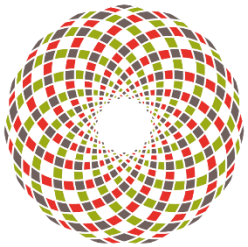
LINK ONLINE, 7 July 2020

Mathematics, modelling and simulation supporting the COVID-19 response in New Zealand

Alex James Michael Plank Shaun Hendy
Nic Steyn Rachelle Binny Audrey Lustig



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Manaaki Whenua
Landcare Research

Te Pūnaha Matatini

- A national research centre in complex systems established in 2015 with 70 investigators
- Broad expertise in data and modelling, mostly social, economic, and ecological problems, and how these systems interact
- Have also worked on disease, e.g. *M. bovis,* seasonal flu and Havelock North gastroenteritis
- Strong track record in working with central government

Shaun Hendy

Alex James

Mike Plank

Nicholas Steyn

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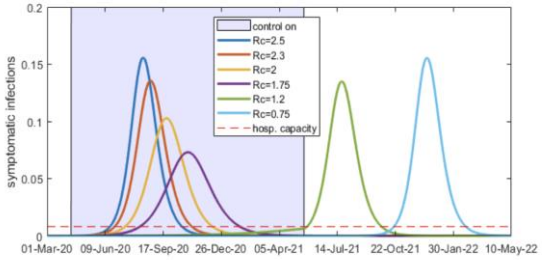
Modelling timeline

March

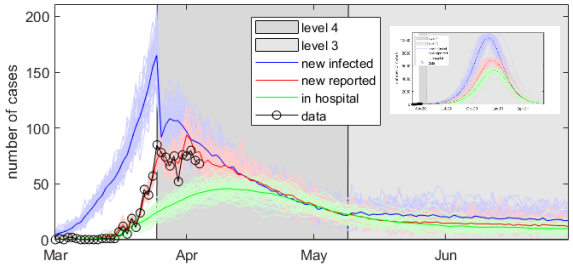
Deterministic SEIR model



- Long-term scenarios for an established outbreak

Early April

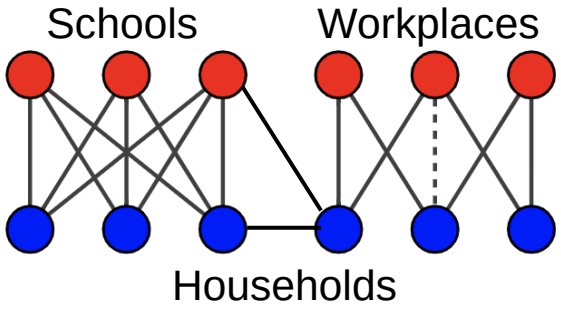
Stochastic SEIR model with case isolation



+ Short-term containment or elimination scenarios

Early May

Network/agent based model



+ Ability to segment Alert Level restrictions

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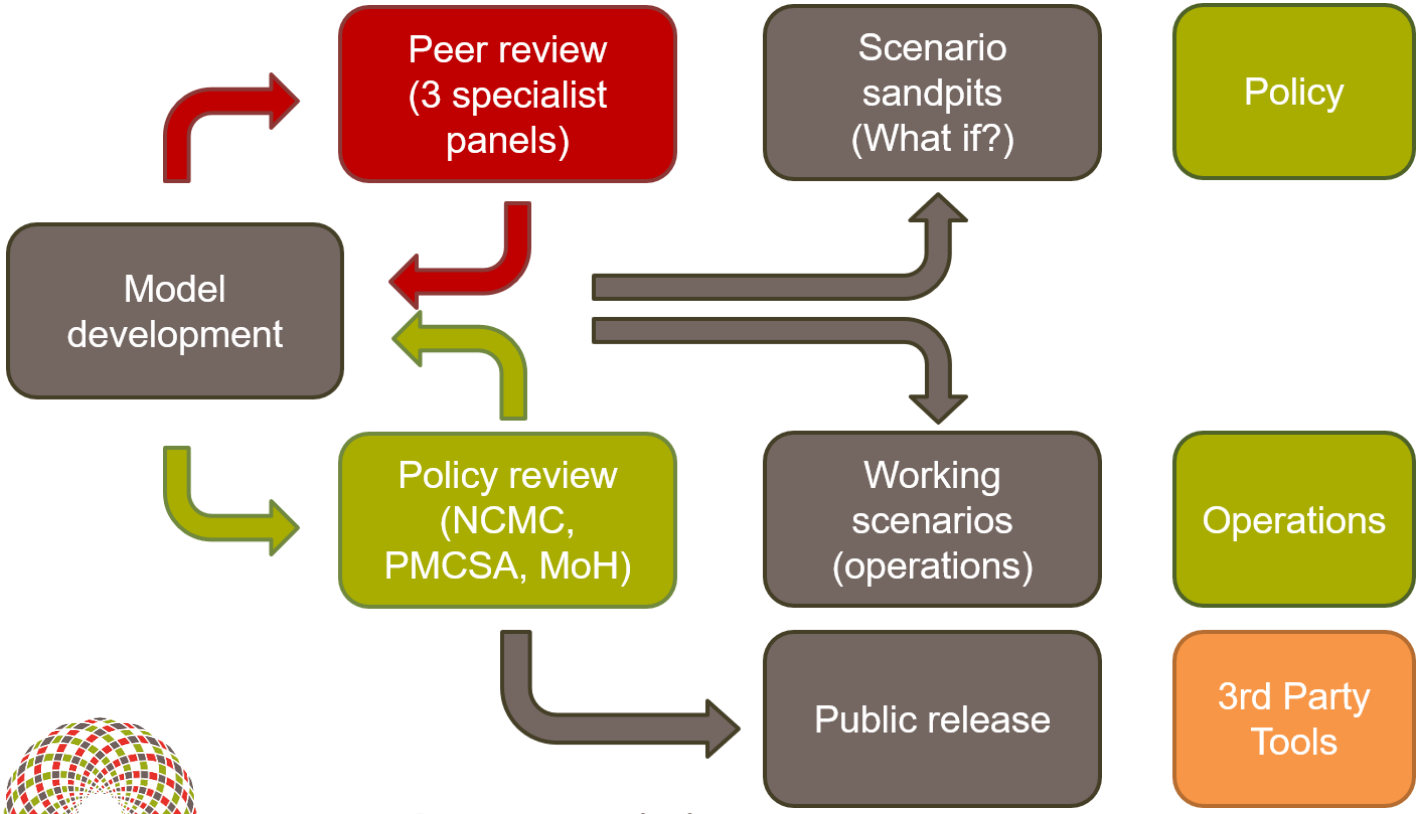
Workflow

- Scenarios to inform policy and operations
- Regular model review and refinement



e.g. DPMC, PMCSA, Ministry of Health, Treasury, Te Puni Kōkiri, Ministry of Education.

e.g. NCMC, forecasts for DHBs via Orion Health

e.g. Take Control simulator app

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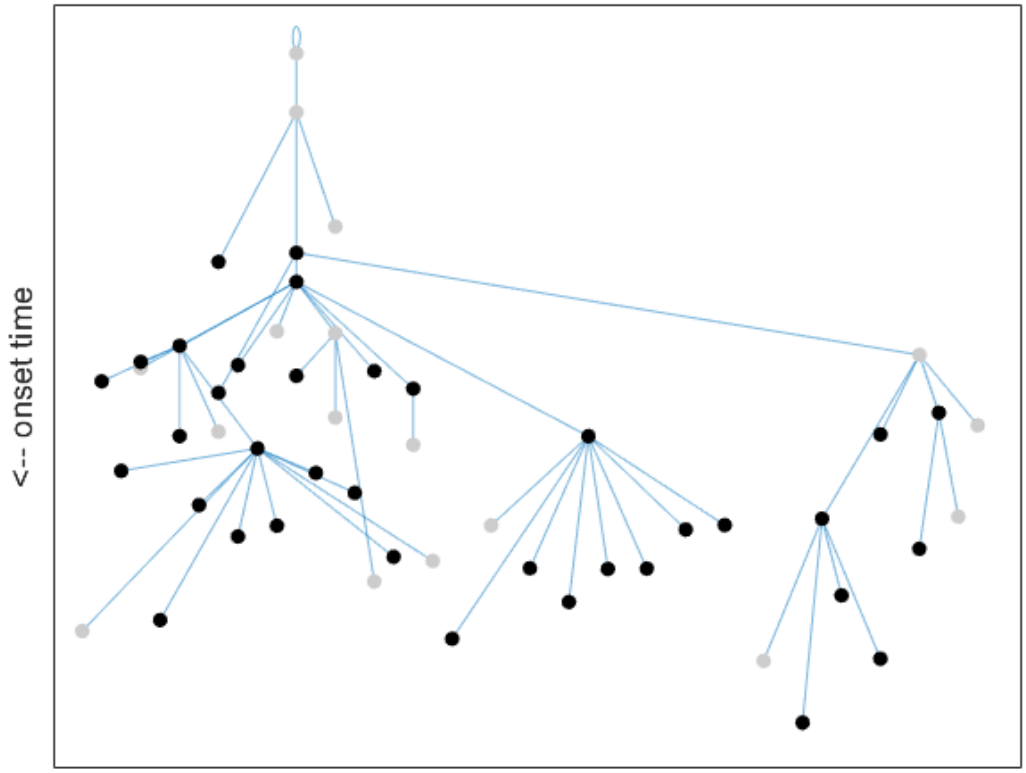
E.g. Mainstream media

Papers available: www.tepunahamatatini.ac.nz

Stochastic model

For elimination/containment and compatibility with real case data need a stochastic model, e.g. branching process



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Plank MJ, Binny RN, Hendy SC, Lustig A, James A, Steyn N (9 April 2020). A stochastic model for COVID-19 spread and the effects of Alert Level 4 in Aotearoa New Zealand. MedRxiv preprint, doi: https://doi.org/10.1101/2020.04.08.20058743

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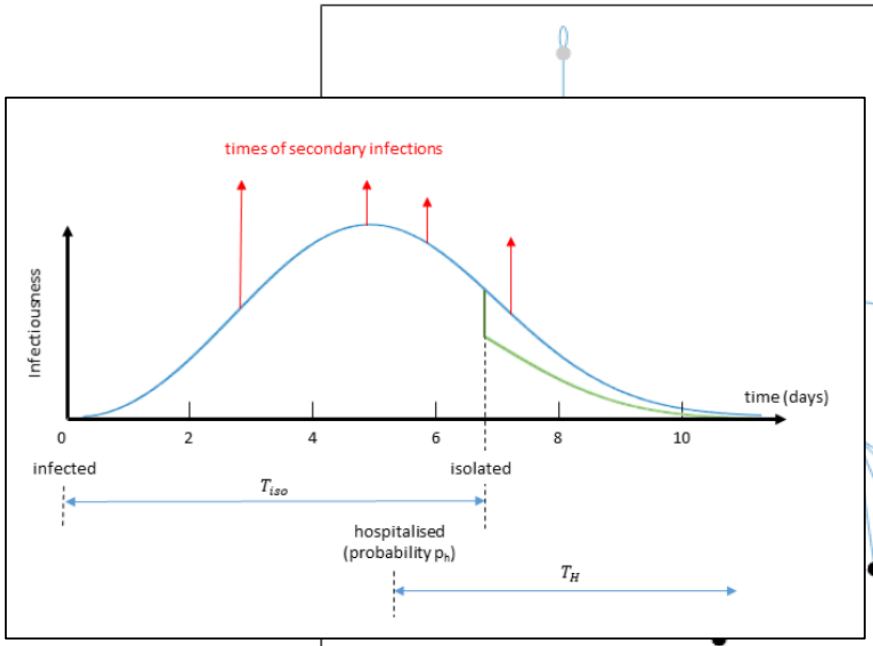

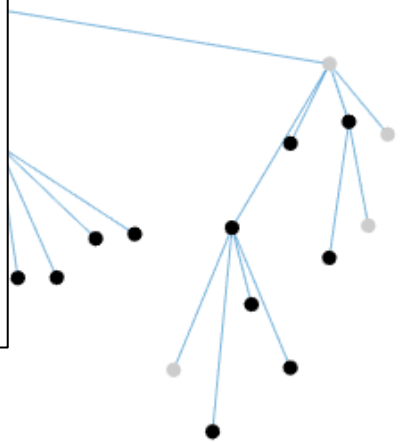

Core model ingredients: susceptible population, reproduction number, control measures, case isolation, infectiousness, super-spreading

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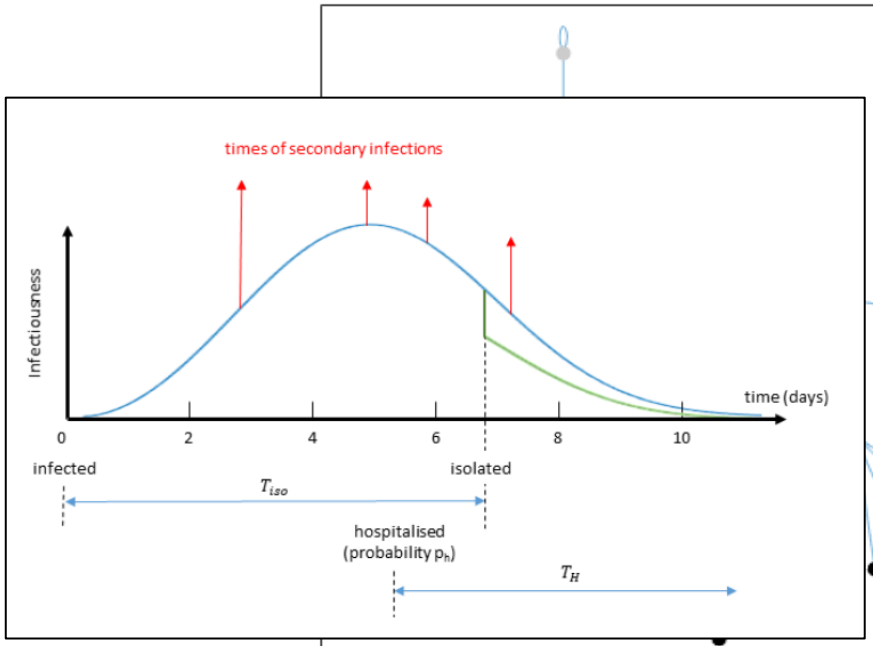

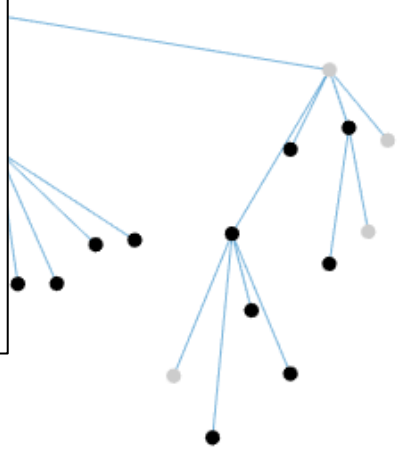

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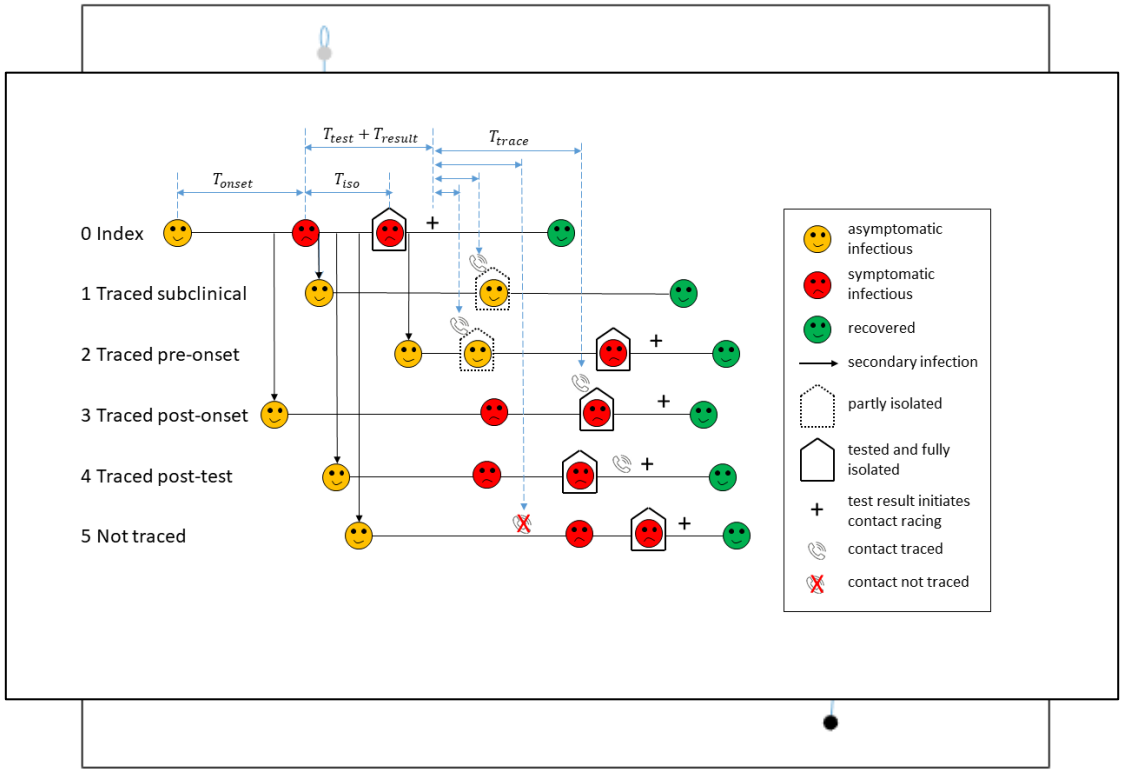

Contact tracing

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James A, Plank MJ, Binny RN, Lustig A, Steyn N, Hendy S, Nesdale A, Verrall A (2020). Successful contact tracing systems for COVID-19 rely on effective quarantine and isolation. medRxiv preprint, doi: https://doi.org/10.1101/2020.06.10.20125013

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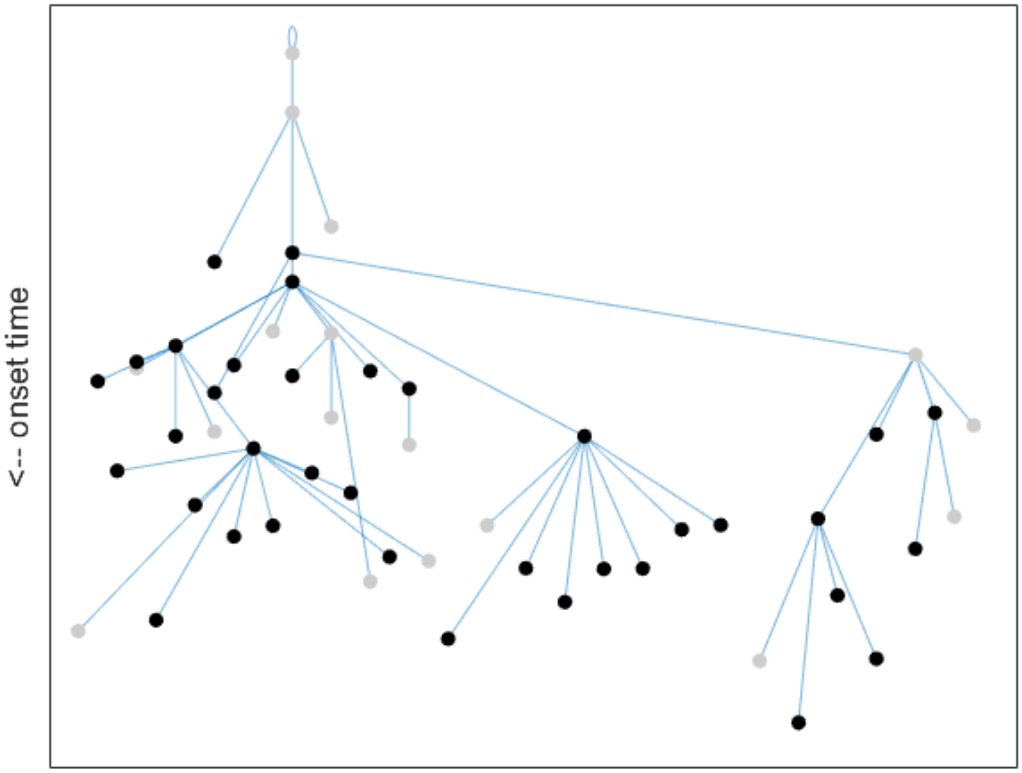

Contact tracing

Age structure & inequitable access to healthcare

Te Pūnaha Matatini
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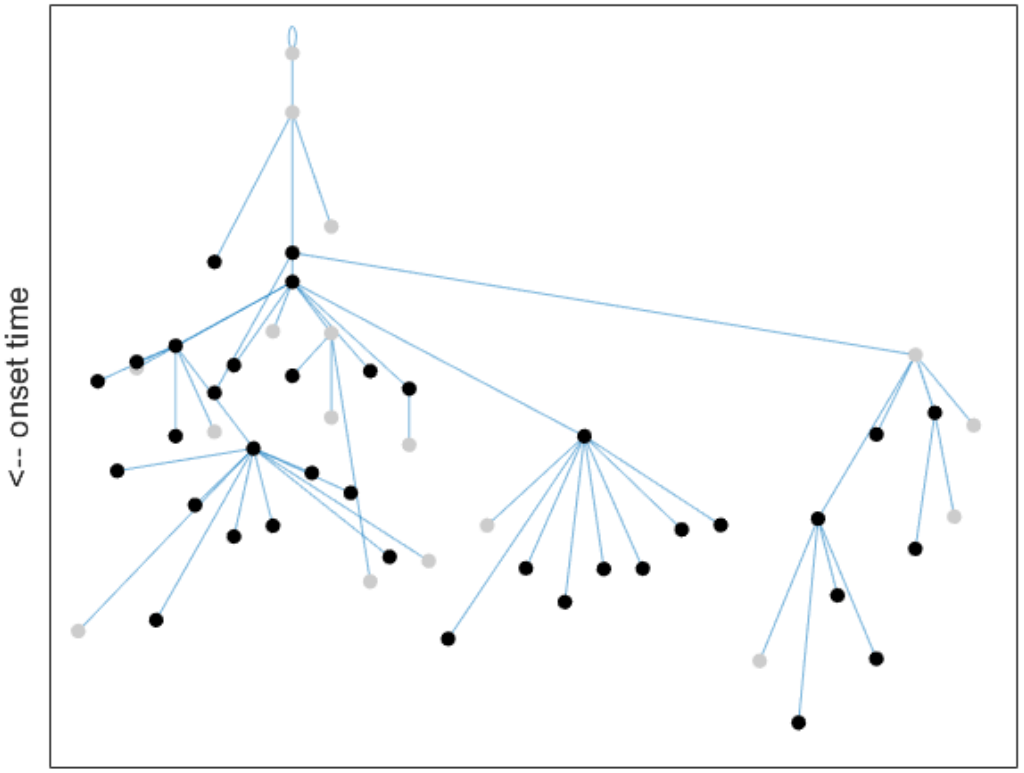
James A, Plank MJ, Binny RN, Hannah K, Hendy SC, Lustig A, Steyn N (2020). A structured model for COVID-19 spread: modelling age and healthcare inequities. medRxiv preprint, doi: https://doi.org/10.1101/2020.05.17.20104976

Stochastic model

For elimination/containment and compatibility with real case data need a stochastic model, e.g. branching process

Age, ethnicity and regional variation in IFRs



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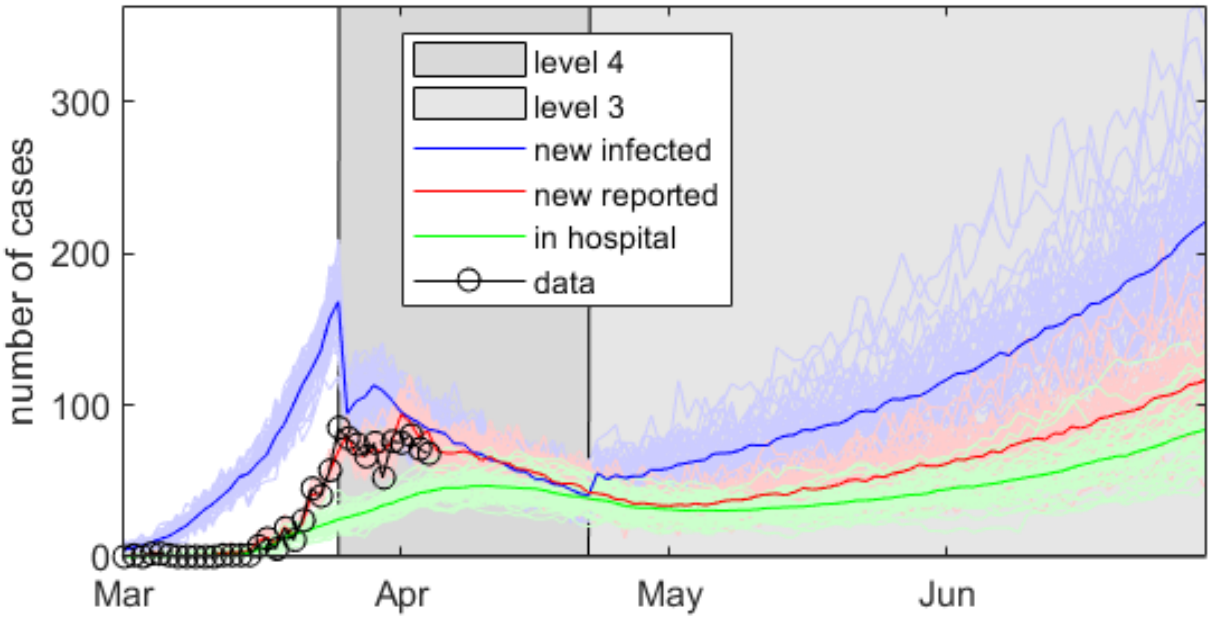
Steyn N, Binny, RN, Hannah K, Hendy SC, James A, Kukutai T, Lustig A, McLeod M, Plank MJ, Ridings K, Sporle (2020). Estimated inequities in COVID-19 infection fatality rates by ethnicity for Aotearoa New Zealand. medrxiv preprint, doi: https://doi.org/10.1101/2020.04.20.20073437

Stochastic model scenarios



Assumptions

- Model Structure
- Clinical and Public Health parameters (e.g. under-reporting)
- Alert Level Policy
- Alert Level Effectiveness

- Can compare:
  - Fast vs. slow case isolation
  - Different durations at each Alert level
  - Different effectiveness of Alert Levels

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Reproduction number

- Basic reproduction number, R_0: average no. of people infected by a single contagious individual in fully susceptible population
- R_0 between 2 and 4 for COVID-19
- Effective reproduction number, R_{eff}: actual transmission at any given time, accounting for control measures
- $R_{eff} > 1$, virus outbreaks
- $R_{eff} < 1$, virus dies out

E.g. $R_{eff} = 2$

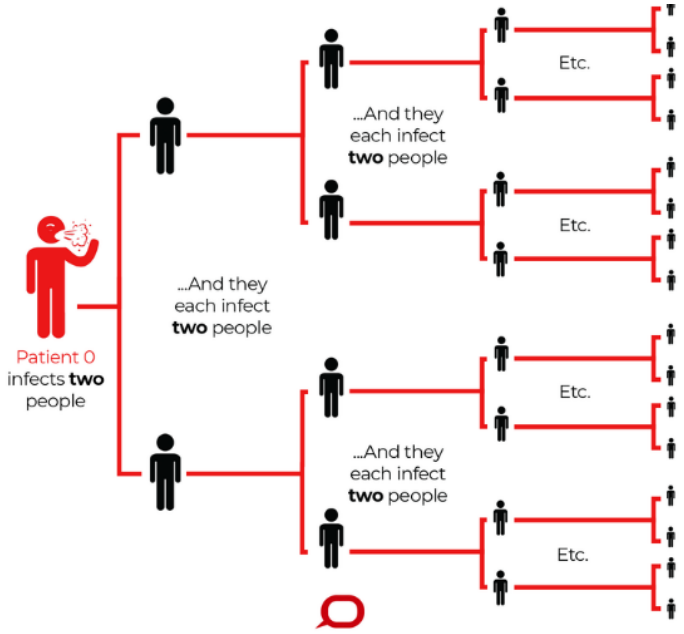

Image: The Conversation

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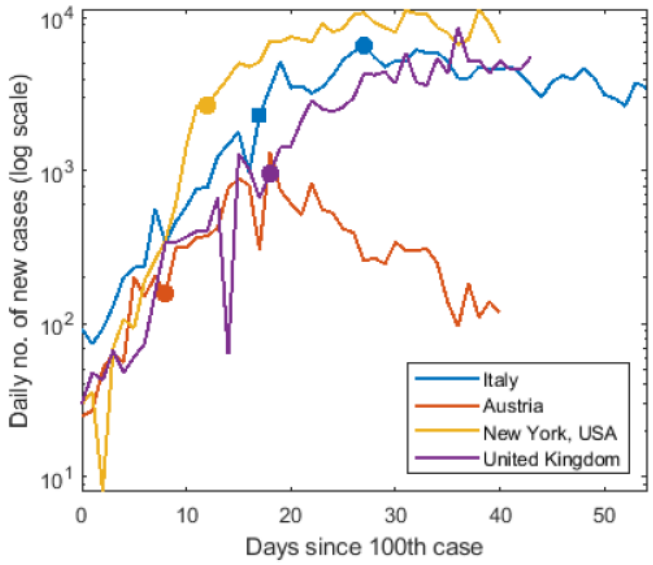
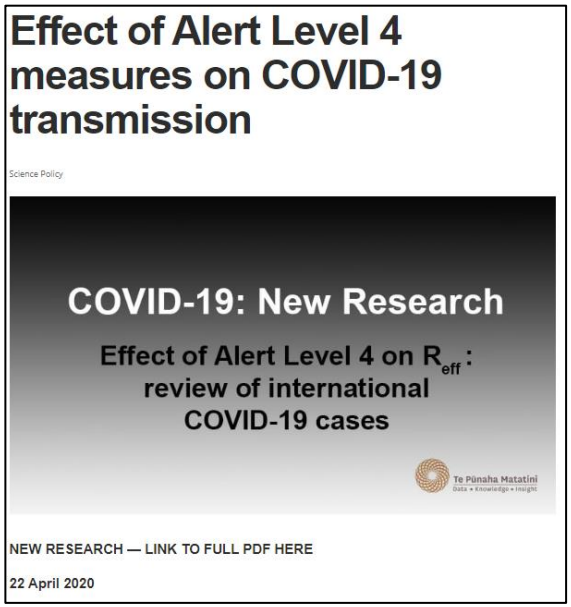
International review of R_{eff} after interventions

- 25 countries (or provinces/states) with high total cases or different intervention approach
- Data:
  - Daily numbers of new cases and deaths from 22 January 2020 (source: Johns Hopkins University)
  - Types and dates of intervention measures (multiple sources)





Binny RN, Hendy SC, James A, Lustig A, Plank MJ, Steyn N (6 May 2020). Effect of Alert Level 4 on R_{eff}: review of international COVID-19 cases. MedRxiv preprint, doi::https://medrxiv.org/cgi/content/short/2020.04.30.20086934v1

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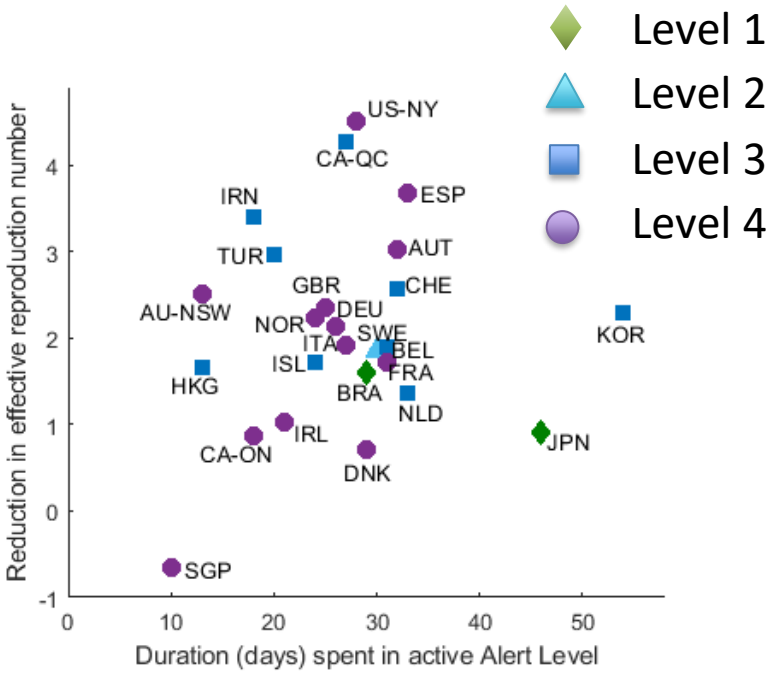

Effective reproduction number

Alert	Effectiveness		
	Low	Med	High
Level 4	2.1 (e.g. GBR)	1.3-1.6 (e.g. DEU)	0.9 (e.g. NOR)
Level 3	1.8 (e.g. USA)	1.3 (e.g. NLD)	1.0-1.1 (e.g. NSW)
Level 2		1.6-1.8 (e.g. SWE)	1.1 (e.g. HKG)

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Italy

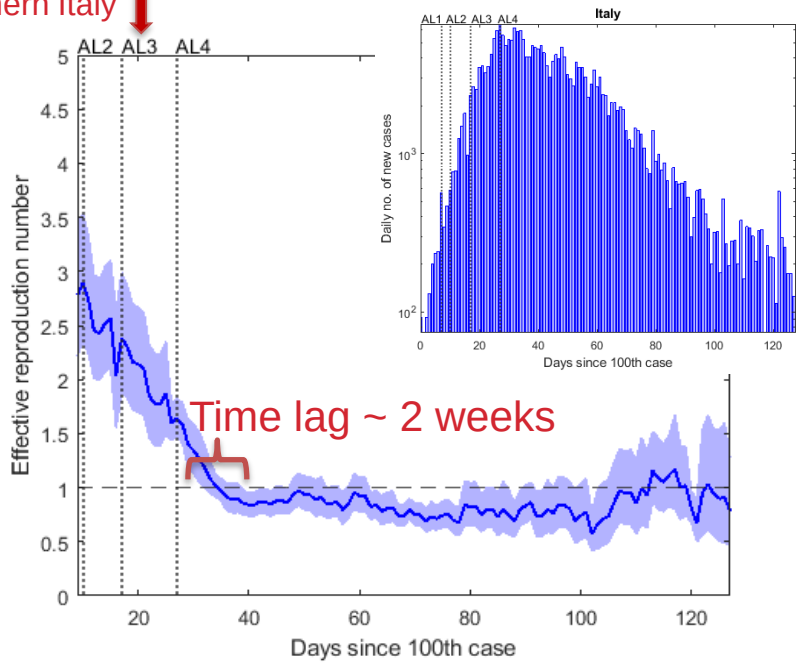
Alert Level 4

Image: REUTERS/Flavio Lo Scalzo

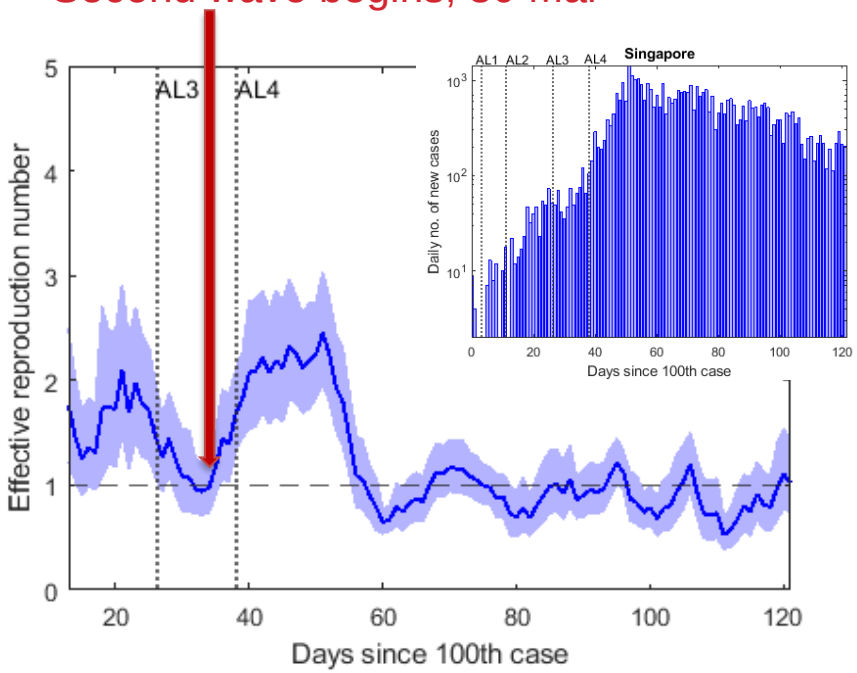
Singapore

Alert Level 4

Healthcare system overloaded in Northern Italy



Second wave begins, 30 Mar



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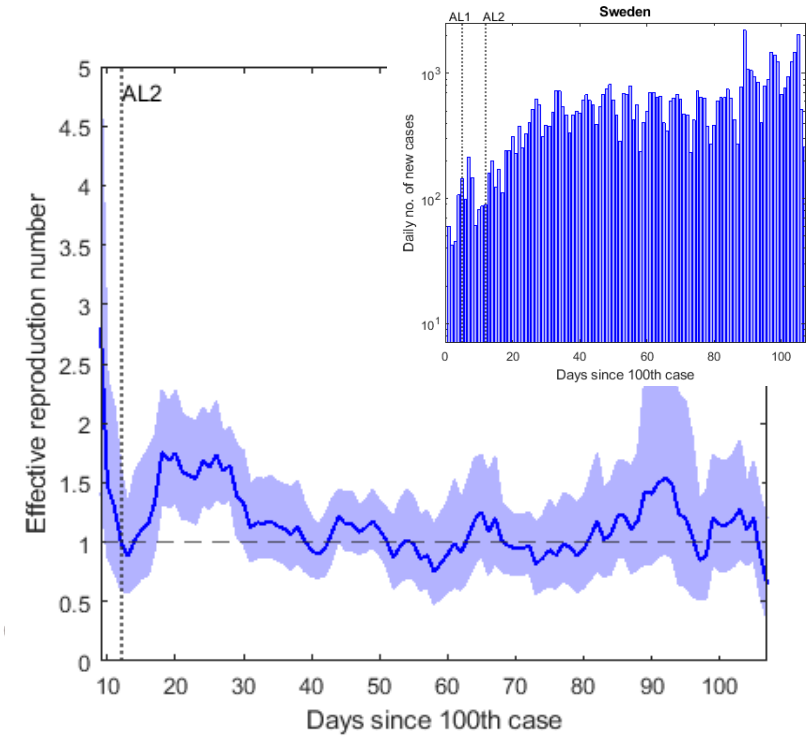
Sweden

Alert Level 2

Country	Total cases (1 July)	Total deaths
Sweden (AL2)	**68,451**	**5,333**
Denmark (AL4)	12,768	605
Norway (AL4)	8,879	250

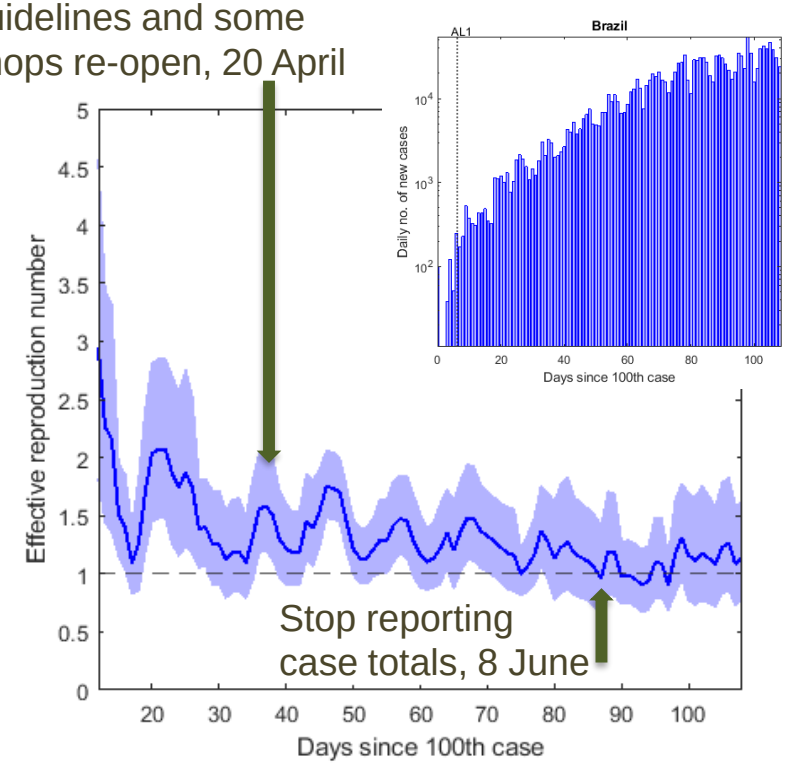


Brazil

Alert Level 1

Total cases (1 July)	Total deaths
1,408,485	**59,656**

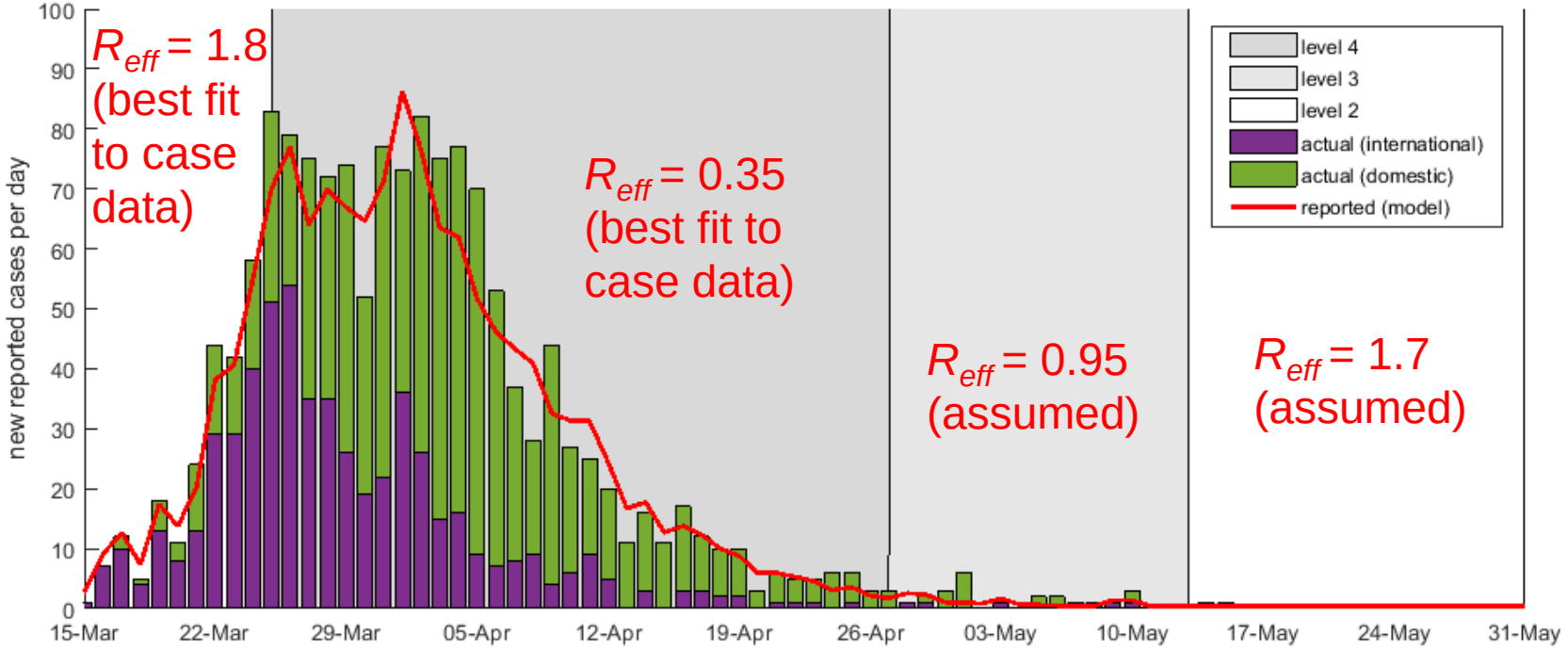
Several cities ease social isolation guidelines and some shops re-open, 20 April



New Zealand's effective reproduction number

- Simulated and actual daily numbers of new local (confirmed and probable) and imported cases
- Exceptionally early implementation of Alert Level 4

Plank et al. 2020 model



(Case data source: Ministry of Health)

Total cases (1 July)	Total deaths
1528	22

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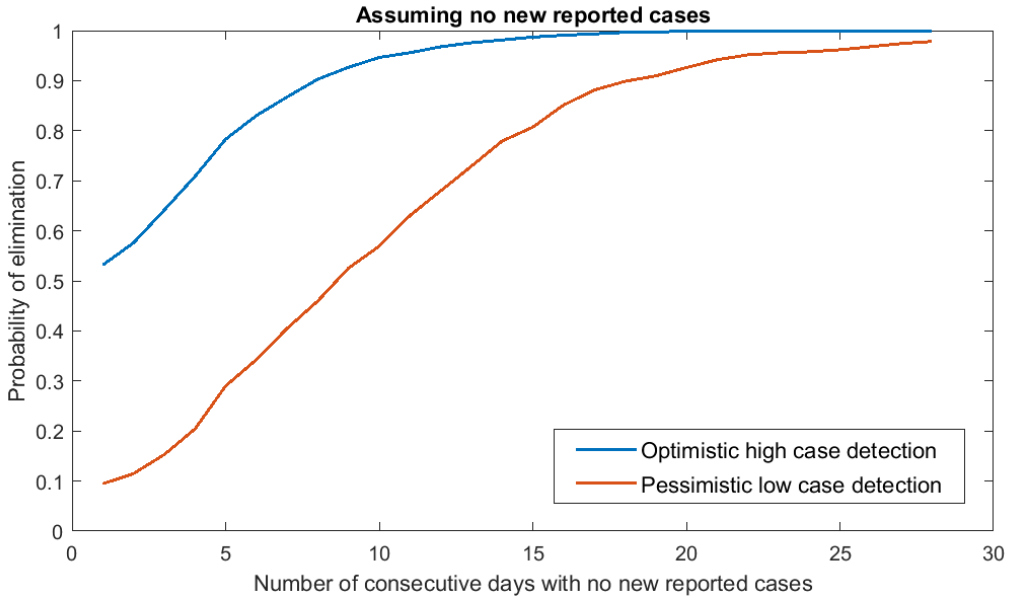
Declaring elimination in NZ

- After 2-3 weeks of no new reported cases, there is a 95% probability that COVID-19 has been eliminated in NZ
- NZ declares elimination 8th June and moves to Alert Level 1 (zero active cases and 17 days of no new reported cases)
- New cases arriving at the border



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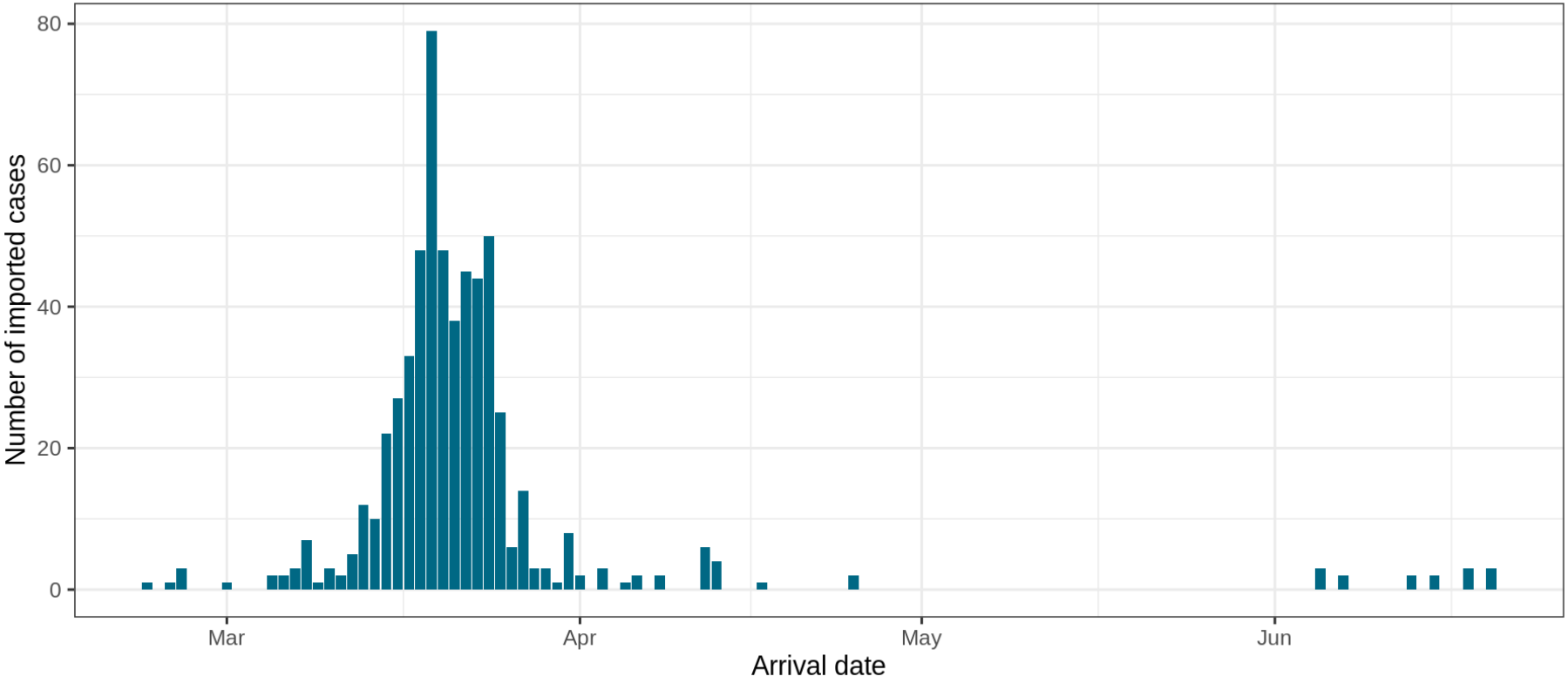
https://theconversation.com/new-zealand-hits-a-95-chance-of-eliminating-coronavirus-but-we-predict-new-cases-will-emerge-139973

Modelling border risk and controls

After weeks of no new cases of COVID-19, in the last week we've recorded more than twenty. That's sounds pretty scary, but "what we're seeing is no great surprise, and it's no time to panic" (Siouxie Wiles)!



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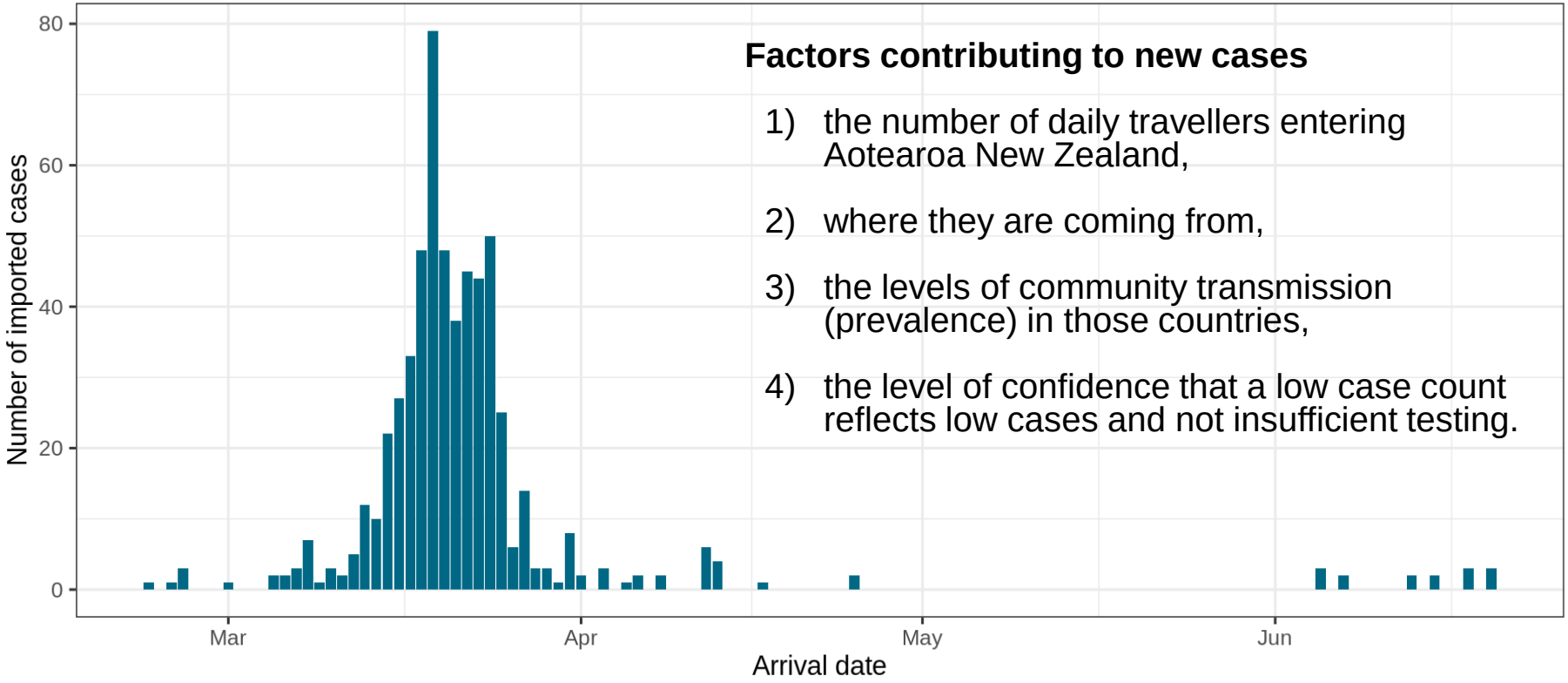
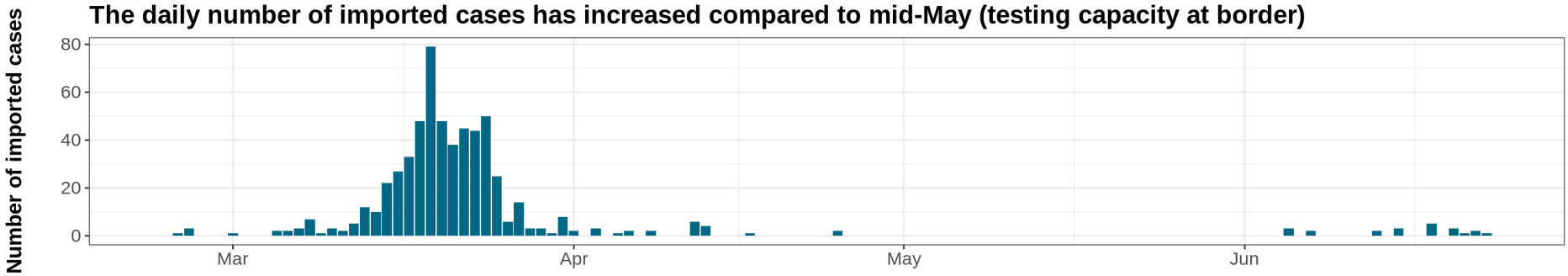
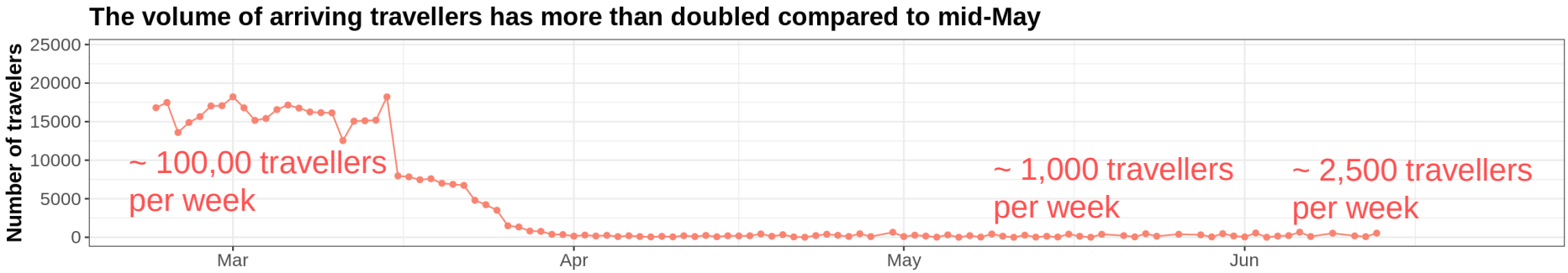


Volume of arriving travelers





Source: The Spinoff

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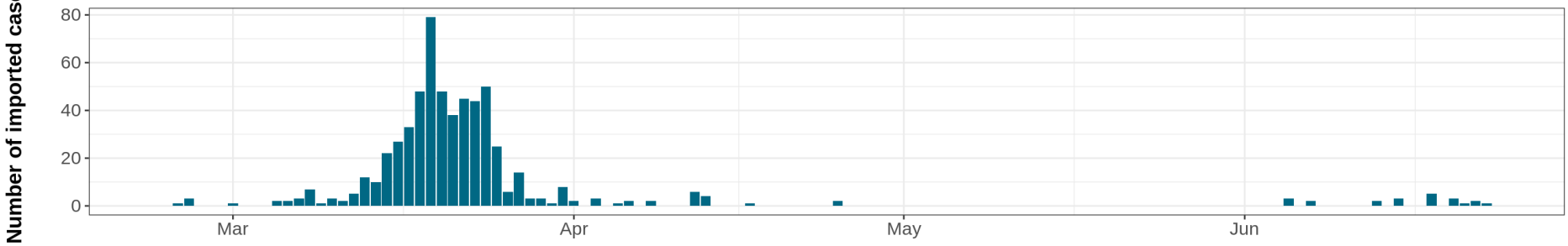
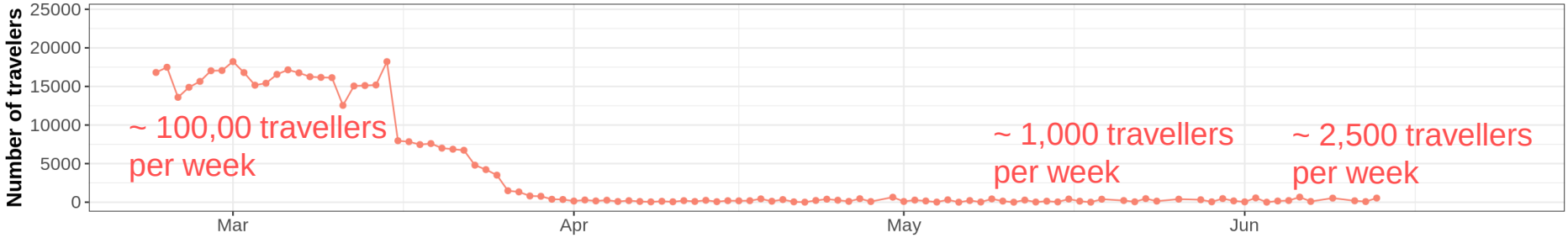
Prevalence at source

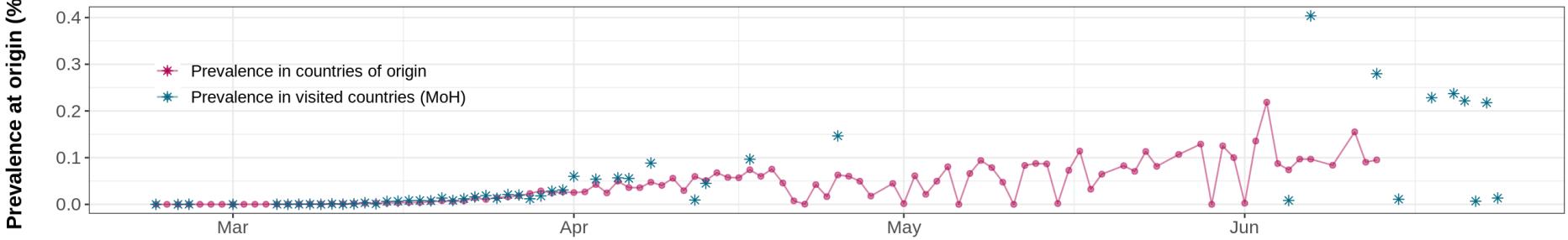
The daily number of imported cases has increased compared to mid-May (testing capacity at border)



The volume of arriving travellers has more than doubled compared to mid-May



The prevalence has rapidly increased in countries people are traveling from



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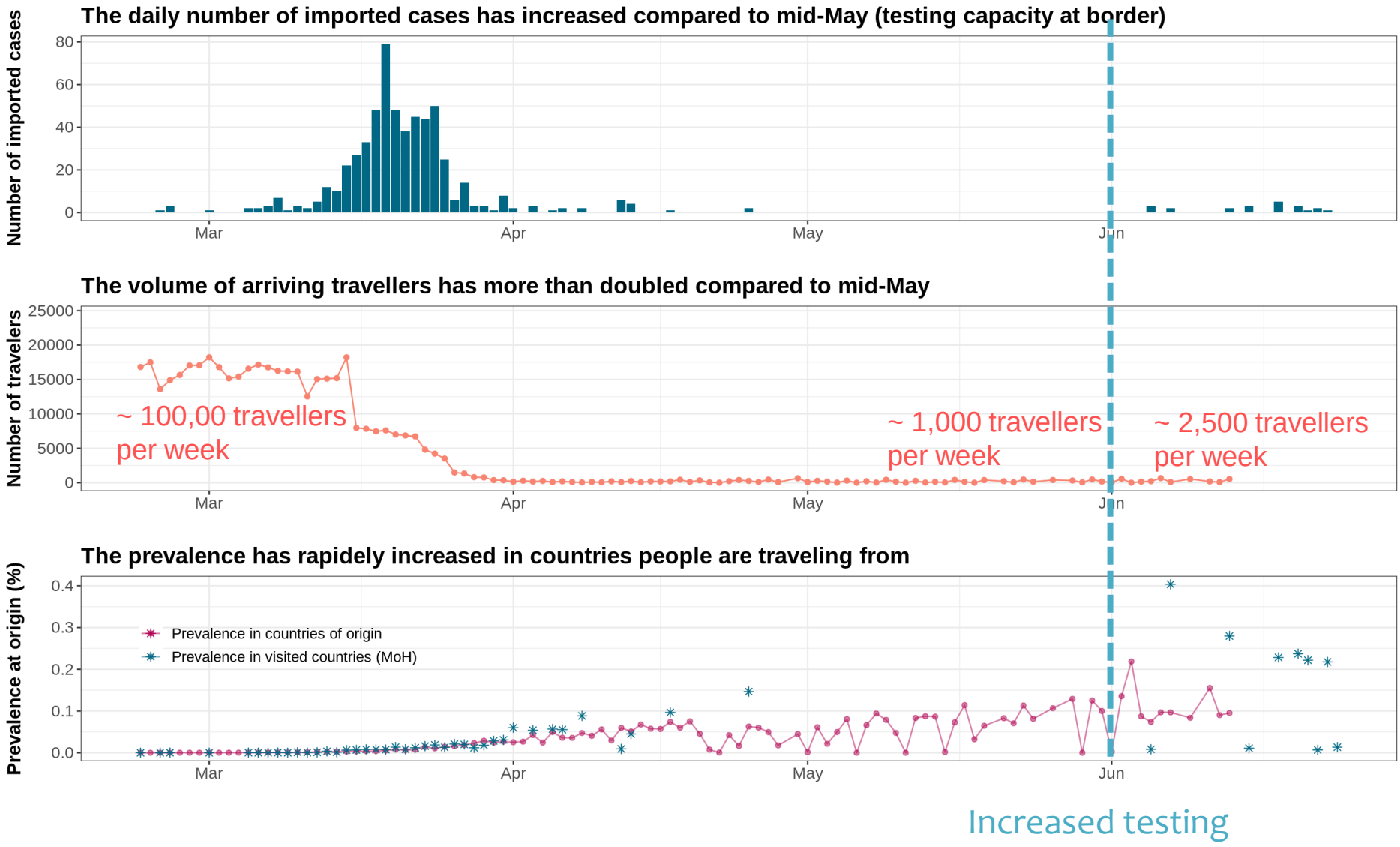
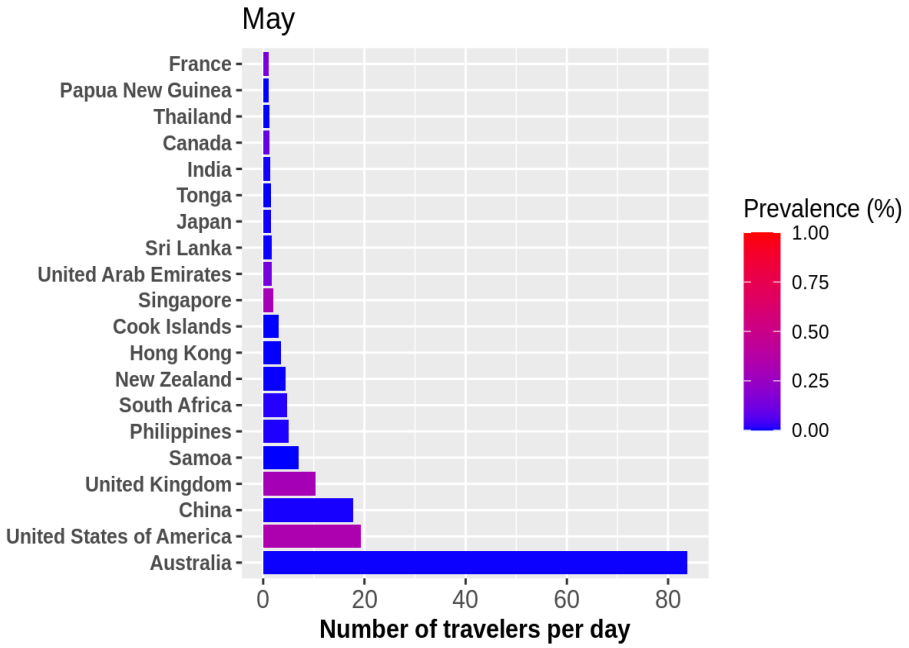
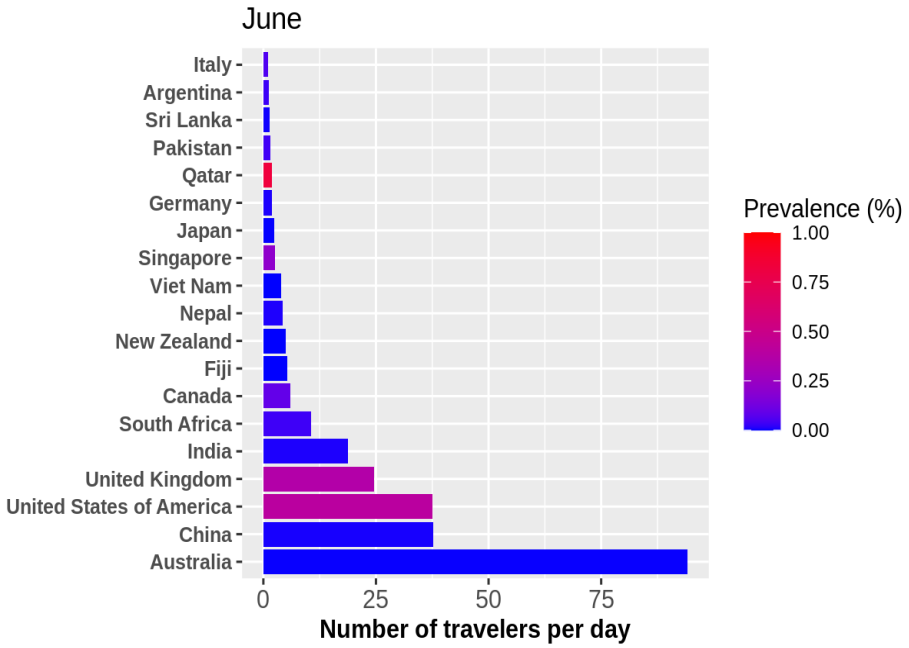


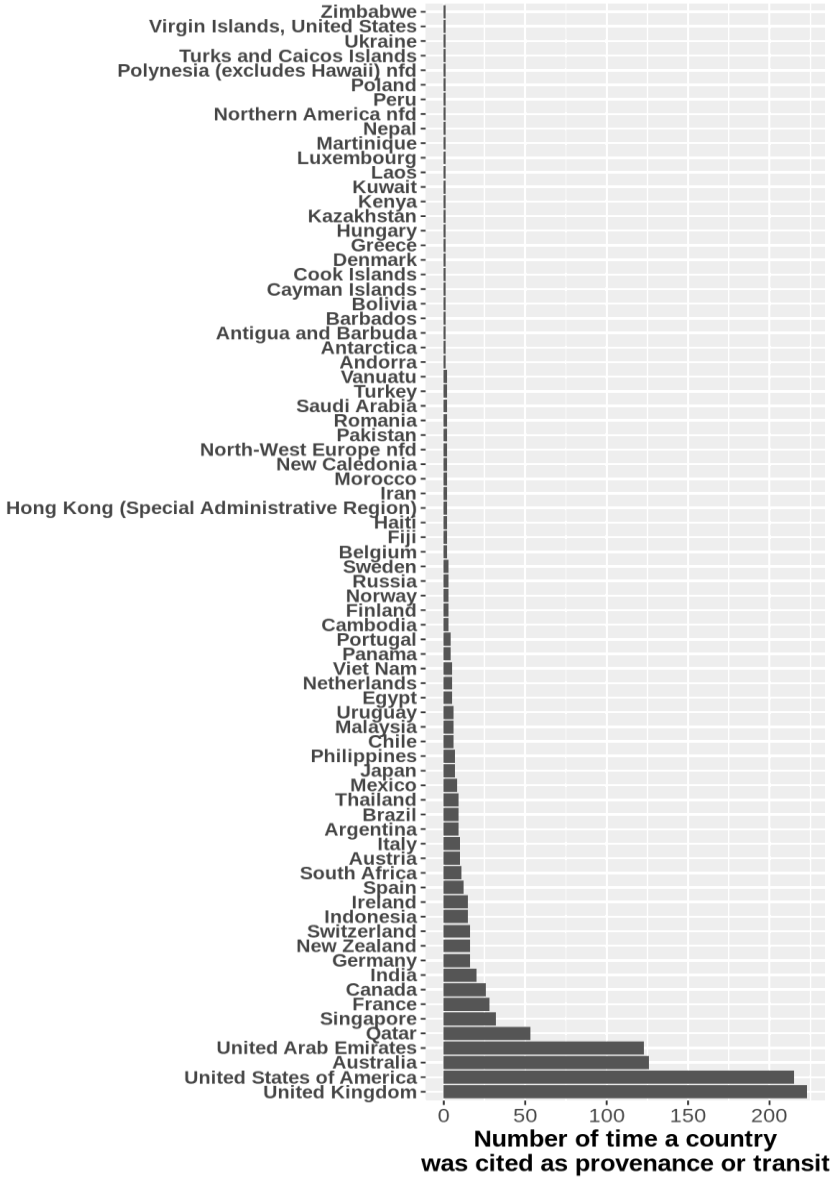
Make up of countries people are traveling from

In the latest fortnight period, we have seen an increase in the number of people arriving from the USA, UK, South Africa and India, where Covid-19 is relatively widespread.





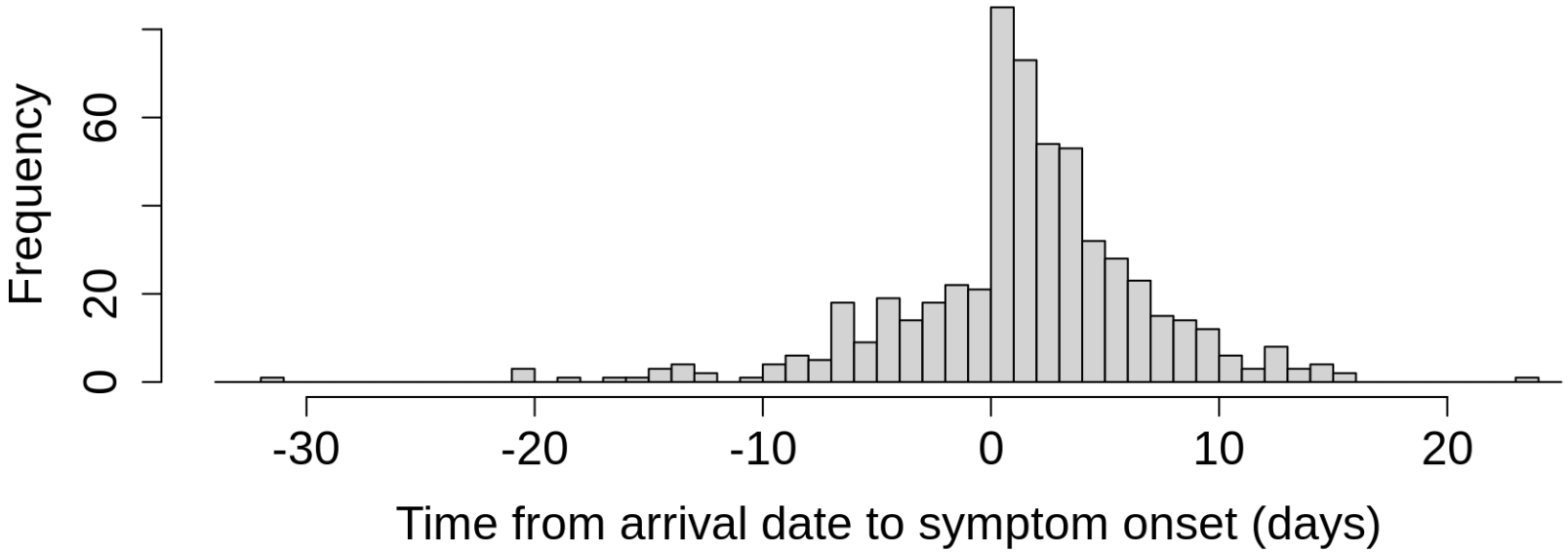
Source of acquisition



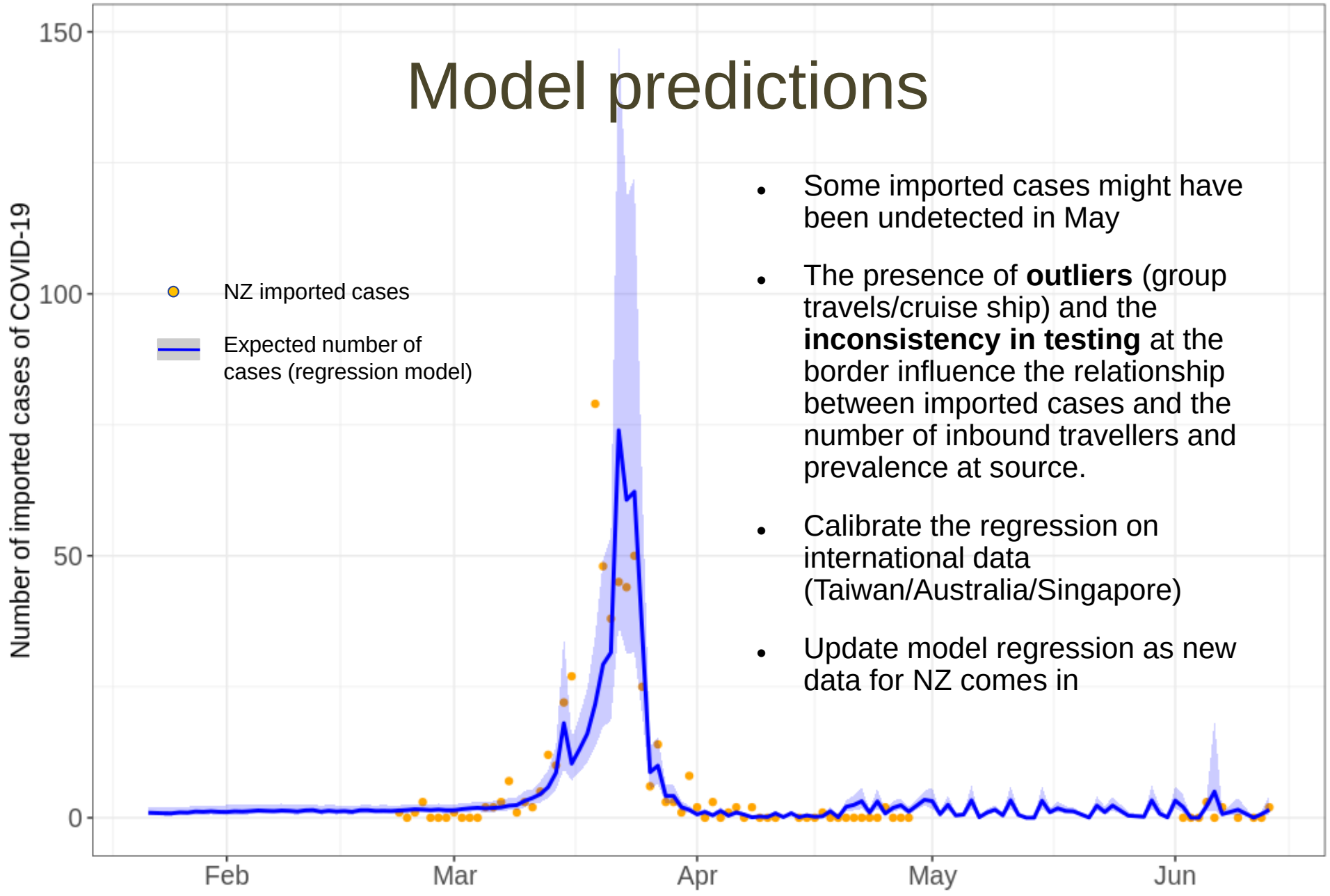
- The data are a bit noisy because many of our imported cases visited or transited trough multiple countries. It is sometimes difficult to associate a country of provenance/transit to a case.
- Most overseas-acquired cases have been from USA, UK and Australia.
- The source of acquisition has varied in the latest fortnight period. 14 out of the 24 last cases have been from India.

Prevalence in inbound travelers

- Since June 9 (consistent testing in isolation), the average prevalence in inbound travelers is **3.85 cases per 1,000 travelers**.
- 7 cases (1.2%) developed their first symptoms two weeks or more after arriving; providing opportunity for onward transmission in the wider community.



Model predictions



- Some imported cases might have been undetected in May
- The presence of **outliers** (group travels/cruise ship) and the **inconsistency in testing** at the border influence the relationship between imported cases and the number of inbound travellers and prevalence at source.
- Calibrate the regression on international data (Taiwan/Australia/Singapore)
- Update model regression as new data for NZ comes in

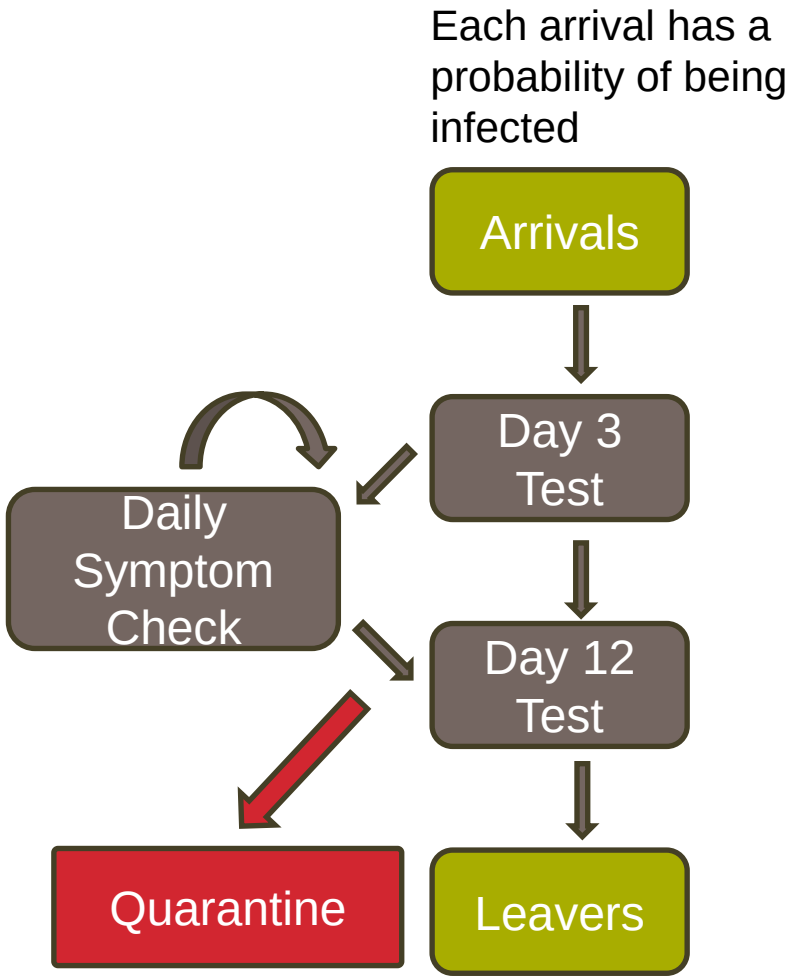
Managed isolation facilities

We have a good idea of how many cases we expect at the borders.

The mandatory 14-days is pretty good, but not impenetrable.

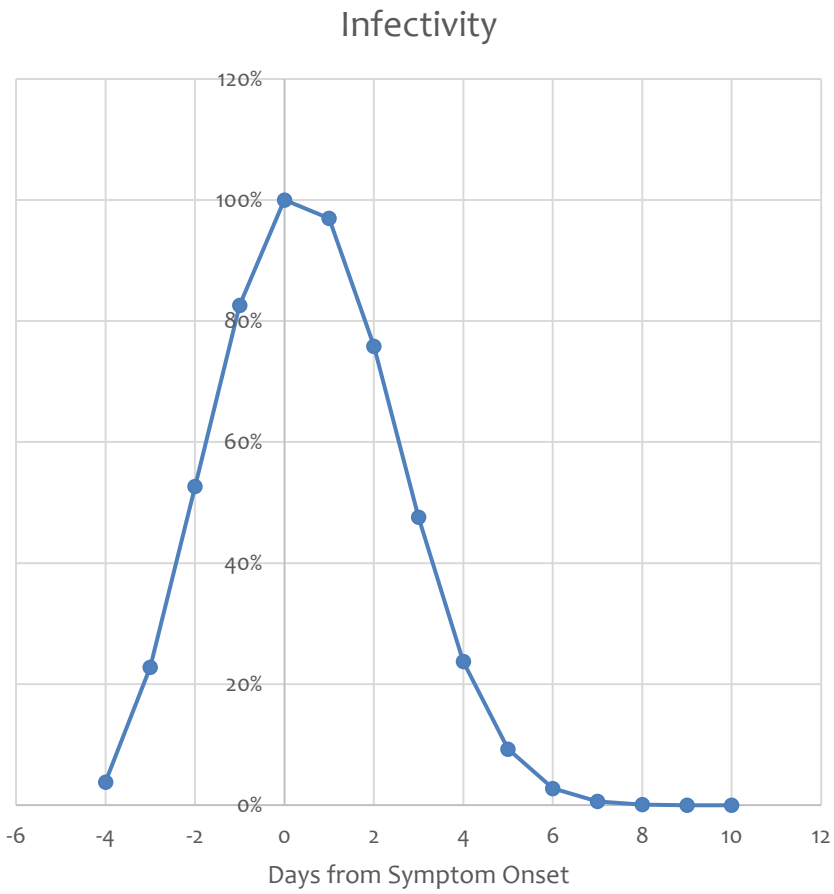
How to measure the effectiveness of managed isolation?

1.1 How many cases have we missed?
1.2 How infectious are those cases?
1.3 How much internal transmission Is there?



Missed cases

- We almost certainly don't detect every case that arrives at the border
- However, the model suggests these 'missed cases' pose little risk
  - On average they have passed 99.9% of their infectious period



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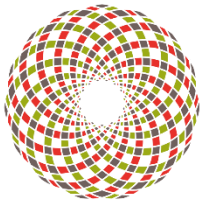
Internal Transmission

- Typically still infectious when they leave (if undetected)
  - Likely only passed ~50% of their infectiousness
- Hard to know the level of internal transmission
  - Someone that develops symptoms on day 8 may have been exposed before arrival *or* in the facility
  - Someone that tests positive on day 12 may have just had a false negative on day 3
- What observable data may indicate the level of internal transmission?
  - Ratio of cases detected in the 2nd weeks to cases detected in the first week



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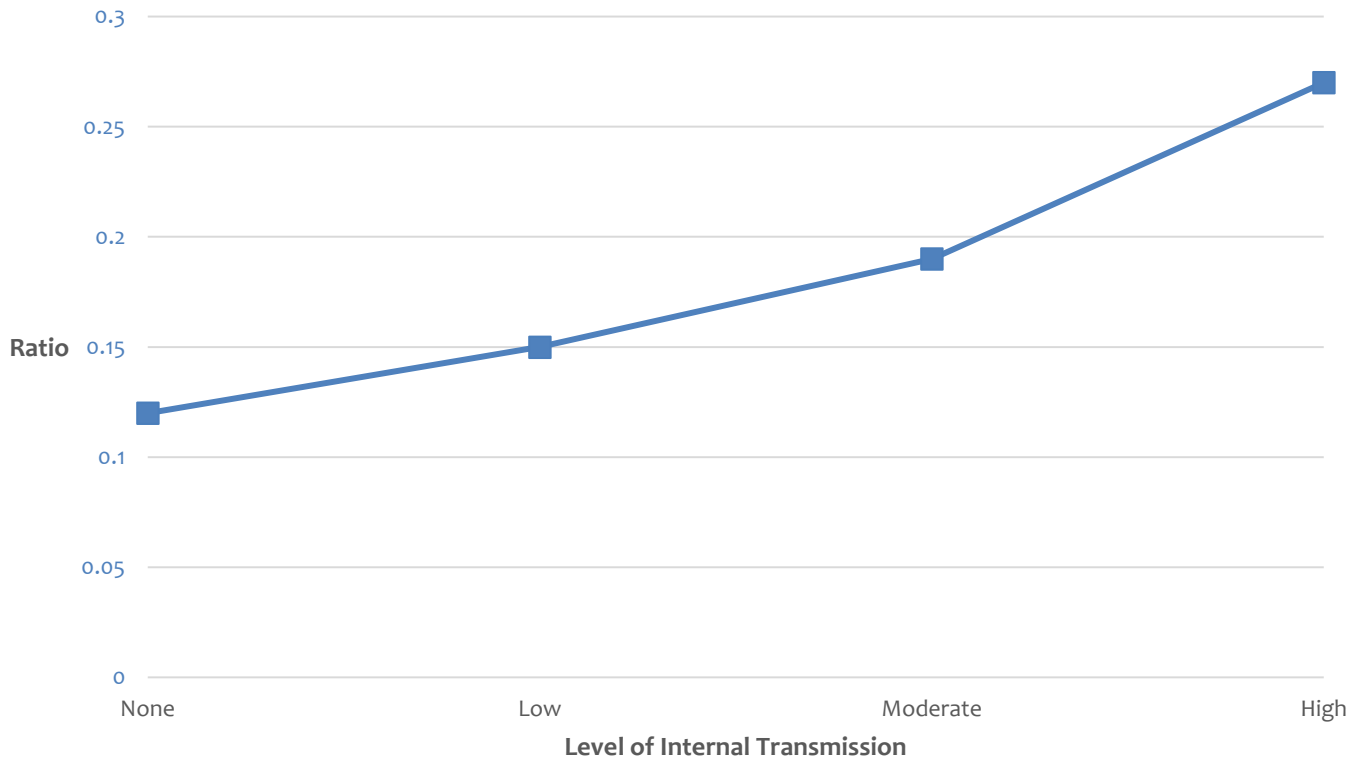
Internal Transmission

Modelled Results (too early to use current data):



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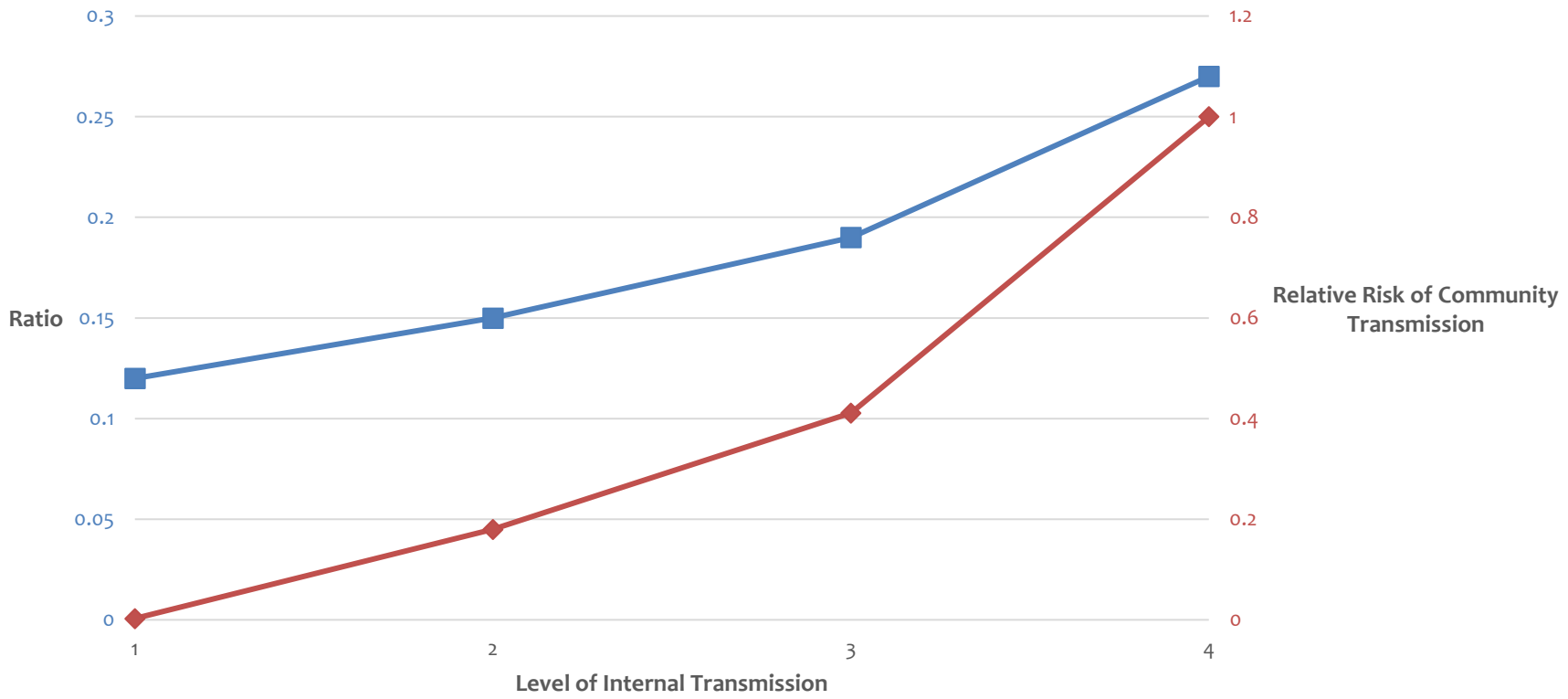
*Ratio approximate and depends on parameters

Internal Transmission

Modelled Results (too early use real data):



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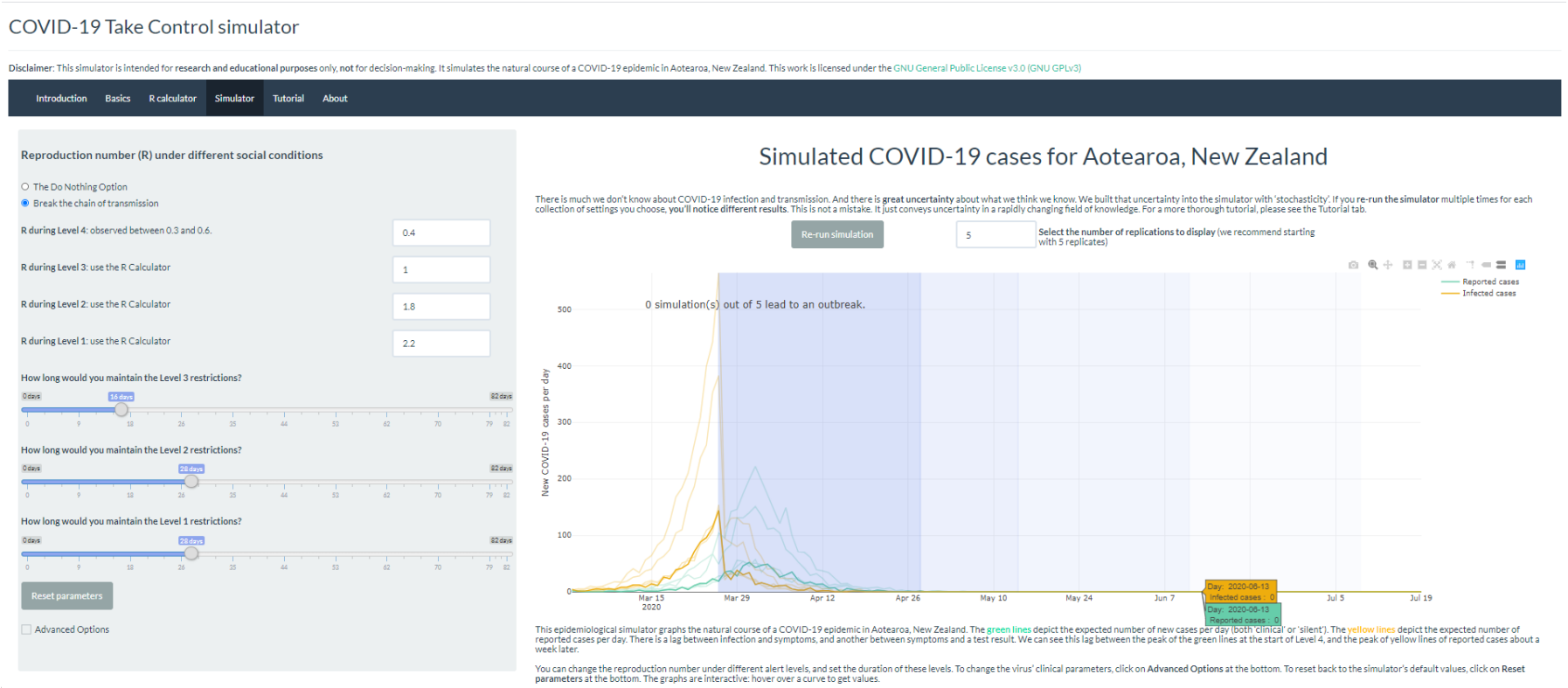
*Ratio approximate and depends on parameters

Other Scenarios

- Is it worth separating recent arrivals from those nearing the end of their stay?
- What additional risk do special exemptions pose? How can we make them safer?
- Can we have more relaxed rules for people coming from safer regions? (modeling the Australian – NZ bubbles)

Thank you for listening

- Papers available from: www.tepunahamatatini.ac.nz
- Take Control simulator: http://covid19takecontrol.nectar.auckland.ac.nz/covid19_takeControl/



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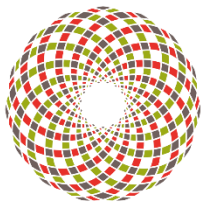

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