EMERGING DISEASE INSIGHTS

Research from the PREDICT Modeling & Analytics team

Simulating Outbreak Scenarios: Novel Bat Coronavirus from Guano Harvest

This hypothetical scenario examines what might occur if one of the viruses discovered through the PREDICT-1 project spilled over into humans. We also examine ways to reduce this risk. In 2013, the PREDICT project discovered a novel beta-Coronavirus in bat guano in Thailand [1]. This virus does not currently pose a known threat to human health, but its presence in bat guano, which is harvested in Thailand for use in fertilizer and in other countries for traditional medicine, highlights a potential pathway for viruses to emerge.

This scenario hypothesizes that a different strain or alternate coronavirus with pathogenicity similar to SARS-CoV emerges from bat guano. It allows us to test the efficacy of various intervention strategies, and explore how analysis of air travel networks could be used to anticipate the spread of such a virus.

SIMULATING EMERGENCE, SPREAD AND CONTROL

We assume that the initial spillover to people occurs through environmental exposure to the pathogen in bat guano harvested for use as fertilizer. Once spillover occurs, we assume the virus is pathogenic in humans in the absence of control measures, and spreads via a respiratory pathway with an R_0 greater than 1 (i.e., each person infects more than one additional person).

We developed a base scenario where an epidemic starts via random spillover events in locations where humans have contact with bat guano and then spreads through a network of human population centers (Figure 1). We compared this base scenario against those with different possible interventions designed to reduce viral spillover.

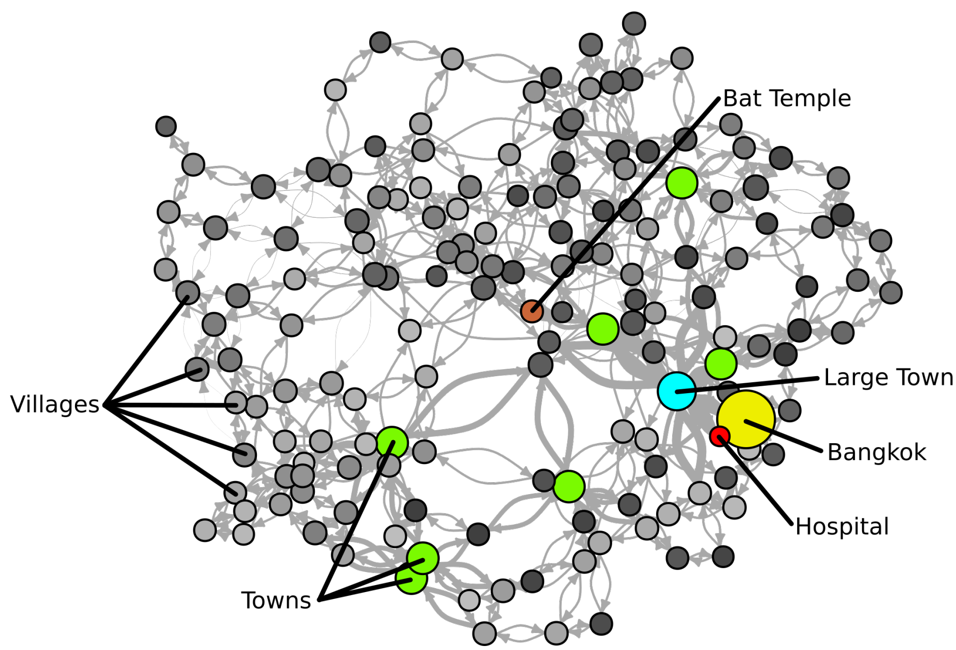

Figure 1: One instance of the human population networks used for epidemic simulations. Random networks were generated for each simulation based on available real data on the distribution of villages, towns, and major centers. Circle sizes are based on the log population size of cities, and arrow widths represent travel rates between cities.

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We simulated intervention scenarios which either reduced worker exposure to guano via personal protective equipment (PPE) or hygiene practices, via reducing the harvesting and use of guano for fertilizer, or via culling of bats. Table 1 summarizes the outcome of the base scenario and scenarios with these interventions. The percent of computer simulations where spillover and subsequent epidemic spread occurs provides an estimate of the *relative* probability of an epidemic occurring in reality.

Table 1: Probabilities of spillover and epidemic spread for the seven scenarios examined. Percentages marked with an asterisk (*) are significantly different from the base scenario.

Scenario	% of simulations with spillover and epidemic spread
Base scenario, no interventions	96%
Reduce worker exposure 10x via PPE and hygiene practices	**36%***
Reduce worker exposure 100x via PPE and hygiene practices	**12%***
Reduce amount of guano harvest by 50%	98%
Reduce amount of guano harvest by 95%	93%
Cull wildlife, increase bat mortality by ~10%	94%
Cull wildlife, increase bat mortality 5-fold	94%

The variation among the scenarios relates to the relative *likelihood or probability* of spillover and an epidemic occuring rather than the average *number of people infected* in an epidemic. The most effective interventions are those that reduce the exposure of workers to guano via PPE and hygiene during guano harvest and use. These reduced risk by between 64% and 88%. Reducing the amount of guano harvested or culling bats resulted in no statistical change in risk of spillover and epidemic spread. This is because even a small number of workers or a small guano harvest can still entail significant spillover risk when workers are unprotected.

INTERNATIONAL SPREAD

We predicted how this hypothetical virus could spread globally via air travel. Using methods we have previously published that analyze global flight data [2], we estimated the relative time it would take the virus to arrive in different countries. This provides a ranking that can be used for prioritizing surveillance from an outbreak. We assumed the the virus arrives in Bangkok via overland travel, and enters the air travel network from there. There are 60 countries that can be reached via direct flights from Bangkok, and 157 that can be reached by including two flight legs. Based on typical passenger numbers, the 12 countries with the earliest expected arrival of an infected person are (from earliest to latest): Singapore, India, China, South Korea, Japan, Bangladesh, Vietnam, United States, Australia, Philippines, Germany, and the United Arab Emirates.

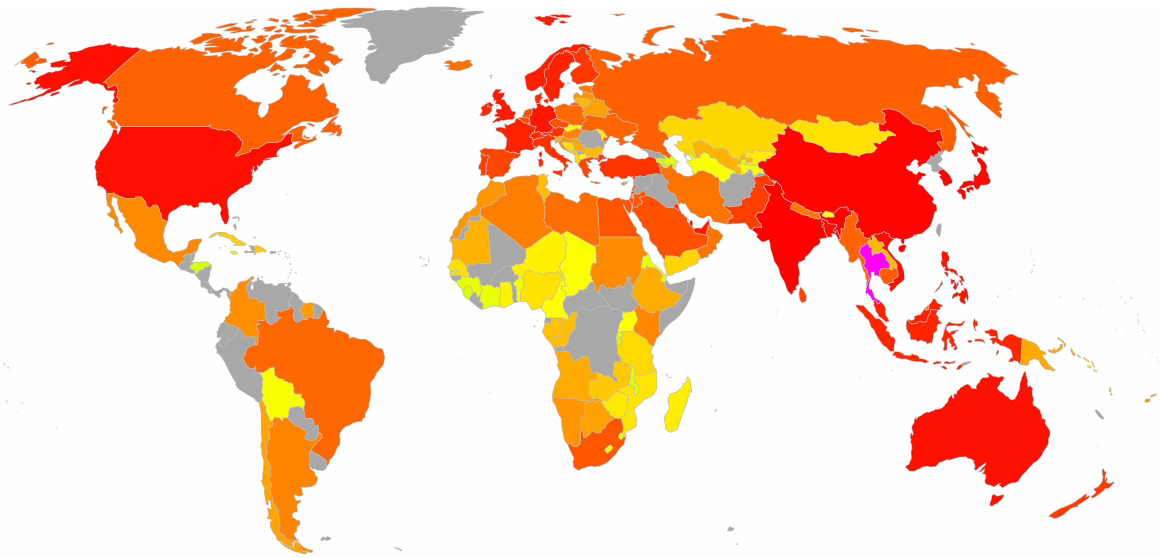

Figure 2: Rank arrival time of the virus via air travel from Thailand (purple). Early-arrival countries in red, medium in orange, and late in yellow .

DISCUSSION

This scenario demonstrates that by modeling the disease spillover process of newly discovered viruses, strategies to reduce impact can be explored even before potential outbreaks begin. Our results show that reducing exposure during bat guano harvesting and use is more effective in preventing possible outbreaks than reducing the amount of bat guano harvesting. This is the case because in our scenario, the high spillover potential and pathogenicity of the virus make even small numbers of exposed workers likely to spread the disease.

We modeled hygiene practices to reduce worker exposure to guano, and common practices (PPE, good sanitation) can reduce exposure broadly. The best methods to reduce human exposure, though, will require a greater understanding of viral transmission processes at this interface. For instance, understanding seasonality of load in guano, the dosage require for human infection, and viral survival under different conditions (temperature ranges and wet/dry guano storage) could enable efficient targeting of policy.

It is important to note that all of the interventions we examined aim to reduce the spillover rate of virus into humans, rather than mitigate spread within the human population. These interventions can therefore reduce the risk of viral spillover, but may not reduce impacts once spillover has occurred.

Finally, while in this case we modeled a scenario based in Thailand, the potential for viral emergence in bat guano harvesting is not specific to that country, and these methods may be applied in other locations where this activity occurs.

CONCLUSIONS

- Reducing human exposure to bat guano, through hand washing and other hygiene practices, or through personal protective equipment is likely to be the most successful intervention to prevent spillover of novel Coronaviruses carried by bats and excreted in their guano.

- Reducing the cultural practice of guano use as fertilizer or traditional medicine, or culling wildlife is predicted to have little effect on disease spillover risk.
- Air travel data can be used to predict international spread of viral disease to inform global surveillance during early stages of an outbreak.
- Further surveillance and research should include other interfaces where people have contact with bat guano.

References

[1] Wacharapluesadee S, Sintunawa C, Kaewpom T, Khongnomnan K, Olival KJ, Epstein JH, et al. (2013) *Group C betacoronavirus in bat guano fertilizer, Thailand*. Emerg. Infect. Dis. 9(8): 1350-1351. doi: 10.3201/eid1908.130119

[2] Hosseini P, Sokolow SH, Vandegrift KJ, Kilpatrick AM, Daszak P (2010) *Predictive Power of Air Travel and Socio-Economic Data for Early Pandemic Spread*. PLoS ONE 5(9): e12763. doi: 10.1371/journal.pone.0012763

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