in the process of transmitting viruses carried by wild animals over long distances. Most recent emerging infectious diseases have been zoonotic in origin [1]. Such emergence is the result of trade in wildlife and bushmeat in particular. At the same time, as a large market, the contribution of wildlife trade to the local economy is significant. In balancing the pros and cons and formulating relevant policies, how to quantify the link between wildlife trade and infectious disease transmission and obtain analysis results that can guide policy formulation is a goal that governments around the world are committed to achieve.

2. TRIMM model and Hypothesis

2.1 Objectives of *TRIMM* model

In order to deal with the problem mentioned above, we establish our novel *TRIMM* Model.
The objectives of *TRIMM* Model are listed as follows,

- To prove that the wildlife trades is closely linked to the main epidemics caused by zoonotic viruses
- To digitize the transmission process from abstract to make it more graphic and precise
- To make predictions about possible future outbreaks caused by wild animal trades
- To better control the epidemic so as to reduce the damage brought by virus to social security and economic losses

We define *TotalTradeNum* to describe the degree of wildlife animal trades and continuously obtain the most traded species and the main purposes behind the trade. Meanwhile, we monitor the fluctuation of wildlife trade over a period of twenty years through our indicators, which assists us further conclude our core perspectives towards correlations between wildlife trade and main epidemics.

2.2 Assumptions

We make assumptions for *TRIMM* Model listed as follows,

- The recovered persons have no antibodies and go back to being susceptible
- The sample species are all carrying same kind of virus and the epidemic model describes the outbreak of the virus
- Total population equals to aggregated number of susceptibles and Infectives

2.3 Nomenclature

Table 1. Notation table

Symbols	Definition
T_{TN}	Total trade num
PD_i	Total trade num of species*i*
PP_i	Purpose percentage
t	Time experienced since the beginning of the propagation
s	Number of species
$S(t)$	Susceptibles
$I(t)$	Infectives
δ	Proportion of infectives in the total population
r	The number of susceptibles that infectives in contact with per unit of time
β	The probability that susceptibles infected after being exposed to infectives
γ	The recovery probability of infectives
$N(t)$	Total population

2.4 The TRIMM Model

We first begin with defining β as the probability that susceptibles infected after being exposed to infectives and s as the number of species.

The equation of β listed as follows,

$$\beta = 1 - e^{-(0.01s)} \tag{1}$$

We assume both equation (5) and (6) are true

$$S(0) = S_0, I(0) = I_0 \tag{2}$$

$$N = S(t) + I(t) \tag{3}$$

Combining three equations as follows, we reach to equation (9), which directly demonstrate the correlations among factors

$$\frac{dS}{dt} = -r\beta S\frac{I}{N} + \gamma I \tag{4}$$

$$\frac{dI}{dt} = r\beta S\frac{I}{N} - \gamma I$$

$$\frac{dI}{dt} - (r\beta - \gamma)I + \frac{r\beta}{N}I^2 = 0 \quad (5)$$

$$I(t) = \frac{\frac{N(r\beta-\gamma)}{r\beta}}{\left(\frac{N(r\beta-\gamma)}{I_0 r\beta}-1\right)e^{-(r\beta-\gamma)t}+1} \quad (6)$$

As t approach to infinity, we end up with the conclusion: longer the time last, more likely the number of infectives approaches to $\frac{N(r\beta-\gamma)}{r\beta}$.

$$\lim_{t\to+\infty} I(t) = \frac{N(r\beta-\gamma)}{r\beta} \quad (7)$$

$$\lim_{t\to+\infty} S(t) = \frac{N\gamma}{r\beta}$$

$$\delta = \frac{I(t)}{N} \quad (8)$$

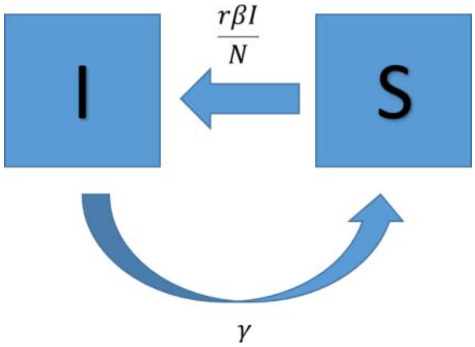

Figure 1. Basic relationship of two parts in *TRIMM*.

3. Research methods

3.1 Quantitative research method

Based on a full records over the past two decades wildlife trade database (https://caiyun.139.com/m/i?0F5CKACoDDpEJ) of the data in the analysis and study, this article understands the correlations between wildlife trade and the infectious disease, the changes and trend of development, In this way, we can correctly reveal and predict the major outbreaks that may occur in the future.

3.2 Modeling method

In this paper, the existing data are used to establish a mathematical model of infectious disease transmission. Through the simulation of diseases transmission, we study whether wildlife trade is an important component of infectious disease transmission.

3.3 Data collection

All of our data comes from existing and reliable databases. The data is drawn from national databases that document the wildlife trade publicly

4. Analysis of results

4.1 Measurement of Trade : T_{TN}

We define Total Trade Num as T_{TN} to describe the degree of trade. Meanwhile, we define Q_i as the quantity of import and Q_e as the quantity of export. We determine the aggregated amount of import and export of certain animal species equals to T_{TN}.The equation listed as follows,

$$T_{TN} = Q_i + Q_e \quad (9)$$

To measure the degree of trade visually, we fill the T_{TN} for each species in a bar chart. Specifi- cally, considering the range of data varies dramatically, the bar chart 1 we conduct only picks animal species whose trading number is more than a thousand.

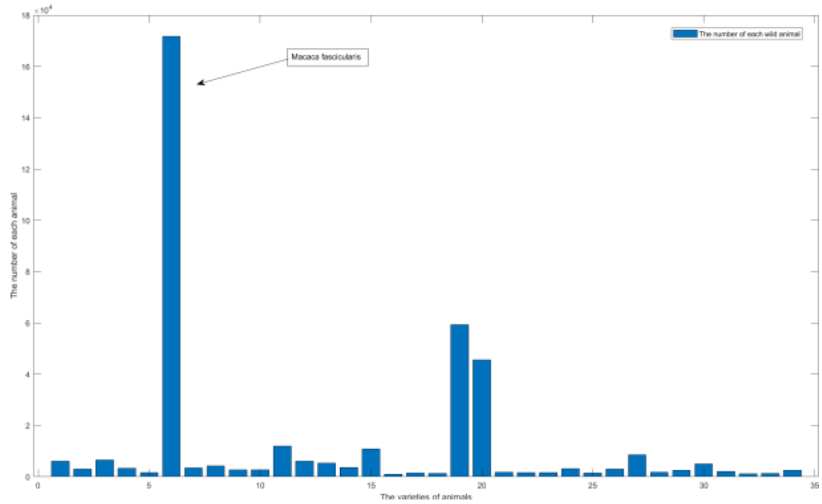

Figure 2. The T_{TN} for each species.

4.2 Macaca fascicularis: The Most Traded Species

We consider the owner of the T_{TN} as the most traded wildlife species. As shown in the chart, **Macaca fascicularis** is the most traded wildlife species, which had the highest number of illegal transaction, surpassing the second-most and third-most illegally traded species combined. All but the top three illegally traded species have traded populations of less than 20,000.

4.3 Indicator for Trade: PP

We define *PurposePercentage* , PP for short. In addition, each of the main purposes for trade of these animals has an metric: *PurposeDigit*, for short PD_i, which equals to the total trade num of purpose *i*, represented as $\sum T_{TNi}$. For each purpose *i*, there is a PD_i. The *PurposPercentage* can be therefore obtained by dividing PD_i by $\sum T_{TNi}$.

We conclude the equations as follows,

$$PD_i = \sum T_{TNi} \tag{10}$$

$$PP_i = \frac{PD_i}{\sum PD} = \frac{\sum T_{TNi}}{\sum PD} \times 100\% \tag{11}$$

Though our indicator PP has a relatively conclusive coverage to data shown in the database, there are missing data points. In this situation where all trades need to be included, we do not filling these data gap with imputed estimates.

Instead, to illustrate the proportion of species selected as comprehensive as possible, we allocate the data without purpose to each of the purposes according to the weighted proportion of each purposes. The following pie chart is finally obtained to demonstrate the percentage of each species.

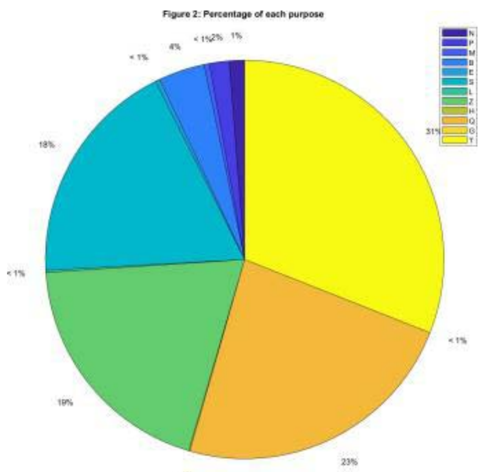

Figure 3. Percentage of each species.

4.4 Four Main Purposes for Trade

Concluding from the pie chart, we list the main purposes for trade of these animals species as follows,

- **Commercial**
- **Circus or travelling exhibition**
- **Zoo**
- **Scientific**

4.5 Fluctuation of Activity Level of Trade

We sum up T_{TN} from 2003 to 2021 annually so as to figure out the fluctuation of activity level of the wild animal trade during the past two decade.

We obtain the line chart as follows,

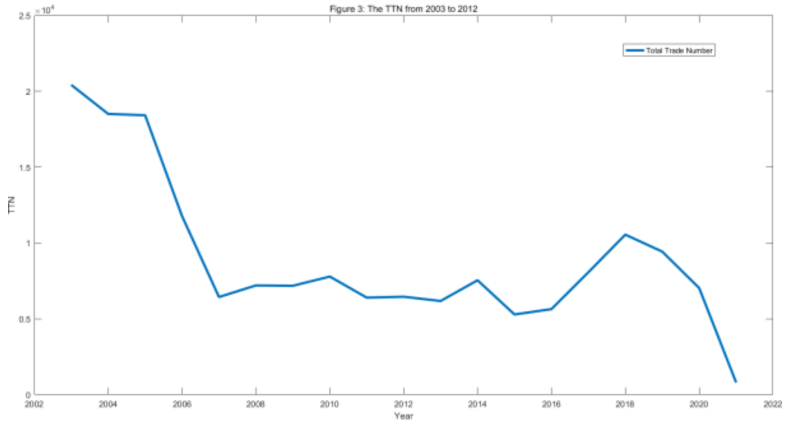

Figure 4. The T_{TN} from 2003 to 2021.

The chart depicts how the T_{TN} changed from 2003 to 2021. Overall, the T_{TN} declined fairly, reached a plateau and plummeted ultimately. Initially, T_{TN} stood at 20, 422 as the highest rate in next 20 years. And soon after that it suffered a substantial decline, reaching 6, 437 in 2007. In next nine years, T_{TN} remained relatively constant at approximately 7, 000 with fluctuation. It peeked at 1, 0549 in 2018, and plunged to 803 in 2021.

4.6 Trading tendency: Tapering Off

Correspondingly, as the $T_{T\ N}$ represents the degree of trade, we conclude that **wildlife animal trading volumes are tapering off with fluctuations** for the past two decade.[2]

4.7 Preliminary Conclusion

Without doubt, virus-caused public heath issues have had a significant impact on human health and economic security [3]. As Figure 3 presents, coincidentally, *TotalTradeNum* (T_{TN}) always seems to rebound to a maximum at the time when major infectious disease pandemics occurred. In this case, we draw a preliminary conclusion that wildlife trade is a factor of vital importance to the global spread of emerging zoonotic infectious diseases.

4.8 Further Study: Introducing More Parameters

To study the correlation between wildlife animal trade and zoonotic infectious diseases. We con- tinue to introduce *Numberof HostSpecies* and *ZoonoticV irusRichness* of 15 orders.

By dividing animal into four groups,

- Domestic
- Wild mammals in trade(present)
- Wild mammals in trade(future)
- Wild mammals not in trade

We are able to sense mammal-virus association in wildlife trade suggested structured variation in host richness and total and zoonotic virus richness across mammalian orders.

In order to visualize the result, we obtain graphs of number of species in each order hosting total viruses and zoonotic virus richness simultaneously as follows,

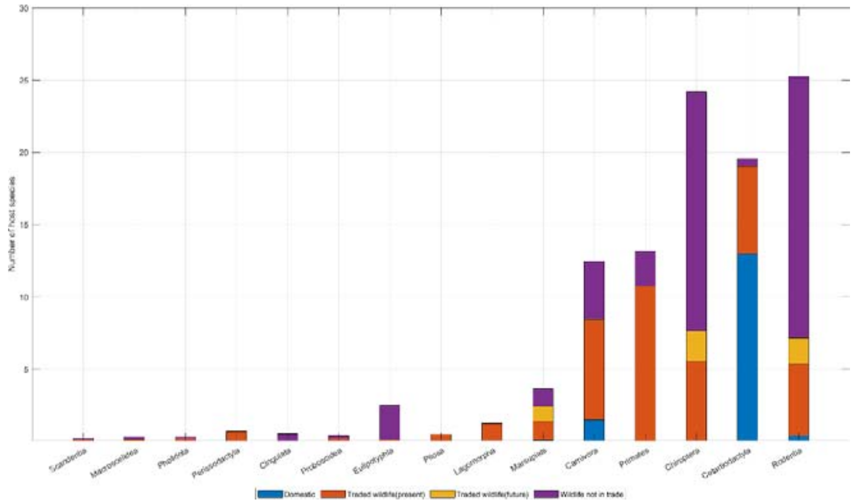

Figure 5. Number of species in each order hosting total viruses.

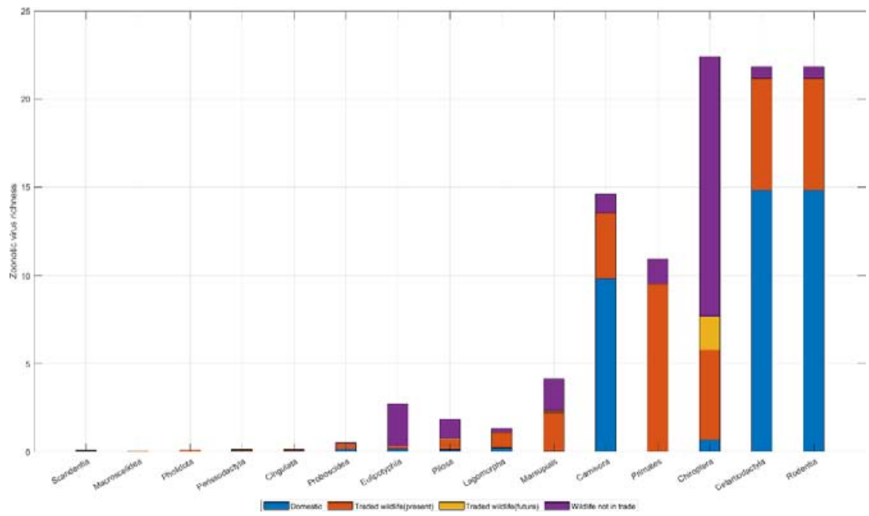

Figure 6. Zoonotic virus richness.

4.9 Key Conclusions of Correlation between Trade and Disease

According to above two graphs, mammal-virus association in wildlife trade suggested struc- tured variation in number of total viruses and zoonotic virus richness across mammalian orders and mainly lead to three conclusions.

- Future wildlife trade might increase zoonotic disease risks as novel mammal species get included in wildlife trade
- The 210 mammal species known to have been legally traded between 2012 and 2016 alone host 51% of known zoonotic viruses in our database
- Cetartiodactyla (89, 39%), Rodentia (42, 19%), and Carnivora (39, 17%) were the major reservoirs of zoonotic viruses among domesticated mammals, whereas Rodentia (111, 49%) and Chiroptera (48, 21%) were exclusively the major reservoirs of zoonotic viruses for mammals not in wildlife trade

From the above conclusions,we acknowledge that the wildlife trade (both legal and illegal) has led to the introduction of many pathogens which possibly results in spread of diseases. To further reveal the correlation, we establish infectious disease model *TRIMM* (Trade-Related-Infected- Measurement-Model)

In the *TRIMM* Model, as t approach to infinity, we end up with the conclusion: longer the time last, more likely the number of infectives approaches to $\frac{N(r\beta-\gamma)}{r\beta}$. This push our theory forward dramatically since the high possibility of infection contributed by involving more species into our model.

Moreover, by using δ to depict proportion of infectives in the total population, we therefore obtain two curves of TRIMM model as follows,

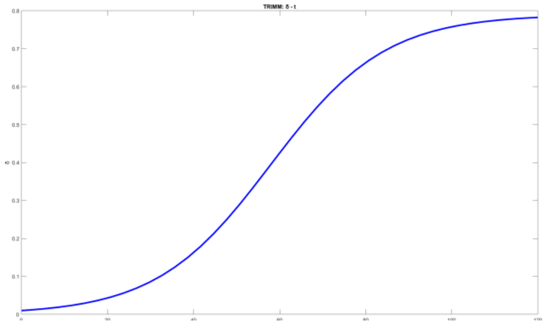

Figure 7. Standard Curve of *TRIMM*.

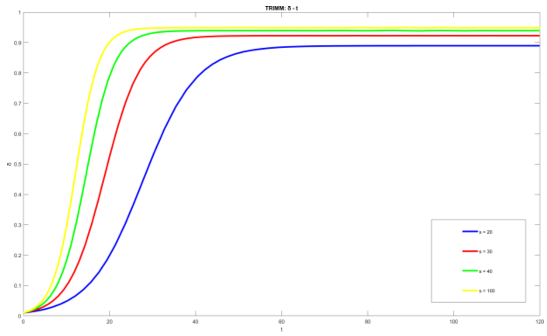

Figure 8. The value of β with different *s* in *TRIMM* (*s* = 20, 30, 40, 100).

According to TRIMM model analysis, we are able to conclude that the more species involved in the wildlife trade, the more likely it is to cause an outbreak of infectious disease.

5. Conclusion & future work

According to our study, there is a strong and significant relationship between the spread of an animal-first host viruses like COVID-19 and the wildlife trade. To balance the pros and cons, we are more than glad to demonstrate our unique ideas as references for government's policies decisions.

Our ideas listed as follows,

- We are not opposed to banning on wildlife trade for a long period of time since wildlife trade is an indispensable link in the process of transmission
- The action of banning requires more concentration in certain species orders like Cetartio- dactyla, Rodentia and Canivora, which are the major reservoirs of zoonotic viruses
- We need to limit the size of wildlife trade market and the number of species for the reason that the risk increases sharply with the increase of. size of the trade and the number of species included

In conclusion, banning on wildlife trade, or in other words, curbing the marketing of wildlife products and developing principles to support sustainable and healthy wildlife trade can be cost- effective investments [4].

However, both advantages and disadvantages will appear:

Advantages

- Protect some directly traded endangered species and prevent others from becoming endan- gered
- Protect the structure of the ecosystem and indirectly protect species that are not directly traded
- Avoid or mitigate the probability of species invasion

Disadvantages

- Once the ban fails to take into account some rural areas that depend on wildlife trade as a source of food or income, it may make them more vulnerable or increase their dependence on illegal activities, making it difficult for local people to obtain income through legal means.
- Banning all legal animal trade could drive the trade underground. Not only will governments lose tax revenue previously earned through legal trade, but an unregulated black market means it will be difficult to protect wild species populations, while health and safety standards designed to protect people and prevent the spread of

zoonotic viruses will not be effectively monitored and en- forced.

To properly deal with the concerns, our solutions listed as follows,

Recognize the drawbacks from history

We should take some communities which rely on wild sources as food and income into consideration.

We can permit wildlife trade in that communities, and completely prohibit the trade in other case. The community which permitted to trade should be supervised strictly.

Otherwise, banning can bring some side effects. For example, when the SARS outbreak in 2003, the trade of palm civets were banned. However, the ban was reversed ultimately due to the severe economic effect on native farmers and traders.

Banning in a proper way

Ban-makers are required to realize that potential impacts on marginalized groups and offer support to them. In addition, it is crucial to encourage non-government organizations to monitor the wildlife market since government may not have enough resource. The public should have easy access to wildlife information, their uses and the way to complaint, in order to report the risky and illegal events timely.

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