Projecting international mpox spread in Asia: ongoing global health risk

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Background

The novel mpox outbreak has rapidly spread globally in early 2022, particularly among men who have sex with men (MSM). In 2023, following sustained local transmission in Japan, many countries in Asia began to experience mpox introductions and local transmission. Using a mathematical model incorporating heterogeneous in sexual networks among MSM, calibrated to incidence data in Japan, we projected the patterns of international mpox spread across 42 Asian countries.

Data

- Self-reported 4-week partner numbers from the British National Surveys of Sexual Attitudes and Lifestyles (Natsal).
- Mpox incidence in Japan from 16 January to 26 June 2023.
- MSM population size (assumed to be 1% for each country).
- 2019 travel volume data from the United Nations World Tourism Organization (UNWTO).

Method

We first fitted our model to the mpox incidence in Japan from 16 January (date of medical attendance for the first case in 2023) to 26 June 2023 using the approximated Bayesian computation (called the alive particle filter) [1] to obtain posterior samples of the sexually-associated secondary attack risk (SAR; transmission risk per sexual partner) for mpox.

We then simulated mpox transmission from 16 January onwards in Japan and other Asian countries with these posterior samples and the international outbound travel volume data, assuming for simplicity that cases in Japan initiated the international mpox spread in Asia in 2023 and that importations from outside Asia were negligible.

Model

We developed a stochastic meta-population SEIR model accounting for heterogeneous MSM sexual networks. The MSM population in each country was subdivided into 50 groups of different sexual activity levels with evenly spaced bins on a logarithmic scale between 1 and 10,000 partners per year. We allocated individuals to each group according to the sexual partner distributions estimated from the Natsal data [2].

The force of infection per day for each sexual activity level, k, in each country i is modelled as follows (m_{ij} is the daily number of travellers from country i, who is staying in country j):

$$\lambda_{i,k} = \beta \frac{r_k}{365}\left(\theta_i + \sum_{j\neq i} m_{ij}\theta_i + \sum_{j\neq i} m_{ji}\frac{C_{inf,j}}{C_{gen,i}}\right),$$

SAR per partner

Partner formulation rate per day

Prop. of infectious partners with travellers returning from country j.

Prop. of infectious partners with travellers visiting country i.

where θ_i (proportion of infectious partners) are modelled as

$$\theta_i = \frac{C_{inf,i}}{C_{gen,i}} = \frac{\sum_k \max\left(0, \frac{r_k}{365\gamma_2}-1\right)\gamma_2 I_{i,k}}{\sum_k \frac{r_k}{365}P(r_k)N_{i,MSM}}.$$

Simulated trajectories in Japan

Estimated SAR (95% CI.) by fitting the model to mpox incidence in Japan was 66.2% (40.6%, 88.9%).

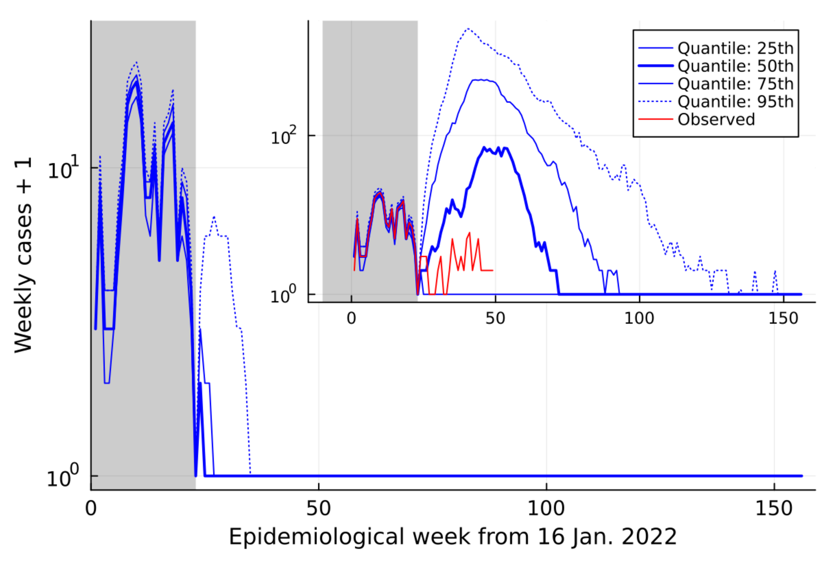

Figure 1. Simulated trajectories of mpox in Japan. The inset in the figure represents trajectories given 10 infections observed in Korea and observed incidence in Japan.

Simulated importation dates.

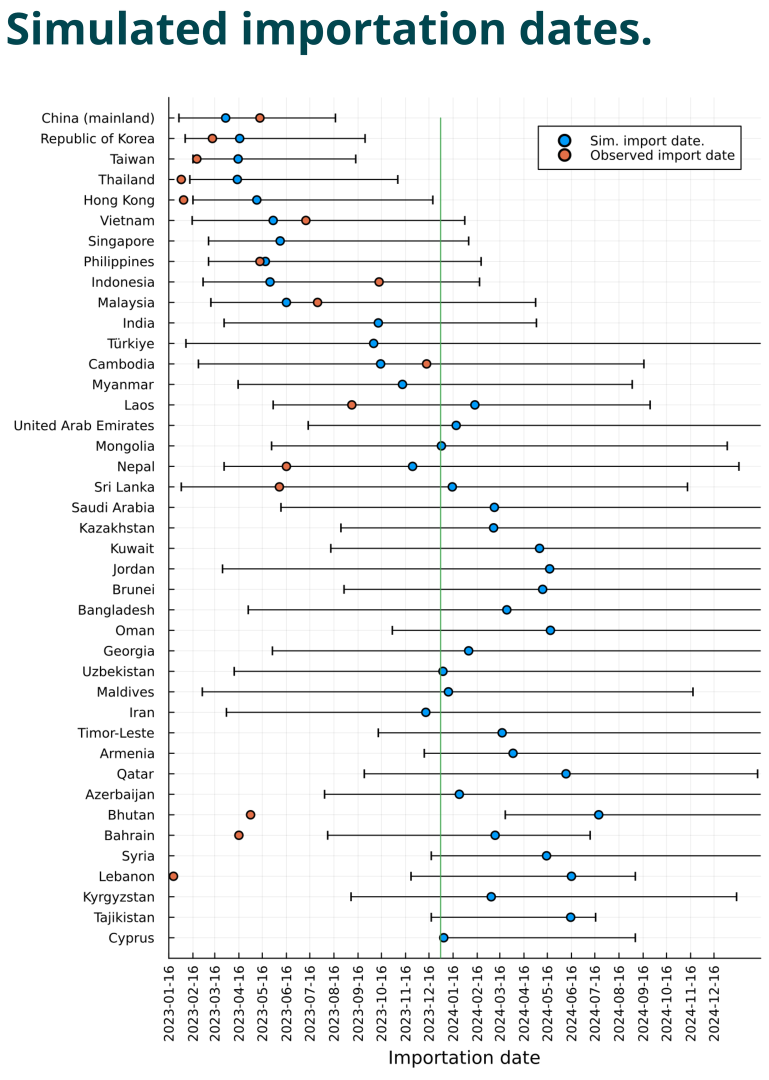

Figure 2. Simulated importation dates compared to the observed importation dates. Points and error bars represent the median, 5th and 95th simulated importation dates.

Acknowledgement

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Simulated mpox importation probabilities in Asia

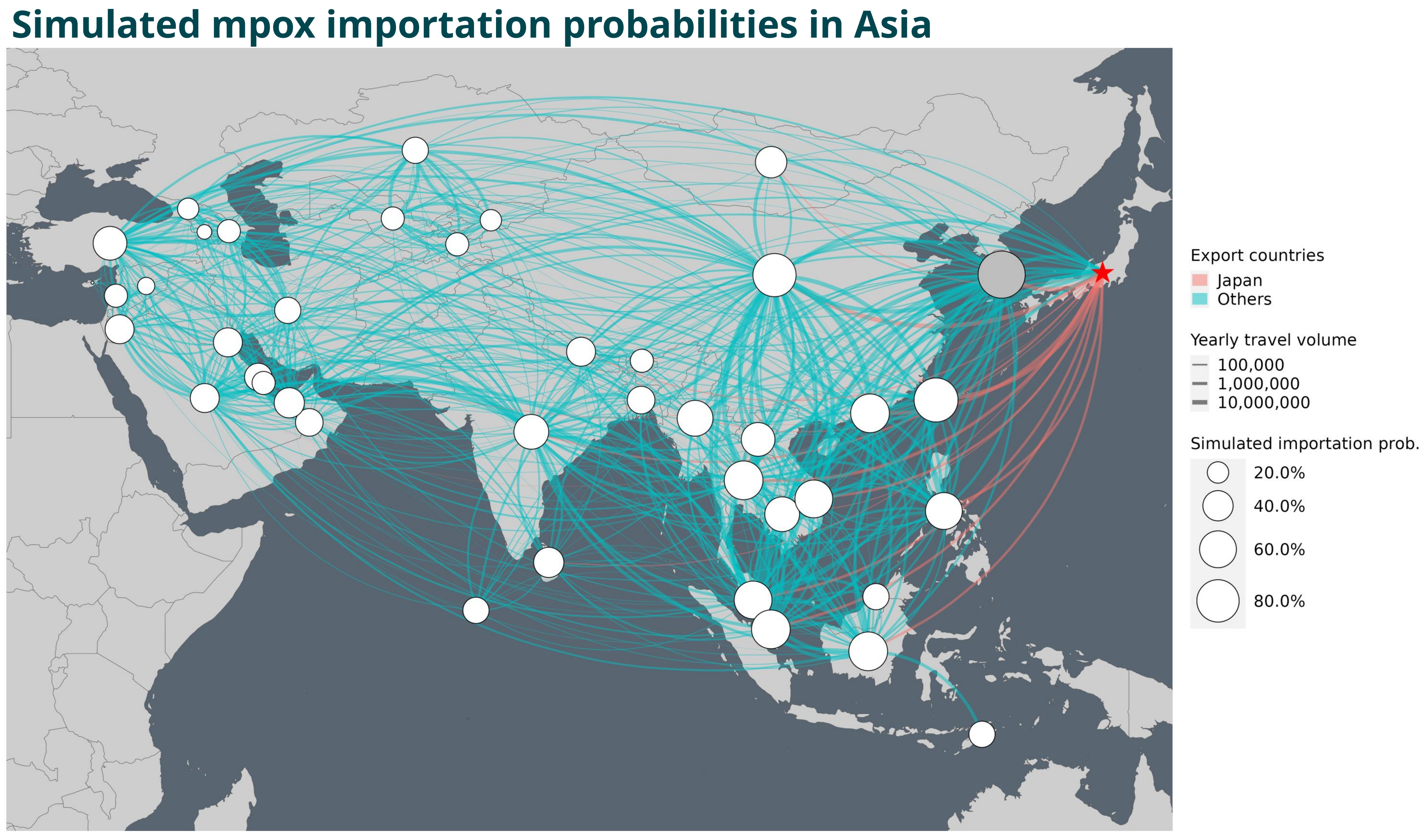

Figure 3. Simulated mpox importation probabilities in Asia given 10 infections in Korea. Each circle size represents the simulated importation probability for each country. The widths of links between circles indicate the average weekly outbound travel volume between countries. The outbound travel volume from Asian countries to Japan is coloured in red. The links for the outbound travel volume of less than 10,000 per year were removed from the figure. Grey circle for Korea has 100% simulated importation probability.

Simulated mpox importation probabilities, global final outbreak size and number of imported countries.

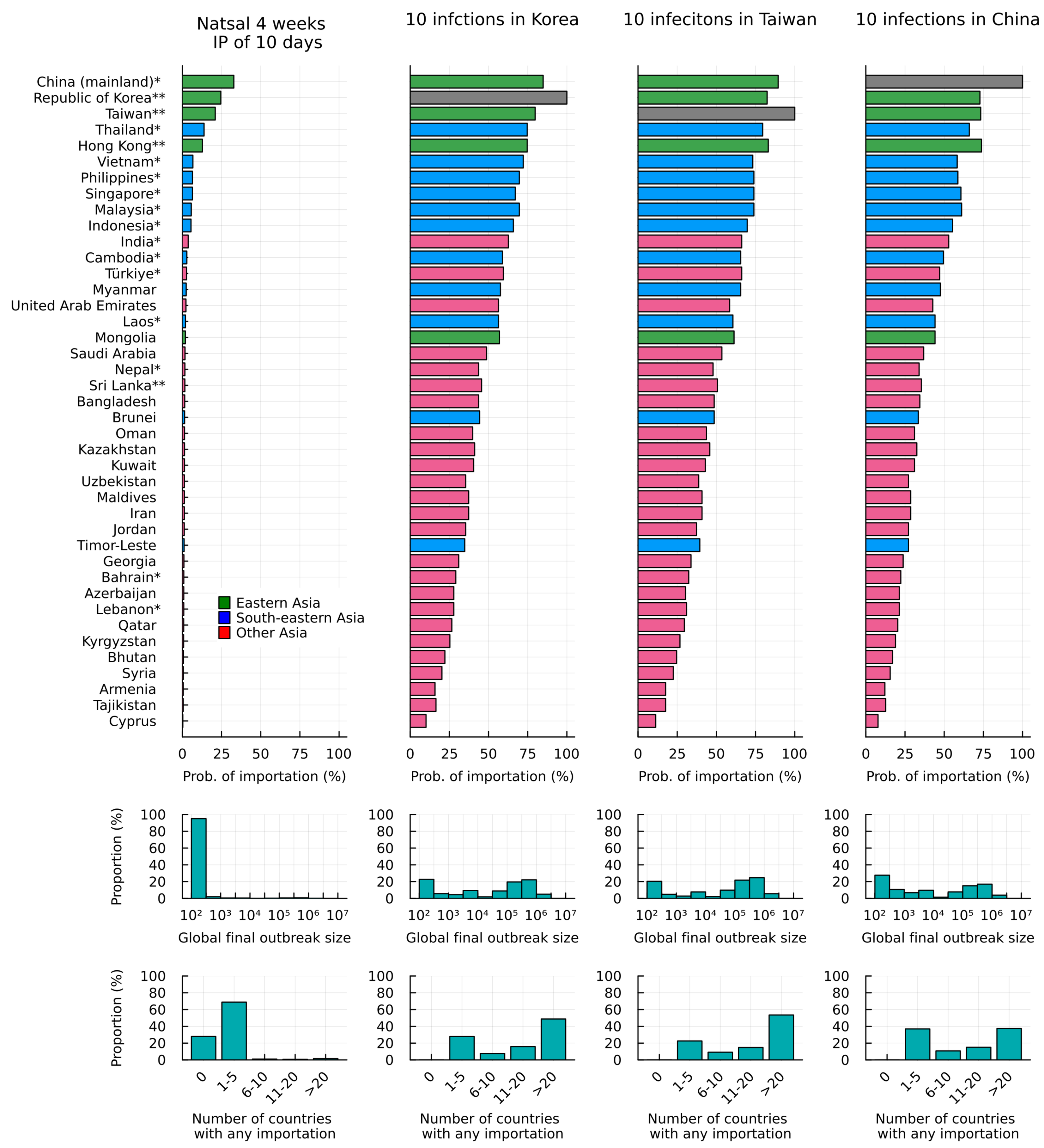

Figure 4. Simulated importation probabilities (upper panels), global final outbreak size (middle panels) and number of countries with any importation (lower panels) for simulations unconditioned and conditioned by 10 infections in Korea, Taiwan and China. In the upper panels, a single asterisk (*) represents at least one mpox report in the country, and a double asterisk (**) represents one or more importations from other Asian countries. Other Asia corresponds to Central, Southern and Western Asia. IP represents the infectious period.

Conclusions

Our simulations highlighted countries at a high risk of mpox introductions, many of which were low- and middle-income countries (LMICs) in South-eastern Asia. The results also suggested that the focus of mpox introductions would shift from Eastern Asia to South-eastern Asia, followed by Central, Southern and Western Asia, which roughly coincided with the observed patterns of spread in 2023. Global cooperation and support are warranted, especially for LMICs with an elevated risk of mpox introduction, to minimise the risk of continued circulation in Asia and beyond.

[1] McKinley, T. J., et al., (2020). Bayesian Anal. 15(3): 839-870. [2] Hiroaki Murayama, et al., 2023, preprint.